Journal of Print and Media Technology Research

Scientific contributions

Journal of Print and Media Technology Research

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A mission statement

To meet the need for a high quality scientific publishing platform in its field, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries is publishing a quarterly peer-reviewed research journal.

The journal is fostering multidisciplinary research and scholarly discussion on scientific and technical issues in the field of graphic arts and media communication, thereby advancing scientific research, knowledge creation, and industry development. Its aim is to be the leading international scientific journal in the field, offering publishing opportunities and serving as a forum for knowledge exchange between all those interested in contributing to or learning from research in this field.

By regularly publishing peer-reviewed, high quality research articles, position papers, surveys, and case studies as well as review articles and topical communications, the journal is promoting original research, international collaboration, and the exchange of ideas and know-how. It also provides a multidisciplinary discussion on research issues within the field and on the effects of new scientific and technical developments on society, industry, and the individual. Thus, it intends to serve the entire research community as well as the global graphic arts and media industry.

The journal is covering fundamental and applied aspects of at least, but not limited to, the following topics:

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- Packaging
- Fuel cells and other printed functionality
- Printing on biomaterials
- Textile and fabric printing
- Printed decorations
- Materials science
- Process control

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- Image and reproduction quality
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- Media industry developments
- Developing media communications value systems
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Social impact
- Media in a sustainable society
- Environmental issues and sustainability
- Consumer perception and media use
- Social trends and their impact on media

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Submissions are invited at any time and, if meeting the criteria for publication, will be rapidly submitted to peer-review and carefully evaluated, selected and edited. Once accepted and edited, the papers will be published as soon as possible.

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A letter from the Editor

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The March issue of the Journal in 2023 comprises two research papers and one case study. The first paper is dealing with the formulation of the rotogravure printing inks for Li-ion battery anodes, and the adoption of their rheological properties to achieve a good balance between their electrical properties and suitability for printing.

The second paper is on artificial intelligence-based color corrections in social media, based on ColorNet neural network. The reduced color differences of chosen spot colors were achieved with only a minor impact on the representation of skin tones shown in the same videos and gifs.

A case study is bringing insight into Malaysia's printing industry after two years of the Covid-19 pandemic. Though the study is limited to the case of only one country, the results and conclusions can also give an insight into the disruptions of the global printing industry caused by other, mainly online media and pandemics.

In the Topicalities section, Markéta Držková (marketa.drzkova@jpmtr.org), the Associate Editor, is bringing an excellent overview of some news, publications, and events in the fields covered by the Journal. Traditionally, in the news of the March issue, a brief overview of patents granted to the printing press manufacturers in the last year is showing the trends in the development of technology and thus also the opportunities for the printing industry. It sounds promising not only the constant improvements of construction features on conventional machines are present, but some patents are granted also for hybrid presses, digital printing, machines for printed electronics, and security printing among several hundred patents.

In the overview of the recently published books, the two-volume book on 4D printing, an upgrade and also an alternative to well-known 3D printing is highlighted. An overview of books on textiles, history, design, and materials of importance for print and media technology is also presented.

Traditionally, also three theses are bringing an overview of the contemporary research topics in the field. Jana Chaaban defended her thesis at ETH Zurich, dealing with electrohydrodynamic nano printing as a promising technology for high-resolution and security applications. The thesis on the bio-inspired coloring of surfaces by imitating structural colors, based on the colors of butterflies of the genus Morpho, was defended by Heike Gute at the Technical University of Darmstadt. The third presented thesis was defended by Sani Yakubu Adam at the University of Cape Town. He studied a Kano book market in Nigeria in the last century, challenged by tradition, historical influences, and modern impacts.

An overview of events is oriented mainly to the conferences, meetings, and symposia aimed at the academic and research community in the field. The good news is a return of the in-person events, however, some organizers are also offering the hybrid format giving an opportunity also for those with limited possibility to travel and gather with their colleagues in person.

In the coming period, some changes in the editorial team are announced. The details will be presented to you in the next issue of the Journal because currently, we are at the beginning of the transition period. Editing of the already accepted papers is in progress and also the submitted papers are processed by reviewers and editors as expected. I would only like to point out that the call for papers is constantly open and we would appreciate your manuscripts and cooperation in sharing your expertise in the future.

Ljubljana, March 2023

Li-ion battery anodes printed by rotogravure

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Abstract

Inks for Li-ion battery anodes were formulated for printing with the rotogravure printing process. Graphite powders with different particle sizes were used as conductive materials along with nanoparticle carbon black fillers. As polymer binders, polyvinylidene fluoride (PVDF) (commercial names Kureha 9100 and Kureha 9300) and polyvinyl pyrrolidone (PVP) were tested. Inks were printed using proprietary gravure engraving. Ink solid content of 30–70 % was examined. At 70 % solids, ink layers were 25–27 μm thick with mass loading of 2.1–2.5 mg/cm². A solids content of 50 % was found the highest that produced a smooth uniform film. Half cells were made using print with 1 000 μm holes or they were bar coated. Half cells were charged and discharged in order to measure irreversible capacity loss (ICL). Inks with mixed binders Kureha/PVP were performing better than sole polymers. Half-cell testing revealed that PVP as a sole binder has not good electrical performance, thus it was mixed with PVDF. The ICL was lower when mixed PVDF/PVP binder was employed in anode ink.

Keywords: printed batteries, ink formulation, half cell, capacity, irreversible capacity loss

1. Introduction and background

Due to the increasing impact of oil pollution on the environment (CO_2 production and liquid spills), more automobile and many other industries have turned to electric item manufacturing. Therefore, the production of more energy-efficient and environmentally friendly batteries has become a hot topic at the moment. The traditional lead-acid battery is bulky and heavy, but the printing processes can produce much thinner and lighter batteries to provide power for wearable devices, flexible displays, and smart labels among others (Costa, Gonçalves and Lanceros-Méndez, 2020; Khan, Lorenzelli and Dahiya, 2015). With the advent of printed electronics, flexible batteries have undergone rapid development in the past ten years.

The use of printing processes in battery manufacturing can lead to mass production of flexible batteries (Arduini, et al., 2016). Printing can produce flexible batteries with different design patterns, and their multilayer printing stack can shape the geometry and structure of the battery and improve its electrochemical performance. There are usually two types of the printed structures of printed batteries, such as stack or sandwich architecture and the coplanar or parallel architecture. Components used are anode, separator, electrolyte, cathode, and current collectors deposited on the flexible substrate (Lanceros-Méndez and Costa, 2018). Most of the batteries are manufactured in a stacked structure (Willert, Meuser and Baumann, 2018), while some are made in a coplanar configuration (Kim, et al., 2015). The advantage of coplanar configuration is that it, among other manufacturing processes, can be made using the screen-printing process and the total thickness of the battery can be reduced to 0.5 mm. Its disadvantage is that its discharge current and area ratio charge density is lower, and it has a higher internal resistance.

Currently, many researchers are focusing on screen printing of battery electrodes. This printing technology can use high viscosity inks for printing, which allows them to have good coverage on different materials, such as copper foil (Vicco Mateo, 2022), or plastic (Zhao and Wu, 2019), which are suitable for printing lithium-ion battery electrodes (Khan, Lorenzelli and Dahiya, 2015). Based on the size required to print battery electrodes, the amounts of active materials, the roughness of the electrode layer, and the thickness of each layer of the battery can be modified. There have been many studies using printing methods such as gravure printing, flexographic printing, screen printing, extrusion printing, and inkjet printing to explore

battery electrode production (Søndergaard, Hösel and Krebs, 2013, Hübner, et al., 2015) as well as attempts to print electrolyte (Hübner, et al., 2022). Lithium metal powder-based inks, which contain lithium metal powder, polymer binders, and other conductive materials can be used in anode printing. In general, the advantages of printed batteries are based on mature printing technology, and the fact that they are light, flexible, low-cost, can be mass-produced, customizable, and more environmentally friendly.

Research in the printed batteries based on gravure printing showed that the quality of the gravure printing layer mainly depends on several physical parameters such as ink, substrate, and process. To enable the mass production of batteries through gravure printing, the study was done using carbon coated $Zn_{0.9}Fe_{0.1}O$ (encapsulated in a thin film of carbon) as a reference alloying material (Bresser, et al., 2013). With the water-based electrode inks, 2-propanol can be used as a cosolvent to reduce the excessive surface tension of water-based inks in combination with corona pretreatment of the substrate for increased surface energy and thus ink adhesion (Biscay, Ghoufi and Malfreyt, 2011). Using the gravure printing process, multiple layers can be deposited, and the multilayer method applied is able to obtain the required mass loading (about 1.7 mg cm^{-2}) to achieve high homogeneity of the gravure printed layer, and its highly reproducible electrochemical performance up to 400 life cycles (Montanino, et al., 2021).

Printing inks for anode and cathode layers contain active materials, such as graphite and graphene, and active fillers such as nanocarbons, and resins or binders, which are selected based on ink – chemistry whether ink is solvent, or water-based. Graphene can be doped by ball milling technique, and can be combined with silicon, silicon oxide, and iron oxide for improved performance (Yu, et al., 2022). Resins can include lithiated polyacrylic acid, or polyvinylidene fluoride (PVDF) of different degrees of polymerization. The advantage of printing batteries is that layers of variable thickness can be produced. Printed layers are flexible, and they can be integrated into various substrates and devices. Printing technologies make it possible to easily scale up the products (Costa, Gonçalves and Lanceros-Méndez, 2020). Printed layers should be thick, preferably up to 100 μm and therefore screenprinting is the process of choice (Rassek, et al., 2019). There was not much information found specifically in gravure printing of anodes and cathodes, which calls for need to explore gravure process for printing these features for batteries.

In this work, the aim was to formulate rotogravure printing inks for anodes and evaluate their printability in terms of print uniformity, thickness of the layers and ultimately, half-cell battery performance.

2. Materials and methods

The substrate for anode Li-ion battery printing was copper foil from MTI Co., with caliper of 9 μm. Its surface roughness was 0.32 μm as measured by Bruker white light interferometry. Sheet resistivity of Cu foil was measured using SRM-232 sheet resistance meter with four-point probe and it was 0.0018 Ω/sq. Surface energy of copper foil was measured via contact angle with water: $87.2 \pm 1.3°$ and hexadecane: $3.3 \pm 0.1°$, as well as surface tension of water via pendant drop measurement: 71.1 ± 0.6 mN/m; surface tension of hexadecane via pendant drop measurement: 24.5 ± 0.3 mN/m. These values were plugged into the Owens–Wendt equation and surface energy of copper was estimated to be 26.5 ± 0.7 mN/m.

A Thinky Mixer AR 100 (THINKY Co., Tokyo Japan) was employed for mixing the inks. As the conductive graphite powders, Philips 5 μm, 10 μm, 15 μm (Philips 66, Houston, Texas) and Mage 3 graphite (Hitachi Chemical, Sakuragawa, Japan), and conductive nanoparticle carbon black filler (CB 4400 or C45) with particle size of 20 nm were used. The PVDF from Sigma Aldrich with different degrees of polymerization and commercial names Kureha 9100, Kureha 9300 (Kureha Co., Japan) with molecular weights of 2.8×10^5 to 1×10^6 was dissolved in N-methyl-2-pyrrolidone (NMP) solvent and used as the vehicle. In some inks, a polyvinylpyrrolidone (PVP) with molecular weight of 10 000 or polyvinylpyrrolidone/polyvinylidene fluoride mix of binders (PVP/PVDF) was employed. Rheology of finished inks was evaluated on an Anton Paar MRC302 rheometer.
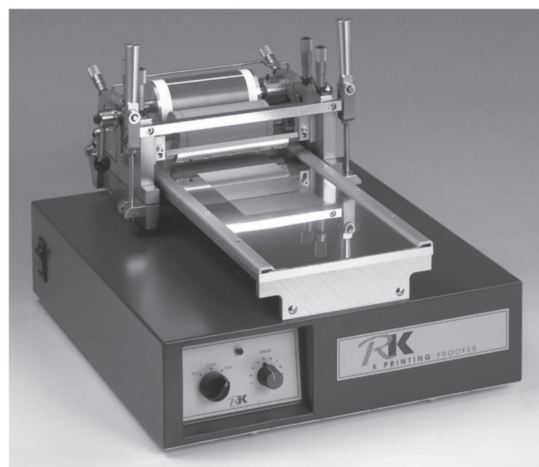

Figure 1: Gravure RK-proofer

Printing was done on Cu foil using a gravure RK gravure K-proofer (Figure 1), which uses a flat plate as an image carrier. The gravure plate for the RK gravure K-proofer was engraved by WRE/ColorTech (Greensboro, NC, USA) with proprietary engraving at 75 LPI. A plate was

engraved with 1000, 500, 250 and 125 μm circular hole shaped nonimage areas. Detail of 500 μm nonimage area is shown in Figure 2 and white-light interferometry detail is shown at Figure 3, showing depth of cells at 75 μm and the cell opening in one direction of the 1000 μm designed hole was measured at 1194 μm. Engraving was done by hybrid process of laser ablation and chemical etching. Such holes in the printed image improve the battery performance at high C rates and reduce lithium dendrites that collect on the electrodes.
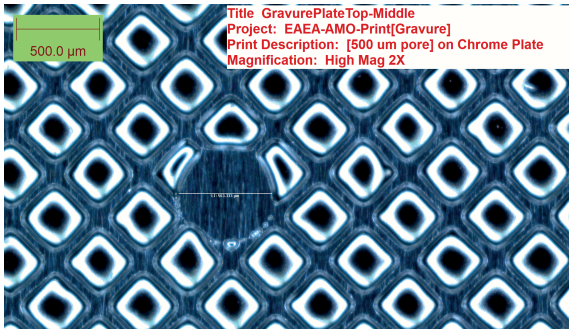
Figure 2: Detail of new gravure engraved plate (by WRE Color/Tech, Greensboro, NC, USA) with 500 μm nonimage area (circular hole)

a)

b)

c)
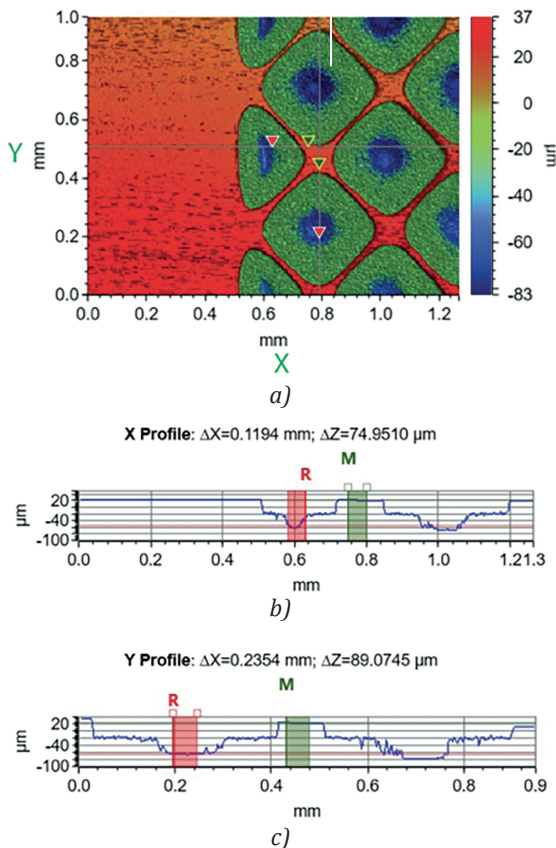
Figure 3: White-light interferometry of gravure engraved plate: view from above (a), cell profile in X-direciton (b), and in Y-direction (c)

Precisely controlled porous architecture of electrodes is necessary for fast charging cells. Fast charging requires electrodes with high porosity and low tortuosity enabling fast electrolyte transport and at the same time prevent lithium plating (Mijailovic, et al., 2021). Thus, circular holes, or non-image areas were designed on printed electrodes with the aim to create so called secondary porosity. Secondary porosity was found useful in suppressing Li dendrites formation in graphite electrodes at fast charging rates (Emani, et al., 2022, Palaniappan, et al., 2022).

The profile of the plate and ink films was prepared on a Bruker white-light interferometry instrument. Image analysis of printed ink films was done using PAX-it 2 software.

In order to test irreversible capacity loss (ICL) of anodes, half coin cells were constructed (Figure 4) in a glove box to avoid moisture and oxygen damage. A half-cell contains a conductive electrode, conductive electrolyte and a current collector. Reversible/irreversible capacity and stability of the electrode was obtained from the galvanostatic cycling technique (Figure 5).
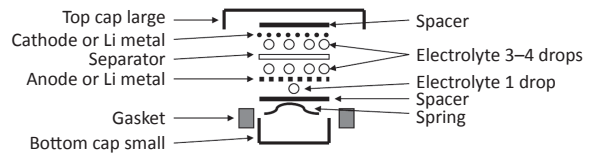
Figure 4: Schematic of half coin cell (Jansen, et al., 2018)
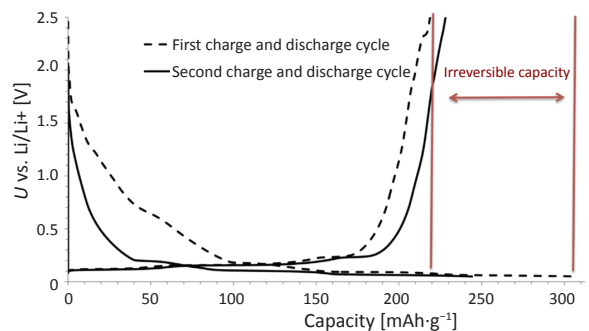
Figure 5: Illustration of ICL determination (Libich, et al., 2017)

3. Results and discussion

Anodes for Li-ion battery electrodes were printed with long-chain PVDF polymer inks. As active materials, graphite powders of different particle sizes were employed. Graphite powders are deemed to be efficient and economical conductive materials; thus, they were considered very suitable for this work. At this stage, particle size of the graphite powders from 5 μm to about 22 μm was assessed; thus only the graphite part

Table 1: Gravure anode ink formulation

Ink	Ink composition Active material	Conductive additive	Binder	Ink formulation (graphite/CB/PVDF)
1	Phillips graphite powder (5 μm)	Nanoparticle	PVDF	92/2/6
2	Phillips graphite powder (10 μm)	carbon black filler (CB)	or PVP	
3	Phillips graphite powder (15 μm)			
4	Mage 3 graphite powder (22.4 μm)			

of the ink formulation was changed, and the rest of the formulation was held the same (Table 1). Solid content of all four inks was kept at 50 %, because higher solid content could not be printed uniformly on the designed structure of gravure plate. As a binder, Kureha 9300 PVDF was used and as a solvent, NMP was employed. The PVDF is a highly non-reactive thermoplastic fluoropolymer. It is a special polymer used in applications requiring the highest purity as well as resistance to solvents, acids, and hydrocarbons with excellent mechanical properties. It was selected because it is a known binder for carbon electrodes in supercapacitors and other electrochemical applications. The NMP was selected as a solvent for this system because of its high chemical and thermal stability, and compatibility with many solvents such as alcohols, ketones, chlorinated and fluorinated hydrocarbons.

the stress or shear rate is decreased, the viscosity of polymer suspensions or inks is regained, e.g., when ink is printed its viscosity increases again, which helps the ink to set on the substrate and create required print features. Not all inks set at the same speed. The speed at which the structure is restored is related to thixotropy. Figure 6 shows that all the tested inks after increased shear drastically decreased in viscosity, but after returning to the original shear rate, the viscosity was regained rather quickly, which shows that all of those inks display only weak thixotropic behavior. The highest viscosity was found for ink with Philips 5 μm, while the inks with Mage 3 and Philips 15 μm had the lowest viscosity. Pseudoplastic behavior of the inks was confirmed in regime of shear rate of 0.1–200 s^{-1} for the flow curve. All of inks were shear-thinning (Figure 7).

Figure 6: Rheology testing of PVDF inks with graphite particle size 5 μm to 22.4 μm and solid content of 50 %; testing conditions 0.1 s^{-1} → 200 s^{-1} → 0.1 s^{-1} were applied for thixotropic behavior testing
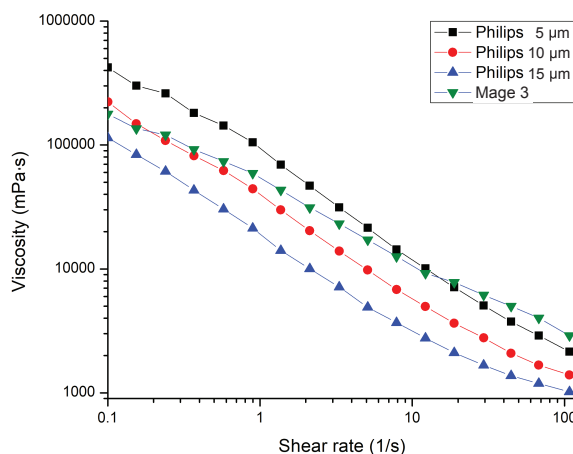
Figure 7: Viscosity change of PVDF inks with graphite particle size of 5 μm to 22.4 μm and solid content of 50 % with shear rate; shear rate of 0.1–100 s^{-1} was applied

Formulated inks were tested for their rheological properties (Figures 6 and 7). Viscosity of polymer suspensions usually increases with increased degree of polymerization, and higher solids content. At certain composition, its viscosity is reduced by increasing the applied shear rate, because the bonds between the polymer chains are broken (Triantafillopoulos, 1988). Tendency of ink to lose viscosity when stirred is called pseudoplasticity. This property favors the ink in the moment of printing because it flows more easily. When

All of these inks were printed on an RK gravure K-proofer (see Figure 1), and these experiments showed that ink containing graphite powder with 5 μm particle size exhibited the best print quality. The reason may be that the 5 μm graphite particle size could deposit the ink film with lowest primary porosity and the best ink film integrity. Also, 5 μm particle size of graphite probably enables easiest ink release from gravure image carrier. Overall, all applied PVDF inks seem to have too high viscosity for rotogravure printing process. Therefore, we wanted to experiment
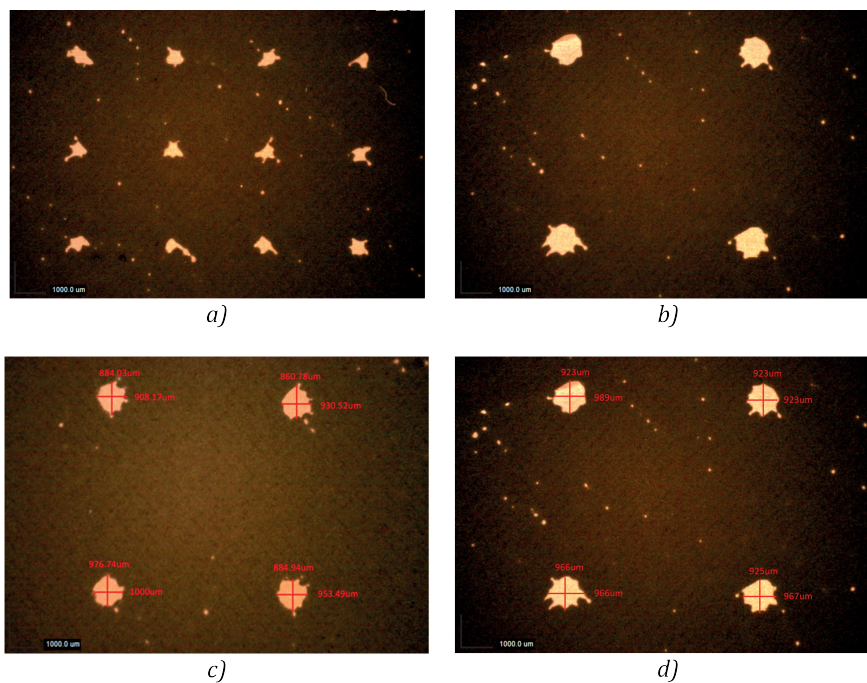
Figure 8: Illustration of printed non-image areas (holes) 500 µm (a), and 1 000 µm (b)
with graphite 5 µm and P5/CB/PVP ink (a and b);
and 1 000 µm holes printed with P5/CB/PVP-PVDF Kureha 9100 (c) and P5/CB/PVP-PVDF Kureha 9300 (d)

with lower ink viscosity, for which a new PVP resin at 10 000 molecular weight was tested to disperse graphite and nanocarbon active materials. Inks with 30–72 % solids were formulated with graphite from Philips (P5) with size of 5 microns, and conductive filler CB 4400 with the ratio of ingredients Philips P5, CB 4400 and PVP of 80/5/15. As a solvent, ethanol or NMP were used. Ethanol was evaporating too fast, thus NMP was chosen as a more suitable solvent. The average surface tension of NMP ink with 70 % solids was 39.4 mN/m and average contact angle with copper surface was 40.8° (data not shown). At 70 % solids, ink layers were 25–27 µm thick with mass loading of 2.1–2.5 mg/cm^2 (data not shown). PVP inks showed excellent dispersing characteristics and improved print quality when compared with PVDF ink prints.

Printed inks with PVP resin are shown in Figures 8a and 8b. Gravure prints with NMP as a solvent were easier to work with than using inks with water or ethanol as a solvent. Designed circular holes with diameter of 1 000 µm were resulting in printed circles of 846 ± 20 µm in diameter, while 500 µm circular holes were printed with 219 ± 11 µm diameter, smaller than those shown in Figure 3 (Figures 8a and 8b). Primary porosity of printed electrodes mostly depends on different particle sizes of active material, in our case graphite of different particle sizes of 5–15 µm. Designed circular holes, or nonimage areas are responsible for secondary porosity.

Printed ink films on copper foil were used to construct half coin cells according to Figure 4. Half cells were used to assess reversible/irreversible capacity and stability of printed anodes. Irreversible capacity loss of half coin cells made with PVP inks was too high and half cells did not have sufficient electrical performance. Thus, in the next step PVP was mixed with PVDF – Kureha 9100 or Kureha 9300 and half cells were made again. The first attempts showed that mixing Kureha and PVP resins is possible, so far 2 : 1 ratio was tested, and inks exhibited uniform prints. Their performance in terms of ICL was tested again (Figure 9). Inks were bar coated, not gravure printed to ensure higher thickness of layers than what was possible to achieve with gravure printing. Figure 9 should be compared with Figure 5.

From Figures 10 and 11, it can be seen that performance of mixed PVP/PVDF inks was greatly improved compared to PVP or PVDF alone, and mixed PVP/PVDF achieved actually better performance and suffered from less ICL than inks made with sole Kureha 9100 or 9300. The PVP is known to have excellent dispersing properties. The macromolecule of PVP contains strong polar lactam hydrophilic groups and C–C long-chain lipophilic groups, which can be well compatible with a variety of solvents and can be coated on the surface of particles to form a good dispersion effect through steric hindrance. Introducing PVP, a polymer with an amphiphilic structure, onto the surface of graphite can significantly improve the dispersion properties
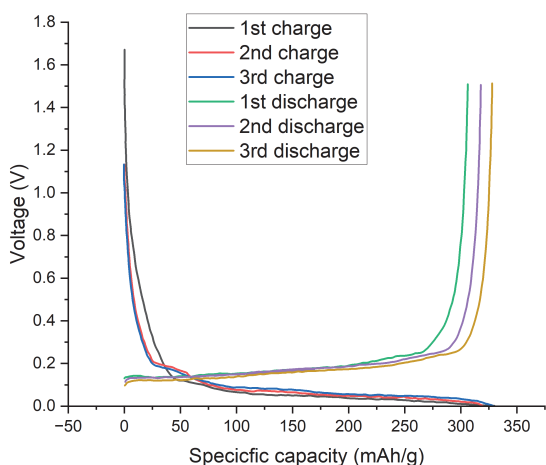
*Figure 9: Irreversible capacity loss
of half cell with anode ink formulation
P5/CB/(PVP + PVDF 9100) = 80/5/(5 + 10);
mass loading: ≈5.26 mg/cm², porosity: ~35 %*
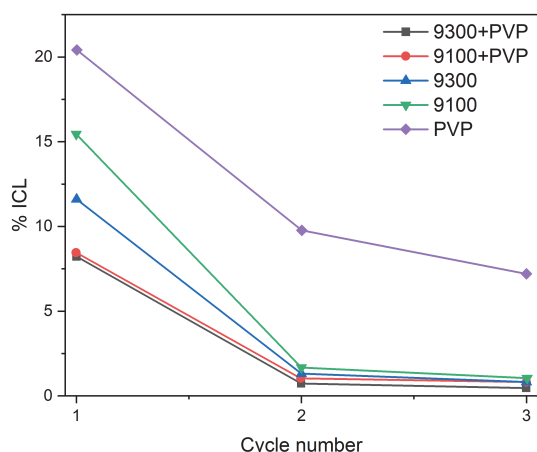
*Figure 10: Comparison of half-cell battery performance
(as ICL) with resins: sole PVP, two types of sole PVDF
and the corresponding combination of PVP/PVDF*
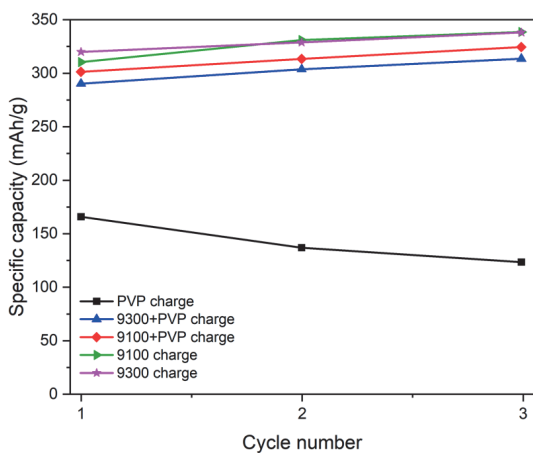
*Figure 11: Capacity of bar coated samples; test
conditions, formation: 0.01–1.5 V, ± 0.1 C*

of graphite in water, or organic solvents. Therefore, PVP can be used as dispersant for Li-ion battery electrode inks and other conductive materials (Bollen, 2021; Li, 2022). This is most likely the reason that PVP enhances the electrical performance of printed anodes in mixed PVP/PVDF inks. PVP with molecular weight around 10 000 creates low viscosity dispersions, which can be suitable for gravure printing, but as a sole binder it does not have sufficient mechanical properties needed for battery architecture. PVDF has large molecular weight (500 000–1 000 000) and its macromolecules create highly viscous dispersions, suited better for screen printing than for gravure printing.

Besides optimized viscosity, mechanical and dispersing properties, mixed PVP/PVDF suspensions exhibit intermolecular forces, beneficial for improved electrical performance. When the two binders PVP and PVDF (Figure 12) were mixed at the ratio of 4 : 1 and allowed to stand for 0–24 hours, obvious darkening of color was observed in the mixtures.
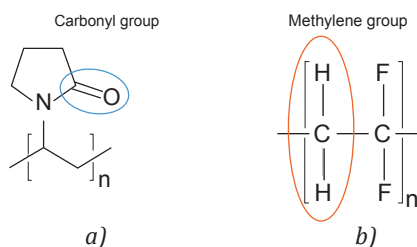
*Figure 12: Illustration of position of carbonyl group
of PVP (a) and methylene group of PVDF (b)*
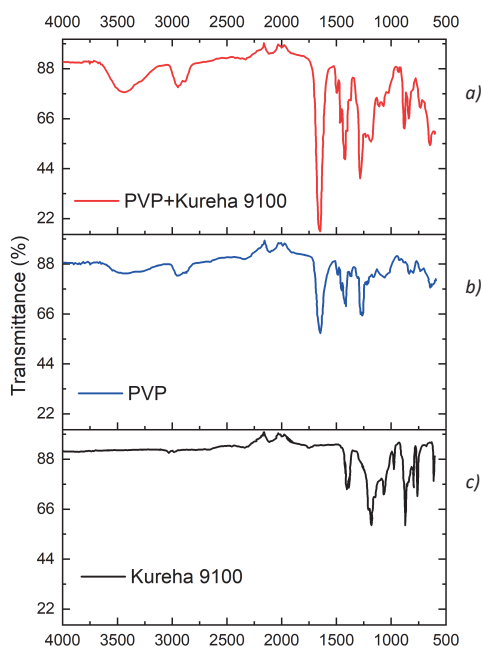
*Figure 13: FTIR spectra of PVP + Kureha 9100 (a),
PVP (b), and Kureha 9100 (c)*

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FTIR was performed on the mixtures to understand what may be contributing to color change and change in ink electrical performance. Binders were dried and ground, and FTIR was performed from 500 cm^{-1} to 4 000 cm^{-1} (Figure 13). The FTIR spectrum showed broadening of O–H groups at 3 434 cm^{-1}, and 3 426 cm^{-1} which could occur due to stretching of O–H bonds. Stretching of C–H groups at 3 000 cm^{-1} and C=O group at 1 652 cm^{-1} was also observed, which strongly suggests the formation of hydrogen bonds between C=O groups of PVP and methylene groups of PVDF (see Figure 12), which could lead to improved electrical performance of printed anodes. Similar behavior was found for PVDF Kureha 9100 and Kureha 9300 in the mixture with PVP.

4. Conclusions

Gravure inks for battery anodes were formulated and printed on a laboratory K-proofer with proprietary engraving. It was found that PVP inks showed good printability, but poor battery performance. Using mixed PVP/PVDF 9300 or PVP/PVDF 9100 binder combination could effectively improve battery performance without significantly sacrificing the printability.

From several graphites having particle sizes between 5 µm to 22.4 µm, graphite with 5 µm particle size was the most suitable for gravure printing. The PVDF inks under commercial name Kureha 9100 or 9300 with NMP solvent showed best specific capacity during three charging/discharging cycles, and ICL was even lower when these PVDF polymers were mixed with PVP.

The FTIR study showed that methylene group ($-CH_2$) and carbonyl groups (C=O) demonstrated lower transmittance and O–H groups showed stretching. This clearly suggests the formation of hydrogen bonds. Hence, the hydrogen bonds formed between the methylene groups and carbonyl groups could be a contributing factor to the reduction of ICL in mixed binder printed anodes.

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Real-world evaluation of artificial intelligence-based color corrections for social media content creators

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Abstract

Brands strive to maintain consistent brand color representation across many digital channels, including social media platforms. This is a challenging goal given the varying real-world circumstances in which brand imagery is produced and shared. The ColorNet neural network tool was developed to automatically target and correct brand colors in imagery without altering non-brand colors. Previously, it was successfully applied to live sports broadcast footage. An open question is whether ColorNet can improve the accuracy, as measured by ΔE_{00}, of brand color representations in still photographs and photographs taken from videos and gifs posted to social media platforms such as Instagram and Twitter. To test this question, we collected a set of posts containing imagery from social media created by Clemson Athletics' social media accounts. We corrected the representation of Clemson orange in these images using ColorNet. After selecting pixel values corresponding to brand colors in each media piece, we demonstrate that ColorNet improves Clemson brand color accuracy across social media channels and for various media characteristics. Despite our observation that brand color representation varies significantly across media types and lighting conditions, the improvement in color representation from ColorNet was relatively consistent. We also showed that ColorNet has a comparatively minor impact on the color representation of skin tones.

Keywords: Twitter, Instagram, ColorNet, artificial neural networks

1. Introduction and background

Achieving consistent brand color is important to brands but challenging in real-world scenarios. Brands spend a significant amount of time determining and protecting brand specifications, including recognizable elements such as fonts, logos, and colors (Moser, 2003; Chang and Lin, 2010). However, consumers look at branded content across many different devices and channels and expect to see similar brand representation (Budelmann, Kim and Wozniak, 2010; Chang and Lin, 2010). For example, a branded product such as Coca-Cola is represented through physical packaging on the grocery shelf, on a jumbotron displaying a commercial during a live sporting event, and on the user's phone in an Instagram advertisement (Mayes, et al., 2021). Even if the actual product that appears on the television and phone screen is printed the correct color of red, the screens may not be color calibrated to display that same branded experience with color-accurate results (Conti and Walker, 2019).

ColorNet is a patented artificial intelligence algorithm that successfully detects and corrects a specified brand color in a live video feed (Walker, et al., 2020a; 2020b). ColorNet was initially developed to address brand color consistency on live video at sporting events. This study looks at the impact that ColorNet can have on content appearing across multiple branded social media platforms and asks the question:

Can ColorNet also improve color consistency on real-world social media content across platforms and content types?

During this study, another question arose when we noticed that the ColorNet algorithm impacted both the branded color (Clemson orange) and some skin tones. This discovery resulted in an additional set of data and analysis to better understand this undesired outcome. By determining situations where this happens, future development and training data will focus on minimizing and eliminating this unintended adjustment.

2. Methods

The Clemson Athletics Content Creation Team creates media for nineteen men's and women's National Collegiate Athletic Association (NCAA) sports, posting content for each across several social media platforms. Their main website highlights every team and includes direct links to an Instagram, Facebook, and Twitter feed with targeted content developed for each channel and sport.

For this study, we focused on content from Twitter and Instagram because both of those channels are used for different types of sports content, which would provide a wide variety of data types. Twitter is often used for play-by-play updates during the season, and Instagram focuses on more visual, summary-style content, including videos and photographs that have been post-processed after the event ends. We chose the following sports to analyze content from different lighting situations (indoor/outdoor, daytime/evening/nighttime): ClemsonTigers, ClemsonBaseball, ClemsonMBB (Men's Basketball), ClemsonWBB (Women's Basketball), ClemsonSoftball, ClemsonWSoccer (Women's Soccer), ClemsonWTennis (Women's Tennis), and ClemsonRowing.

The selection of media was randomized from an initial pool of 46 000 posts. Images that did not include any brand specification orange (for example, a graduate in the uniform of their new pro team or a student-athlete not wearing any branded clothing at a formal event) were removed from the analysis and replaced by the next randomized piece of content from the same channel and platform.

ColorNet 1.5 is a neural network-based model developed for automatic color correction on live video feeds (Mayer, Walker and Smith, 2021). We applied a version of this model pre-trained to correct Clemson orange to the full dataset of images collected from Instagram and Twitter. Original source content included photographs, vector-based graphics, animated gifs, and videos. A frame was automatically pulled from the moving content such as videos and gifs so that each source was represented by an individual jpg for this study. This resulted in a set of paired images where each pair contains the original jpg taken from social media and a version that was processed through ColorNet. Each pair of images was spatially aligned, allowing pixel-level comparisons before and after color correction.

We then labeled the original images to identify pixels that were either Clemson orange or skin tones using an online program called LabelBox, Figure 1. There was no specified limit or target number of pixels selected in each image. Instead, focus was placed on labeling a wide range of items in the image that were supposed to be branded Clemson orange. For example, brand logos found at the facility or on the scoreboard, uniform elements such as jerseys, helmets, shoes, and gloves, and graphic elements added during post-production. In addition, skin tone pixels were labeled with the intent of representing the widest possible range of skin tones across highlights, midtones, and shadows.

When labeling was complete for the full dataset, a JavaScript Object Notation (JSON) file was exported from LabelBox that was used to automate the measurements of each labeled pixel in red, green, and blue (RGB) color values before and after processing through ColorNet. We extracted the color values at each annotated pixel location for the image pairs, forming a set of corresponding color values. This set of paired color readings formed the basis for our analysis of the impact of ColorNet on color representation and consistency. For further analysis, we converted all RGB colors to CIELAB color space using the colormath Python library (Taylor, 2018).

For quantitative analysis, we used the ΔE_{00} (CIEDE2000, notated ΔE below for brevity) to characterize color representation for the points resulting from the above process. The ΔE measures a perceived visual difference between colors, and we were interested in measuring
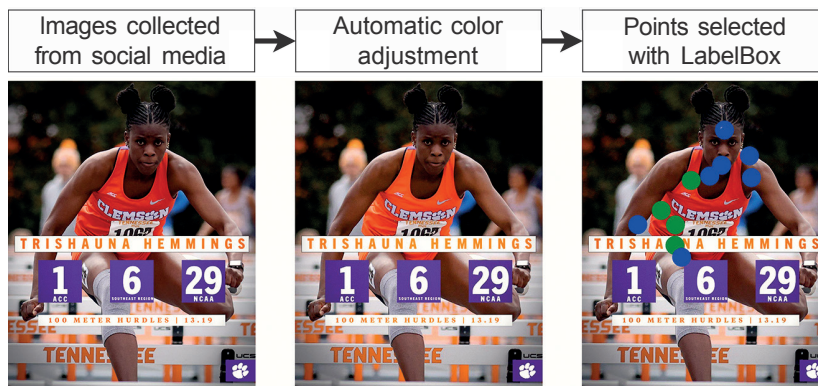

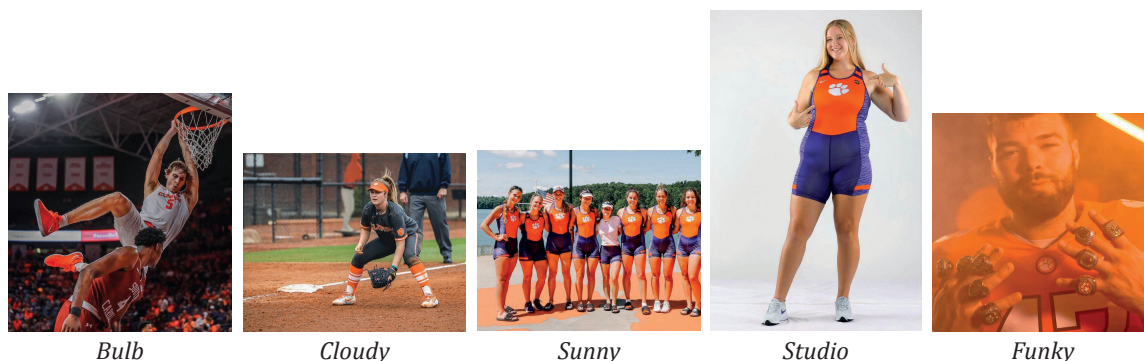*Figure 1: Data processing and annotation process*

Bulb   *Cloudy*   *Sunny*   *Studio*   *Funky*

Figure 2: Examples of the five types of lighting scenarios

the difference in the readings, including the impact of luminance and saturation (Hunt and Pointer, 2011, pp. 61–68).

For brand color pixels, we measured the difference between the observed color and the official brand color specification for both the original and color-adjusted samples (Clemson orange brand, n.d.). To improve color representation, ColorNet should shift the distribution of ΔE values toward zero. In addition, for both brand color and skin tone points, we measured the ΔE between the original and adjusted imagery. We expected ColorNet to produce large ΔE values for the brand color points and small values for skin tones. After computing these ΔE values for each selected point, we examined the performance characteristics in aggregate, comparing across platforms and channels, lighting conditions, and type of source content (still or video).

Lighting was determined to belong to one of five categories that describe the type of lighting present during the initial capture through visual analysis: bulb, cloudy, sunny, studio, or funky (Figure 2). Bulb represented indoor or outdoor situations that were artificially lit. For example, night time on the soccer field with the stadium lights powered on or indoors in the basketball arena. Cloudy or sunny lighting both came from outdoor content. Sunny lighting produced harsh highlights and shadows, whereas cloudy lighting produced more even tones across the image. Content marked as studio lighting was taken, with additional professional lights, in a controlled indoor location. Funky lighting indicates content that was created with lights that have orange or purple gels that skew the actual color of the content in the images.

Qualitative analysis provided a way to more deeply understand which tones ColorNet adjusted more or less accurately. For this process, we looked at the thirty best and worst adjustments to the brand specification orange pixels and the skin tone pixels across both platforms. For brand orange, this was defined as the highest and lowest ΔE values between the corrected pixel

and the target brand color. The skin tone pixels that were adjusted the least (closest to a zero ΔE) and those that were adjusted most significantly (largest ΔE value) from the original skin tone measurement were also examined. Analysis included looking for trends across accounts, platforms, content types (photo, video, or gif), and lighting types (bulb, cloudy, sunny, studio, or funky).

We collected a total of 46 000 messages from nine Twitter and nine Instagram accounts. We then randomly sampled 90 messages containing photographs, graphics, videos, or gifs, 10 from each account, and collected still-images for each post. Posts that included moving images (gif or videos) grabbed the platform-provided thumbnail image from the content. For brevity we refer to such thumbnails as "gif" or "video." Across these 180 images (90 from Twitter, 90 from Instagram), we annotated a total 2 457 points as examples of brand color representation (1129 points) or skin tone (1328). Each image was also labeled according to the lighting condition and content type. The number of images representing each category and other details about the collected data set are summarized in Table 1.

Table 1: Summary of the collected data

		Twitter	Instagram	Total
	# accounts	9	9	18
# images	photo	77	51	128
	video	11	39	50
	gif	2	0	2
	total	**90**	**90**	**180**
# lighting	bulb	27	38	65
	sunny	23	22	45
	studio	17	14	31
	cloudy	11	12	23
	funky	8	3	11
	N/A	4	1	5
	total	**90**	**90**	**180**
# points	brand color	537	592	1 129
	skin tone	700	628	1 328
	total	**1 237**	**1 220**	**2 457**

3. Results

3.1 Measurement of color fidelity

We measured the difference between the 1129 selected brand color points and Clemson orange brand speci-fication (denoted by the brand as RGB 245, 102, 0 and Pantone 165, Figure 3). The CIELAB values are not pro-vided by the brand so RGB color readings were con-verted to CIELAB and back to RGB using the colormath Python library for processing and analysis. Before color correction, the average ΔE value was 14.9 ± 0.6. After color correction, the average ΔE improved to 11.5 ± 0.5. While these values are still large, measurement against brand specification is too strict as it neglects appropri-ate variation in color presentation due to lighting con-ditions such as deep shadows or blown out highlights. The average ΔE in the 1.3k selected skin tone points between the original and corrected images was 2.6 ± 0.1. Though this is larger than ideal, it is encouraging that the shift is much smaller than the corresponding shift for the brand color points (7.1 ± 0.2). This suggests that ColorNet can differentiate between brand color regions and skin tone regions – a challenging task since the tonal range of skin falls close to Clemson brand orange in certain situations.

We next examined how brand color representation and ColorNet performance varies by platform, media type, and lighting condition. Figure 4a shows the mean performance and 95 % confidence intervals for both platforms for the original and corrected imagery. On average, media on the two platforms have similar brand-color fidelity; the improvements from ColorNet are consistent. When we consider lighting conditions (Figure 4b), we see that studio lighting conditions pro-duce significantly better color fidelity in the original and corrected images. Looking at the ΔE values across media types (Figure 4c), we find the surprising result that still photographs have much better color fidelity than videos both before and after correction. We spec-ulate that this may result from the different cameras and camera settings used by the media teams and post-processing techniques applied differently in the two cases.

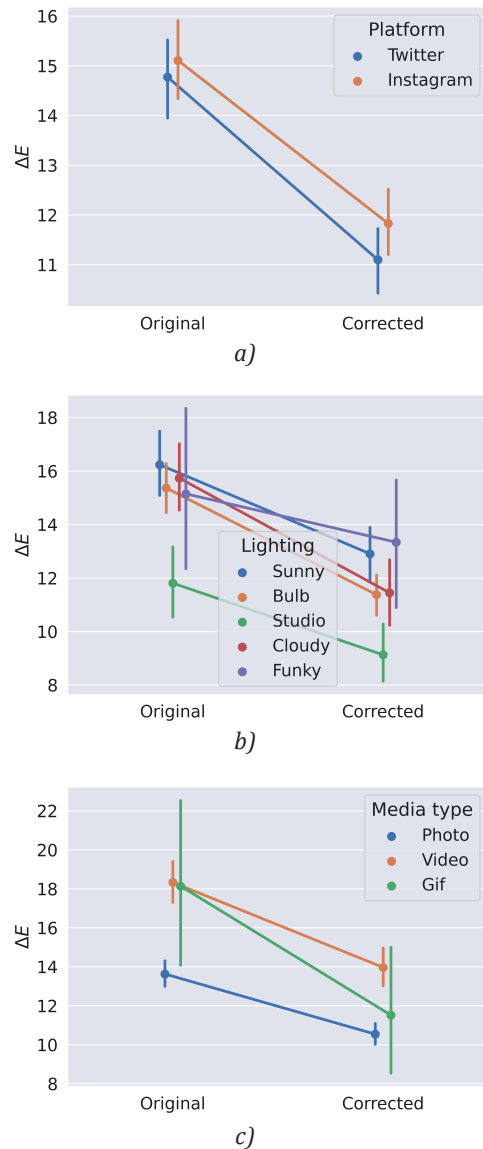*Figure 4: Performance by platform (a), lighting condition ('N/A' samples are omitted) (b), and media type (c); the Y-axes measure ΔE between the collected color points and Clemson brand orange, the "video" and "gif" categories are based on still images collected from videos or gifs*

Figure 3: Brand designations across different media (Clemson orange brand, n.d.)

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Finally, to better understand the average ΔE of 2.6 ± 0.1 for the 1.3k selected skin tone points, we evaluated the average shift by platform, lighting condition, and media type. We found little variation in the skin tone shift by platform or lighting condition. However, when considering media type, we observed an average shift of 2.8 ± 0.1 for photos and an average shift of 2.0 ± 0.2 for videos. In other words, ColorNet led to a greater shift in skin tones for photos than for video. This may be a consequence of the poorer color fidelity in the videos causing skin tones to shift further away from Clemson brand orange, as indicated in the previous paragraph, or it may indicate a deficiency in ColorNet itself.

3.2 Analysis of best and worst-performing pixels

For brand orange, the best-performing pixels were closest to brand specification after being corrected by the ColorNet algorithm. For the top 30 pixels, the ΔE values ranged from 0.49 to 1.69. The distribution included ten accounts with the top four represented by: ClemsonSoftball, ClemsonBaseball, ClemsonWBB, and ClemsonWSoccer. Twice as many came from Instagram as from Twitter (20, 10) despite a nearly even number of source points in the original data set (1237, 1220). Nearly twice as many were from photographic rather than video sources (19, 11), but it should be noted that the full data set includes more than three times the number of photograph content versus video so there may be greater diversity of photographic situations in the original data (1793, 637). Lighting was distributed across all five listed types with bulb and sunny having the most pixels in the top thirty best performers. Further qualitative analysis showed that ColorNet corrects Clemson orange best on uniforms in neutral lighting or highlights and in several cases did not manipulate parts of the stadium that should be brand orange but do not look to be close to specification due to color fade and sun exposure.

For brand orange, the worst-performing pixels were considered pixels that should appear as brand color but were furthest from brand specification after being corrected by the ColorNet algorithm. For the bottom 30 pixels, the ΔE values ranged from 34.3 to 44.4. It should be noted that the original values before processing with ColorNet ranged from 34.6 to 48.0, so these pixels were initially displaying far from the desired color specification even before being processed. ColorNet adjusted the pixels by an average of 5.26 ΔE. The distribution included eleven accounts with ClemsonSoftball and ClemsonBaseball again appearing as the most frequent accounts. Slightly fewer than twice as many came from Instagram as from Twitter (17, 13) and were from photographic rather than video sources (17, 13). Lighting was distributed across all five listed types, with sunny and bulb having the most pixels in the worst thirty

performers. Further qualitative analysis showed that Clemson orange displays furthest from specification in shadowed or very shadowed areas of the frame or occasionally in very low-quality images such as a still image reproduced from a television broadcast.

For skin tones, we ideally want ColorNet to make no adjustments, but, since that was not what the data showed, qualitative analysis helped the researchers identify parts of the algorithm and training data that need further adjustment. The best-performing skin tone pixels were very minimally adjusted or not adjusted at all by the ColorNet algorithm. For the top 30 pixels, the ΔE values ranged from 0.0 to 0.31. The distribution included thirteen accounts with the top four: ClemsonBaseball, ClemsonWTennis, ClemsonWBB, and ClemsonRowing. The distribution between platforms was nearly even, with 16 from Twitter and 14 from Instagram. More were from photographic rather than video sources (18, 12). Lighting was distributed across all five listed types, with bulb lighting taking a heavy lead (17) and sunny in second (6). Further qualitative analysis showed that ColorNet does not tend to correct lighter skin tones in neutral or highlight areas of the frame, with only three out of the least affected skin tone samples including dark skin in neutral lighting.

The worst-performing skin tone pixels were those that were adjusted the most by the ColorNet algorithm. For these 30 pixels, the ΔE values ranged from 7.9 to 15.3, all adjustments that we would consider unacceptable for skin tone representation. The distribution included twelve accounts, with the top four most frequently appearing accounts as follows: ClemsonRowing, ClemsonBaseball, ClemsonTigers, and ClemsonFB. Pixels from Twitter content appeared twice as often as from Instagram (20, 10). Most of the content was from photographs rather than videos (27, 3). Lighting was distributed across all five listed types, with sunny and cloudy lighting conditions appearing most frequently (14, 8). Further qualitative analysis showed that ColorNet can incorrectly identify dark skin tones in neutral lighting and suntanned lighter skin tones in shadow as intended to be brand color. It was also noticed that skin on ears and around the lips are more often confused and therefore more frequently adjusted by ColorNet than other areas of skin.

4. Discussion

Initially, a set of images from social media posts by Clemson Athletics marketing accounts was pulled, paired, and corrected using the ColorNet neural network to address brand color consistency. Relative to the imagery taken directly from social media, ColorNet produces brand color representations with smaller devia-

tions, on average, from true Clemson orange resulting in a positive improvement in brand color representation. This pattern holds when considering multiple channels and media characteristics in aggregate and for each stratum individually. Taken at face value, this suggests that the ColorNet neural network, originally developed for broadcast footage, can also improve brand color fidelity for use with social media content when applied to Clemson brand colors. This quantitative approach assumes that low deviations from brand color specification correspond to a positive value in the eyes of the brand owners and fans. Taken to an extreme, however, this is clearly incorrect, as a distribution with no deviation around brand specification would lose natural variations in the presentation of color caused by natural highlights and shadows present in the environment. Future user studies are needed to assess whether marketers and content creators would value the ability to produce more accurate brand representations. Should that be desired by the brand stakeholders, further devel-

opment of an integrated, quick turnaround tool would be necessary for full integration and implementation at the point of content creation and distribution.

5. Conclusions

Through this study, we demonstrated that ColorNet improves brand color fidelity across social media channels and for various media characteristics for Clemson brand colors. Despite our observation that brand color representation varies significantly across media types and lighting conditions, the improvement of color representation after processing media through ColorNet was relatively consistent. This study also showed that ColorNet has a comparatively minor impact on the color representation of skin tones in imagery but further refinement of ColorNet to address this would be a valuable undertaking to ensure the lowest impact possible on skin tone areas present in the image.

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The health and outlook of printing industry post-Covid-19: the insight into Malaysia printing industry

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Abstract

While it is widely assumed that the printing industry is in a state of declining demand, or "sunsetting" worldwide, our study suggests that the printing industry in Malaysia shows a stabilizing trend. Print service providers (PSPs) diversify and exploit the trend for digitization and automation and also explore new market segments to stay relevant. The industry's performance before, during, and after the pandemic from 2019 to Q2 2022 was analyzed. An interview with the top management of PSPs was conducted to obtain views on the impact of Covid-19 on the print business. The findings show macroeconomic factors' are heavily influenced by growth and suggest that demand will remain resilient going forward, making the outlook for the printing industry optimistic despite domestic and global uncertainty. We also discovered that the pandemic has given PSPs a chance to reevaluate their operations and rebuild using technology to support their businesses in the post-Covid-19.

Keywords: printing industry market, industry performance, developing nations, digitalization, pandemic

1. Introduction and background

Printing is one of the oldest industries in Malaysia and its emergence can be traced back to 1806. On March 1st of that year, following the arrival of Malaysia's first printing press, the daily Government Gazette, under the direction of A.B. Bone, had its inaugural run in Penang (Byrd, 1970). The industry continued to develop, and by the late 1880s the growing presence of printing machinery and equipment saw printing establishments expand to include not only European printers, but local and regional ones as well, such as Chinese, Indian, Jawi Peranakan/Jawi Pekan and the Malay (Harun, 2005). According to Harun (2005), Penang became the center of the printing industry at that time and has remained so to this day. To illustrate, since World War Two more than 20 printing establishments have been set up shop in Penang and contributed to the rise of various industries such as newspaper, magazine, and book presses throughout Malaysia.

More importantly, printing industry's contributions to Malaysia's development extend beyond media. Printing serves as a medium of communication, for protection of goods in packaging and in the art products. Printing industry has a significant impact on business opera-

tions and management in every sector of the national economy (Mtshali, et al., 2018; Rocha, 2019; Mohamad, 2003). Printing sector has offered a wider range of services and is more productive due to the development of technology. The major workforce has switched from craftsmen to technologists as a result of process automation.

The Covid-19 pandemic has a significant influence on most businesses, including the printing industry. However, it has varying impacts on the printing industry based on the sectors and print products. A market report on disrupting of Covid-19 on printing industry shows that publication markets will be most affected, followed by graphics, packaging and labels (Smithers, 2021). Gamprellis, et al. (2021) have studied the challenges for the printing industry in the modern digital and meta-pandemic era. The study concluded that even though the pandemic of Covid-19 has had a huge impact in terms of the financial crisis, the impact on the printing industry is not severe.

The printing industry has demonstrated a stabilizing trend in which label or packaging printing is obviously rising and even growing at extremely high rates. An interesting finding in the brewing industry has shown

that the increase in at-home consumption has a positive impact on packaging printing. Packaging became an important tool to the brewing industry as single serving packages became the most important form of packaging during the Covid-19 pandemic (Pitts and Witrick, 2021). The impact of Covid-19 on food sector has also contributed to a positive dimension for packaging sector in the printing industry. Innovation such as smart packaging, advanced traceability systems, new biosecurity arrangements to protect consumers by ensuring the food and food supply chain's safety and reduce food loss and the environmental impact of the food sector has helped the packaging sector (Galanakis, et al., 2021).

An overview of the European packaging industry due to the pandemic of Covid-19 has shown a significant increase in demand for packaging products in the food and pharmaceutical industry and e-commerce (Naletina, 2021). As of yet, no study has focused on the current state of the Malaysian printing industry during the post pandemic of Covid-19. Existing studies tend to simply presume that commercial and publication print revenues have fallen due to Covid-19 (McNulty, 2020; Brinton, 2021; Gamprellis, et al., 2021; Sheresheva, et al., 2021).

With this gap in mind, the goal of the present study is to investigate the current state of the Malaysian printing industry; post pandemic by looking at industry's performance before, during and after the pandemic period using a time-series analysis. For this purpose, two research questions were proposed:

> RQ 1: How has the Malaysian printing industry performed from 2019 to the second quarter of 2022?

> RQ 2: What impacts has Covid-19 had on print service providers (PSPs); how have they dealt with these and what have they learned during the pandemic?

To answer these questions, we studied macroeconomic data from the Department of Statistics Malaysia and applied a qualitative approach using the multiple case study method. This allowed us to scrutinize the PSPs' experiences and challenges and to offer a prognosis for the future of the printing industry. In so doing, we hope to make this research a potential source for industry competitiveness studies both for the printing industry and other industries that are prone to disruption by digital innovation such as the retail sector and travel agents (Thomas and Douglas, 2021).

We are confident the present study raises the possibility of improving existing policies and encouraging better policies and programs by the government, policymakers, and printers themselves.

2. Methodology

For the first research question, we studied the performance of the printing industry by looking at the statistics published by the Department of Statistics Malaysia, namely the printing industry's contribution to Malaysia's gross domestic product (GDP). According to Callen (2020), GDP – the total value of all goods and services produced in a certain period after deducting the costs of goods and services used up in the process of production – is one of the most widely used indicators of economic performance. Data from the national production and expenditure accounts for the second quarter of 2022 contain statistics of quarterly national accounts (Malaysia's Official Statistics, 2022) estimates by economic activity and expenditure type in both current and constant prices set at base year 2015.

The three-year period in the data allows for an analysis of the changing global business environment, particularly as globalisation forces, trade liberalisation and political reforms in other countries have facilitated accelerated trade and growth, which is especially significant for fast-changing, emerging economies such as Malaysia's. The major advantage of a time-series analysis is that it encompasses a set of sequential quantitative observations to identify dynamic capabilities and superior performance over time based on patterns in the historical data (Kirchgässner, Wolters and Hassler, 2012). This time-series analysis has been used in the past in the field of econometrics, further supporting its validity (Mugableh, 2015; Linton, 2017).

Looking specifically at factors that drive the printing industry and potentially determine its growth, we pay special attention to advertising and promotion expenditures; that is, we study the trends in Malaysia's advertising and promotion expenditures by medium in the years 2020 and 2021.

To answer the second research question, a multiple-case-studies design was used to explore the data related to Covid-19 and its relation to PSPs. According to Bengtsson (2016), the concept of unit of analysis refers to the sample that can best answer the queries set out in the study's aim. In this study, the unit of analysis is a PSP in Malaysia's print industry, in other words, the individual. The target respondents in this study were those who hold top managerial positions (i.e. managing directors / business managers) and who are therefore directly involved in decision making and the direction of their businesses. We collected PSP managers' opinions on the impact of Covid-19 on the print business through semi-structured interviews, which, we believe, allows us to capture the complexities of the pandemic and facilitate further investigation.

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3. Data analysis

To address the first research question, descriptive statistics were used to describe and summarize the data and to present meaningful information about the performance of the printing industry over time. As such the analysis is presented in a time series of quarter 1 (January to March), quarter 2 (April to June), quarter 3 (July to September) and quarter 4 (October to December).

Due to data availability limitations regarding Malaysia's GDP, only the first and second quarters of 2022 are presented (Malaysia's Official Statistics, 2022). Nevertheless, the findings of this research could be considered beneficial because they reflect the pre-pandemic, pandemic and post-pandemic situations in Malaysia.

To ensure the reliability and validity of the data, statisticians at the Department of Statistics Malaysia were consulted if any uncertainty in the data arose during data validation checks. Furthermore, to assist in the analysis and to check the consistency of the data, an independent statistician was employed.

3.1 Selection of participants for case studies

The target participants for the multiple case studies comprised print PSPs in the Klang Valley and the Selangor area (central Malaysia). The sampling approach started by consulting the Yellow Pages Business Directory 2021/2022, which was published by TM Info-Media Sdn. Bhd. The Yellow Pages was selected due to its reputation as a leading business directory in Malaysia since its establishment in 1989. Furthermore, it lists 500 000 businesses and digital platforms for easy searching (Yellow Pages Malaysia, 2022). After searching for a list of PSPs, we filtered the results to include only the manufacturing category, leaving us with 243 listings. Then, for each PSP we consulted the database of the Companies Commission of Malaysia to validate the profile of each company and/or business, and then further consulted with the Malaysia Printers Association, the Malay Printing Entrepreneurs Association of Malaysia and the Selangor & Federal Territory Chinese Printing Presses Association for their feedback as to how to best approach the top managers of selected PSPs, thus reinforcing our understanding of our interviewees.

Subsequently, the top managers with experience and knowledge of doing business during Covid-19 were selected based on purposeful sampling (Creswell and Piano Clark, 2017; Patton, 2002). The function of purposeful sampling is to capture the characteristics of both commonalities and differences that are necessary for producing new knowledge (Palinkas, et al., 2015). Moreover, as reliability and validity of samples are based on availability, willingness and the ability to participate, communicate and share experiences in a reflective manner, candidates in top managerial positions were perceived as the most appropriate because they are directly involved in decision making and the direction of their businesses (Bernard, 2006). A major advantage of this qualitative method is its ability to provide a deeper understanding of the phenomenon under study. This sampling method particularly aims for efficiency and validity (Morse, 2009) with an emphasis on saturation (Miles and Huberman, 1994), whereby we achieve a thorough understanding by sampling continuously until no new significant information is obtained. With this in mind, we restricted the interviews to five Malaysian PSPs at top management levels.

The study was conducted in accordance with proper protocols. Interview sessions adhered to social distancing protocols, and Certificate of Ethics was issued by the Research Ethics Committee of Universiti Teknologi MARA (UiTM). Face-to-face interviews were conducted with the purpose of eliciting information from study participants, all of whom provided consent in written form to participate.

The minutes from each interview were transcribed and then codified using the NVivo software. Key phrases were coded and a tree structure was developed to facilitate the analysis that helped us organize it into an analytical theme.

4. Findings

Firstly, we discuss the performance of Malaysia's printing industry. Next, we consider the impact and challenges faced by PSPs in conducting their businesses during the Covid-19 period. Finally, we describe the insights gained from these PSPs' experiences during the pandemic.

4.1 RQ 1: How has the Malaysian printing industry performed from 2019 to the second quarter of 2022?

The growth of the Malaysian printing industry from 2019 to Q2 of 2022 is illustrated in Figure 1.

In 2019, Malaysia's economy grew by 4.3 %. Similarly, Malaysia's printing industry grew by 4.2 % despite political uncertainty and external conditions (World Bank, 2019). However, some printers experienced delays in government related print projects, particularly textbooks.
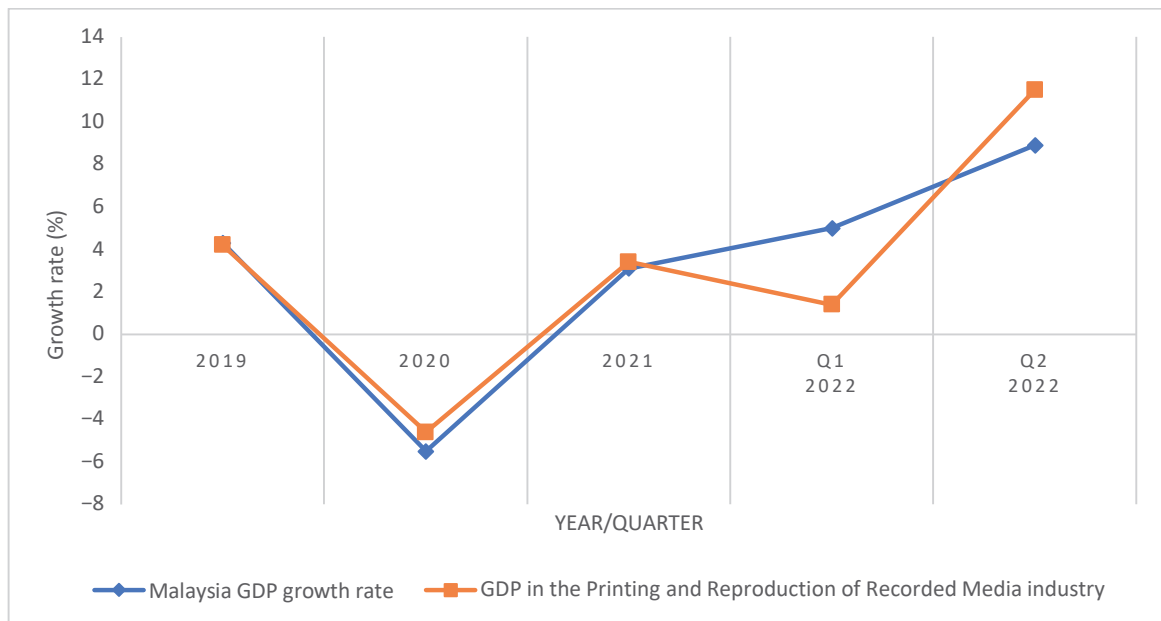
Figure 1: Percentage GDP change in the Printing Industry and Malaysia's GDP

The following year, Malaysia experienced the sharpest recession in twenty years with a recorded −5.5 % negative growth. This negative growth was a direct result of the health impact of the pandemic, the restrictions on movement, and the global recession (which directly impacted Malaysia's trade sectors). This triple shock likewise contributed to the −4.6 % negative growth of the Malaysian printing industry. Domestically, the decline was largely due to a decrease in demand for print materials among Malaysian consumers, which, in turn, may be due to the fact that the pandemic brought about a change in lifestyle among Malaysians. For example, the education sector in particular saw a fall in demand for published items as a result of the government's enforcement of the Movement Control Order (MCO). The temporary closures of public and private educational institutions across the county persuaded educators to utilize virtual learning platforms, including electronic books (e-books), videos, apps and online quizzes and tests (Sim, Sim and Quah, 2021), thereby decreasing the need for printed reading materials.

The pandemic also changed the way Malaysians consume information; for example, the lockdown led Malaysians to increasingly rely on alternative media sources. The same is true of advertising and promotions. During the pandemic, many businesses turned to alternative media, such as the internet, to promote their products and services. This is evidenced by comparing the change in Malaysia's advertising expenditures (ADEX) in 2021 and 2020 (see Figure 2). As reported by the Malaysia Advertisers Association (2021), internet advertising saw a significant increase of 37 %, including on the digital out of home (DOOH) platform. TV and radio advertising recorded increases of 12 % and 4 %, respectively, while outdoor banner advertising recorded the lowest increase of 0.6 %. Overall, ADEX by print medium decreased by 29 % for magazines, and 8 % for newspapers (Malaysia Advertisers Association, 2021).

A closer inspection of ADEX in Figure 3 shows year-on-year growth, but reveals a significant decline in newspaper ADEX from 42 % in 2012 to 7 % in 2022. Similar but less pronounced trends can be seen with magazine ADEX, from 7 % in 2012 to 4 % in 2022. There is thus a clear trend of decreasing demand for print media advertising.

Moreover, the shift in consumer culture was not limited to individuals. The decline in demand in 2020 was also a result of the accelerated trend towards a paperless economy brought on by many companies and government offices adapting to the lockdown, forcing them to transition to home offices. This is particularly evident by reports by some printers that orders for stationary items such as envelopes, business cards, letterheads, and binders were significantly lower. It is surprising, then, that the negative growth of the printing industry was not as substantial as the overall economy in 2020.

That being said, a counterbalancing increase in demand in 2020 was driven by packaging and labels, especially for essential products such as medical supplies, particularly face masks and rubber gloves. Furthermore, the accelerated growth of e-commerce led to an increased demand for corrugated cartons and flexible packaging as more businesses leveraged digital platforms rather than conventional retail outlets.

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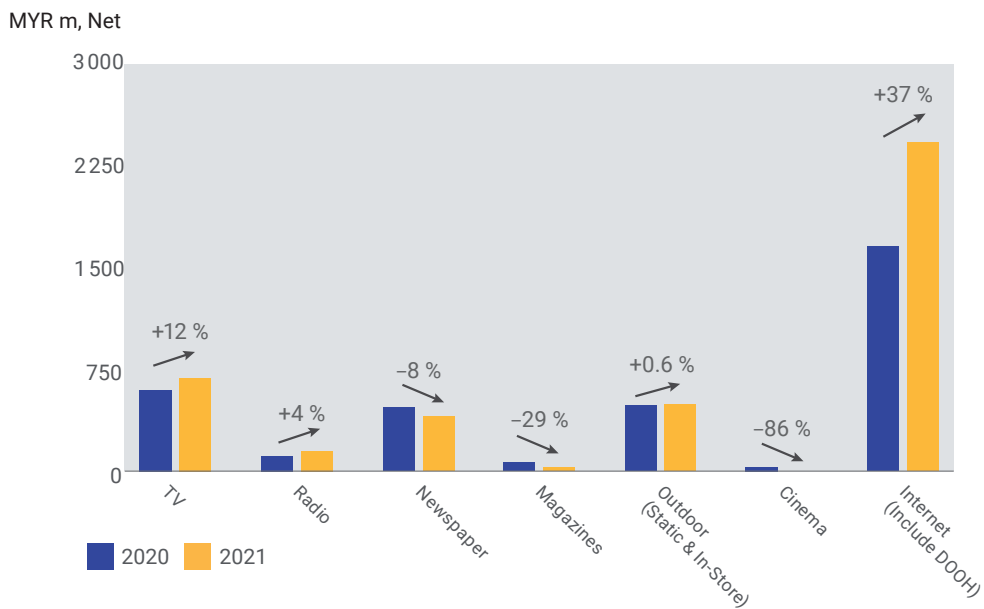
Figure 2: Total advertising expenditures (ADEX) by medium for the years 2020 and 2021
(Malaysia Advertisers Association, 2021)
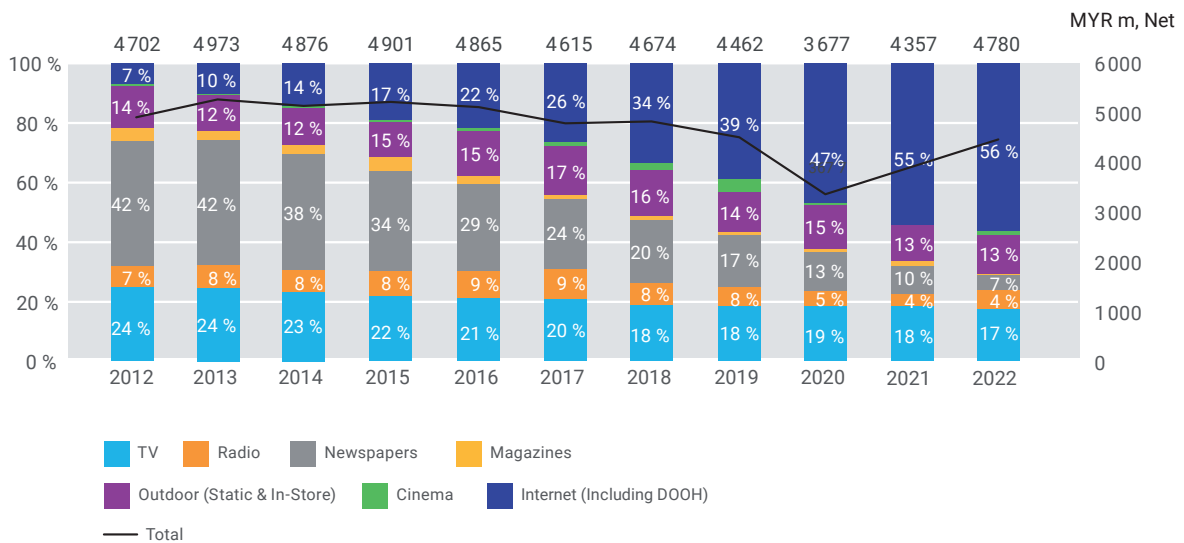
Figure 3: Advertising expenditures by medium in % and in total in million MYR – multi-year growth
(Malaysia Advertisers Association, 2021)

In 2021, economic conditions began to change. The country witnessed a slow recovery from Covid-19 starting in Q3, with the number of new daily cases continuing its downward trend while recoveries showed an upward trend. With 74.9 % of the population fully vaccinated, the withdrawal of restrictions on travel and business operation hours increased economic and social activities. From the data in Figure 1, it is apparent that this had a positive influence on Malaysia's economy with a recorded positive growth of 3.1 %. Figure 1 likewise illustrates that the Malaysian printing indus-

try performed relatively well in 2021 with a higher growth of 3.4 % as compared with 2020 (−4.6 %). As a whole, the relaxed Covid-19 restrictions allowed Malaysia's manufacturing sectors to post stable growth data supported by domestic and external recovery in demand (Malaysia's Official Statistics, 2021).

With all 13 states in Malaysia showing positive growth of 3.1 % in 2021, compared to a decline of −5.5 % in 2020, Malaysia's economy was projecting a clear sign of recovery momentum despite projections of decline

in the global economy to 2.9 % in 2022 (World Bank, 2022). In fact, in Q1 2022, Malaysia's economy had a strong growth of 5 %. However, as shown in Figure 1, the Malaysian printing sector recorded a slower recovery of just 1.4 % in the same quarter despite the move out of the pandemic phase. In contrast, in Q2 2022, while Malaysia's economy rose to 8.9 %, the printing industry, which accounts for just 0.3 % of total GDP, performed at a record growth of 11.5 %. This performance was underpinned by both the intensifying demand for products associated with Malaysian social events, such as the Eid al-Fitr celebrations, and the reduced restrictions on individuals and businesses. It is expected that the manufacturing sector as a whole will remain strong in the following months due to the continued increase in demand as well as the global economic recovery.

4.2 RQ2: What impacts has Covid-19 had on print service providers (PSPs), how have they dealt with these and what have they learned during the pandemic?

This part of the paper answers the previously presented research questions regarding how Malaysian printers overcame Covid-19-related issues and how their actions have helped them plan for changes in Malaysia's print industry going forward (RQ2).

We summarize our findings of interviewees' characteristics in Table 1. It is notable that all of our PSPs have more than 15 years' experience in the printing business.

To address the second research question, we first explored the impact of Covid-19 on printing businesses (Figure 4).
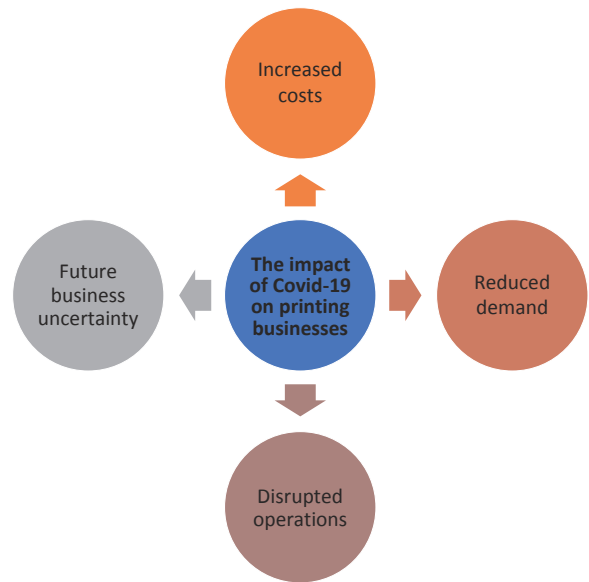
Figure 4: The impact of Covid-19 on printing businesses

Next, we highlighted the strategic management approaches adopted by the PSP during the crisis (Figure 5). Finally we recorded PSPs' perspectives on the future of printing (Figure 6).

Table 1: Characteristics of interviewees and their firms

ID (Company)	Designation[a]	Year incorporated	Sales turnover[b] < RM15 million, ≤ RM50 million	Area of specialization[c]	Technologies[d]
A	Managing Director	1975	≤ RM50 million	Manufacturing of diaries, notebooks and paper stationaries- related products	Offset and gravure printing
B	Managing Director	1984	≤ RM50 million	Book printing, binding, finishing and logistic fulfillments	Offset and flexography printing
C	Managing Director	1993	≤ RM50 million	Paper based packaging	Offset printing
D	Business Manager	2006	< RM15 million	Design services, commercial and publication printing	Event production and digital printing
E	Managing Director	2001	< RM15 million	Business process outsourcing	Digital and variable data printing and mailing

[a] *This column lists the interviewees' roles within the firms.*

[b] *This column represents the size of the PSP's operation as defined by SME Corp. Malaysia (2020).*

[c] *This column represents the area of specialization based on product segmentation.*

[d] *This column lists the main printing technologies used by the firm.*
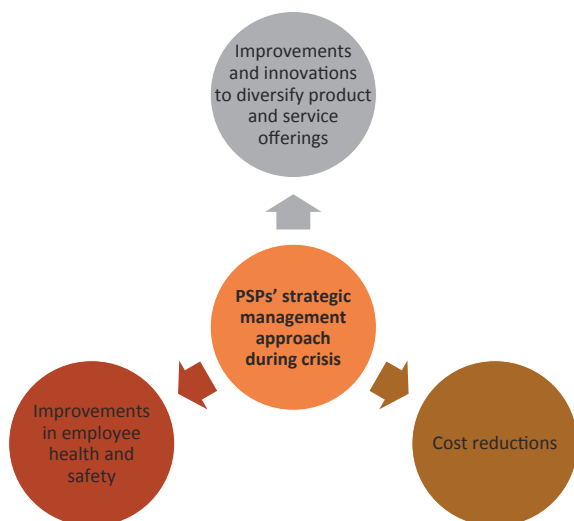
Figure 5: PSPs' strategic management during crisis
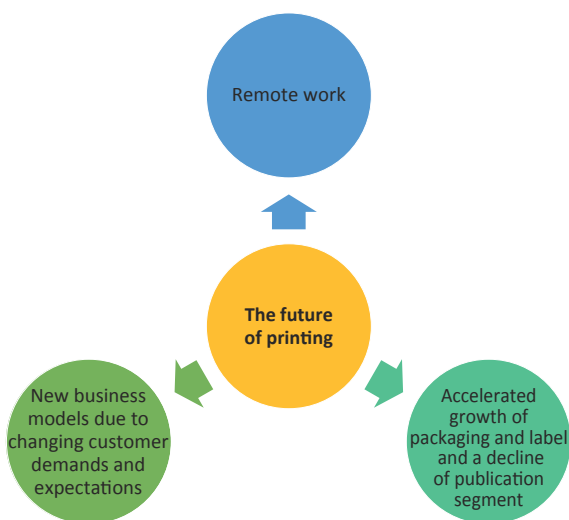
Figure 6: PSPs' perspective on the future of printing

4.2.1 The impacts of Covid-19 on the printing industry

The analysis of the interviews resulted in four broad impact areas resulting from the Covid-19 disruption, namely increased costs, lower demand, operational disruptions and uncertainty in business direction.

Operational expenditures increased during the Covid-19 pandemic. The increased costs, as reported by the respondents, were primarily due to additional expenses needed to comply with compliance requirements. As interviewee C put it: *"The pandemic increased the overall operation costs, especially with the increase of need-for-safety and health compliance requirements."*

The interviewees were also confronted with the serious challenge of a reduced demand for their products and services. As interviewee B said, *"Covid-19 has impacted demand greatly."* Another interviewee (interviewee E) alluded to the consequences of reduced demand by commenting that: *"Adding on to the Covid-19 pandemic, a lot of businesses had to temporarily close largely due to reduction in demand…."* Interviewee D commented: *"We are facing a sharp drop of business of 50–60 %."*

During the pandemic, the MOC imposed by the government resulted in operational disruptions. Consecutive closures, a reduction in employee capacity and classification of essential services were the main causes. Talking about this issue, interviewee A said: *"Business interruption is severely affected – production is partially or totally shut down. During the stage when the printing industry is allowed to operate, only 50 % of the workforce is involved! – the government ruling has created difficulties for the printing industry to mobilize its workforce."*

Other responses to this question included one given by interviewee C: *"We were lucky to be part of the supply chain, which allowed us to get permits from the authorities to operate. However, there was a headcount limit to comply with, hence output was definitely lower."*

There was a sense of uncertainty about the future of the printing business amongst the interviewees, as illustrated by interviewee A, who plainly stated that: *"The pandemic caused uncertainties to future businesses."* This view was echoed by interviewee B who said: *"We have to grow our market and develop new products to offset the drastic drop in demand. But this can only reduce the impact."* There were also some suggestions regarding the direction of the print industry prior to the pandemic. As interviewee E said: *"Even before the Covid-19 pandemic, a lot of businesses already needed to rethink their business models if their businesses were to survive in this new digital era where everything is moving towards digital or electronic."* Commenting on this issue, interviewee E further elaborated: *"However, there is always a silver lining in our printing industry where businesses servicing selected markets (such as glove manufacturers, healthcare, courier delivery services, food packaging, and so on) are doing extremely well during this challenging time."*

4.2.2 Strategic management approaches during the crisis

Interviewees stated that they used several strategies and mechanisms to mitigate the impact of Covid-19.

A common view from the analysis suggests that businesses need to improve and innovate by diversifying product and services offerings, reducing costs, and improving health and safety.

The most resilient PSPs responded to the pandemic by improving and innovating their products and services. A variety of perspectives were expressed by the interviewees in this regard. It was suggested by interviewee A, for example, that: "*production of conventional products and services will be slowed and eventually diminished…*" and that "*diversification of new products is essential*". In another instance, interviewee E thought that improving services and product offerings through investment in Research and Development (R&D) would allow "*[us] to continue investing in our R&D to improve our services and product offerings*". Interviewee D responded to this question by stating: "*…meanwhile, we also rolled out a direct to garment (DTG) shirt printing business and canvas home deco printing services*".

Commenting on improving their products and services, interviewee C said, "*This is a good alarm and indication for us to restructure our business direction, and to reallocate our level of exposure in the market moving forward.*"

It was further suggested that financial management during the pandemic was crucial to the survival of the business. Interviewee B said: "*Cost cutting measures such as reducing overhead and capacity and investing in new technologies to improve efficiency helped us to mitigate the impact.*" This view was echoed by interviewee A, who experienced delays of orders and payments: "*Customers have delayed placement of orders, which causes deferred payments.*"

The pandemic also exposed a severe health risk. There was a suggestion from interviewee C that enhancing employee health and safety should become a top priority. For example, interviewee C said: "*The biggest step is to ensure the safety and health of our employees by enforcing visitor restrictions, scheduling factory sanitization, investing in necessary personal protective equipment (PPE) for all employees and, most importantly, educating them on the importance of keeping good hygiene and following social distancing social operating procedures (SOPs) at work and avoiding going out unnecessarily on off days, which may risk exposure to the Covid virus. This is of utmost importance as it holds the biggest risk of factory closures should there be any infected cluster found in the factory. To keep business and operations going, the safety and health of the employees is not to be compromised.*"

4.2.3 The PSPs' perspectives on the future of printing

While the PSPs expressed several concerns about the future of the printing industry, three broad themes emerged from the analysis. First – changes in working styles; second – the accelerated growth of packaging and labelling materials with the simultaneous decline of the printed publications segment; and third – changing customer demands and expectations.

Lockdowns and movement restrictions have changed corporate dynamics, with many businesses adapting to these changes by increasingly utilizing online platforms. Interviewee C felt that "*during the pandemic lockdown, many businesses came to realize the importance of having an online platform, remote access and cloud servers and to be able to work from home*". Interviewee B, meanwhile, considers online platforms as a growth opportunity. He said: "*E-conferencing and online businesses will have major growth potential.*"

The pandemic has accelerated the packaging and labelling segment due to the growing demand for essential medical supplies and the shift towards e-commerce. Talking about this issue, interviewee D said: "*Packaging & label printing businesses will also accelerate faster than predicted.*" And interviewee A commented: "*We observed growth in the areas of paper box packaging, flexible packaging, digital publication, and e-media marketing.*" Commenting on the other printing segments, interviewee A said: "*The bigger impact will be on reading materials, like newspapers, books, text-books, magazines, etc.*"

There were several negative outlooks about the future of the printing business. For example, interview D said: "*I foresee traditional printing business will decline tremendously, while on-demand printing will be more popular due to technology accelerations in the communications sector.*" In one case, interviewee B thought that "*in the near future, there will be a major repositioning of players and a consolidation of the industry*". The majority of interviewees agreed that e-commerce platforms will have greater significance going forward. Interviewee B, for example, commented: "*Many businesses realize the benefits of having an online/e-commerce platform, which is not actually a new trend but getting more relevant now as it seems to be one of the most cost-effective ways for businesses to survive, or even progress as a result. This has kept us printers with something to think about: how to be part of the e-commerce contactless business game.*"

The interviewees, on the whole, expressed a need to leverage new technology to create innovative products and improve business efficiency. Commenting on this, one of the interviewees (E) said: "*Some digital printers will buck this trend by creating innovative products and services to offer to the consumer market through convenient and impulse online purchases.*" Another commented: "*Last but not least, this is none other than leveraging of technology in the printing industry to keep up with modern societal behaviours and lifestyles.*"

The findings in this chapter therefore clearly indicate that PSPs are experiencing challenges due to the Covid-19 pandemic and on-going digitalization; that they have implemented several strategies and mechanism to mitigate the impacts thereof. Nevertheless, they demonstrate an overall positive outlook for their businesses. In the next chapter, we discuss the findings of the study in depth.

5. Discussion

The goal of the present article is to understand the growth of the Malaysian printing industry in the context of its reaction to the Covid-19 pandemic. In particular, it aims to understand how the Malaysian printing industry performed from 2019 to Q2 2022, as well as how the pandemic impacted Malaysia's PSPs.

To answer the first question, we analyzed the performance of the printing industry and its contribution to Malaysia's GDP by evaluating statistics published by the Department of Statistics Malaysia (DOSM).

Our study found that the printing industry is in a state of recovery and performed moderately well amid domestic and global uncertainty. Furthermore, our findings suggest that the growth of the printing industry is largely influenced by macroeconomic factors and consumer demand. Additionally, according to Kusa, Duda and Suder (2022), opportunity-seeking, proactiveness, innovativeness, diversification and inter-organizational cooperation are among the factors that can lead to growth.

On a more micro level, we found that digital communications have surpassed print media communications as evidenced by declines in advertising expenditure for print media over the last 10 years.

To answer the second research question, we collected and analyzed data via multiple case studies among industry PSPs. Our results showed that the impacts of Covid-19 on the printing industry were increased costs, reduced demand, disrupted operations and future business uncertainty. In addition, we found that our interviewees had utilized strategic management approaches during the crisis by improving and innovating to diversify product and service offerings, reducing costs and improving employee health and safety. This has not only led to increased strategic management planning but to projections of increased remote work, the accelerated growth of the packaging and labelling segments with a simultaneous decline of the publication segment and implementations of new business models due to changing customer demands and expectations.

All of these findings directly affect Malaysia's printing industry. For instance, our findings align with those of Davis (2019), and Mallardi (2017), wherein the industry has performed as expected given the influence of internal and uncontrollable external factors. The outbreak of Covid-19 has greatly and adversely impacted the printing industry by negatively affecting demand. Of particular significance, it is widely believed that lower demand is the direct result of changing consumer behaviour largely due to both demographic shifts and the proliferation of digital media, which has been notably driven by the use of the internet, social media and mobile devices. As the pandemic hit globally, this further accelerated the shift. Thus, as the growth of the industry is largely driven by demand and sensitive to technological changes, PSPs certainly have a vested interest in keeping up-to-date with these. However, as of yet, no research is available that focuses on this aspect of the industry, meaning that PSPs, lacking the necessary guidance, need to develop strategies to oversee their businesses that include exploring new products as a reflection of changing consumer behaviour.

It is likely for the above reason that many people believe the print industry is in a state of decline. Over the past decade, ADEX for print media have seen negative growth as an impact of rising digital communications and media, which consequently impacted on-demand printing tremendously, as shown in Figure 3. This finding is consistent with that of Fuxman, et al. (2014), who suggested that digital advertising is an effective way to target potential customers. Furthermore, there is ample reason to believe that print media ADEX will continue to decline over the next 10 years.

However, the news is not all bad as new opportunities for print and printers have also been created. In fact, today's printers are very much engaged in digital communications for their customers, with print being integrated into a total communications model (Thomas and Douglas, 2021). Therefore, our findings offer a counter argument: print products can be enhanced with special effects to improve acceptance and PSP competitiveness.

To illustrate, consider printed books, which play an important role in education. According to the Mangen, Olivier and Velay (2019), students who read from printed books perform better in reading tests. Previous research by Masod, et al. (2015), has proved that special effects on a printed sample influence user perceptions regarding its content. Of even greater significance, this application enables printers to stand out among competitors. Therefore, with a new line of research to increase efficiency and the quality of printed books, PSPs will certainly be able to provide a new range of offerings.

Thus, we believe that the widely held misconception among the public and within the industry that printing is a "sunset" industry, is premature. On the contrary, the prospects of the Malaysian printing industry are optimistic, despite the slow economic recovery and the influence of external factors. A possible explanation for this might be that printing products play significant roles to Malaysians as a whole. It is thus expected that demand will improve and that the printing industry will gradually grow over time following the Covid-19 health impacts and the global recession. Moreover, we believe that the lessons learned during the pandemic have prepared PSPs for future crises both in terms of adaptation to changing trends, incorporation of strategic management, and an altered mindset in terms of health and safety preparedness.

Several studies (Portuguez Castro and Gómez Zermeño, 2020; Varelas and Apostolopoulos, 2020) have highlighted the importance of strategic management during a crisis, with innovations being observed as having a high level of significance in the printing industry (Tan and Teo, 1997; Thomas and Douglas, 2021). A key to the survival of businesses in the printing industry is their demonstrated entrepreneurial resilience to successfully navigate through a crisis, as similarly observed by Stephan, et al. (2021). The concept of resilience can be viewed in a variety of ways, including as the traits or characteristics of entrepreneurial firms or individuals; as a catalyst for entrepreneurial intentions; as entrepreneurial behaviour that enhances organisational resilience; as the fostering of resilience at macro-levels (regions, communities, economies); as resilience in the context of entrepreneurial failure; and as a process of recovering from crisis and transforming oneself (Korber and McNaughton, 2018).

Applying these findings in the wake of Covid-19, it is evident that the already existing digitization trend accelerated and caused organizations to re-evaluate many aspects of their work (Anderson, Bieck and Marshall, 2021). The availability of technology made PSPs realise new ways of accomplishing a variety of tasks. This led many PSPs to allow employees to implement remote work, particularly for those in administrative positions, most likely due to advances in communications technology and internet access.

Looking ahead, from the perspective of product segments, PSPs foresee the packaging and labelling segment continuing to rise in the future. Their views are in line with Smithers' report, The Future of Global Packaging to 2026 (Platt, 2021; Packaging Europe, 2021). The report shows that packaging demand will grow steadily at 4.8 % over 2020–21 to reach USD$ 1.22 trillion by 2026, which is in line with our findings. One possible explanation for this is the omnipresent nature of packaging in daily life. Another is the demand for e-commerce-ready packaging due to the rise of e-commerce. In fact, it is predicted that specialty packaging, which is made from rigid plastics and metal, will have a place in all product segments. Moreover, as consumer demands and expectations are also trending towards personalization, it is imperative for the printing industry to be more efficient by engaging customers with multichannel strategies. This will allow new opportunities on the global scale rather than being limited to the relatively small Malaysian population.

On the operational side, printers should direct future investments towards new technology to improve operational efficiency, thus creating a competitive advantage (Porter, 1985). Several studies by Tay, Alipal and Lee (2021), and Ghobakhloo (2018) have stressed the importance of technological innovation during crises. In fact, the use of smart manufacturing allows adaptation to changing demand and conditions in the factory and supply chain in real time, as well as changes in customer needs (Abadli and Otmani, 2014). In this study, we found that some PSPs are more resilient and innovative, and adapted to the imposed restrictions and requirements by offering products and services tailored to their customers' needs. Furthermore, some PSPs invested in new technology for research and development, which is in line with the findings of Gamprellis, et al. (2021). These advanced digital technologies, for instance artificial intelligence (AI) (Kinkel, Baumgartner and Cherubini, 2022), enabled companies to achieve highly efficient production. However, according to Tay, Alipal and Lee (2021), Malaysia's manufacturing industry has not yet taken a clear path towards adopting advanced digital technologies. However, as of yet, no research has been conducted to verify the effects of these shifts.

Lastly, in terms of the literature on this subject, very little was found on the question of what impact the Covid-19 pandemic has had on the Malaysian printing industry and how its PSPs fared during this time. With respect to the second research question from this study, however, it was found that Covid-19 provided a new type of challenge for PSPs, and we hope the findings of this study contribute and support business coping strategies during crises as suggested by Kraus, et al. (2020) by providing extended evidence of the economic impact of Covid-19 on the printing industry. Secondly, we feel the findings of this study contribute to and support the impact study of Covid-19 on businesses by Shafi, Liu and Ren (2020) by providing insight into strategic management within the printing industry.

Moreover, this study supports evidence from previous observations (e.g. Kraus, et al., 2020; Shafi, Liu and Ren, 2020) that suggest the impact of Covid-19

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was universal, that is, it affected global economies and printing businesses. The findings of this study are also in line with Liu, Lee and Lee (2020) who reported on the challenges and opportunities of Covid-19 on management and businesses from an Asian perspective, thereby providing further insight into the challenges and opportunities arising from Covid-19.

While our findings suggested that the pandemic has certainly had a significant impact on the industry in the short term, the long-term effects of digitalization and automation are likely to be more radical and pronounced, particularly for the printing industry (Politis, 2019; Naletina, 2021).

As highlighted by Magadán-Díaz and Rivas-García (2021), the on-going shift from analogue to digital production technologies and the internet have altered how the media is produced, distributed and consumed. Thus, it is important to consider the balance between the positive and negative effects of both digitalization and the pandemic.

Our analysis suggests that the printing industry in Malaysia is experiencing both positive and negative effects from digitalization and the pandemic. On the positive side, digitalization has opened up new opportunities for printing companies to expand their services and reach new customers. For example, the companies that we interviewed implemented improvements and innovations to diversify product and service offerings. Additionally, the pandemic has led to increased demand for certain types of print products, such as packaging and labels for food and healthcare products.

However, as highlighted by Thomas and Douglas (2021), the move towards digitalization has also created challenges for the printing industry, such as increased competition from online printing services and declining demand for traditional print products. The pandemic has further exacerbated these challenges, leading to supply chain disruptions, reduced demand for certain types of print products, and increased pressure to adopt digital technologies.

6. Research implications

This study hopes to contribute to the literature on strategic management, especially to disrupted industries like printing, and to provide new managerial insights by sharing new findings on the current state of the printing industry, particularly in the Malaysian context. Furthermore, we find that strategic management, changing customer demands and expectations, and new business models are essential factors for success in the printing industry.

7. Limitations

Our study has two main limitations. First, it should be noted that we consider only Malaysia's GDP and Malaysia's advertising expenditures as macroeconomic indicators to the performance of the printing industry. However, since our study is the first to address this specific industry, the findings are deemed significant to the academic, practitioner and policy maker. Future research should look at macroeconomic indicators holistically to adequately represent the growth of the printing industry.

Another limitation is the low sample size. Our sample size was limited because of the lack of resources to fund the expansion of our research. A larger sample would allow us to cover different types of printing segments, such as security printing and large format printing. However, despite the low sample size our results are significant. This speaks to the fact that all of our interviewees have more than 15 years' experience in the printing business. Further, we observed that their insights support the economic data presented in the first stage of this study. Future research should be conducted across the full spectrum of the Malaysian printing industry to consider diverse printing segments and their supply chains.

Since our study focused on the impact of Covid-19, it is also important to consider the impact of digitalization alongside pandemic. While the pandemic has had a significant impact on the industry in the short term, it is important to recognize that digitalization is a long-term trend that will continue to drive change in the industry. Future research could focus on the balance between the positive and negative impacts of digitalization and the pandemic and how these forces of change are shaping the industry over time.

8. Conclusion

This research helps to better understand the growth of Malaysia's printing industry, specifically as it focuses on PSPs in the Selangor and Klang Valley of Malaysia.

Despite its significant role in the national economy, the printing industry has been disrupted by rapid increases in new media, the internet and, recently, the Covid-19 pandemic. We find that Malaysia's printing industry will have positive future growth driven by demand and macroeconomic conditions. In order for printers to not only succeed but actually survive, they must continue to add value by offering diversification of products and services, adapting to changing consumer needs, implementing research and development and adopting advanced digital technologies.

We found the impacts of Covid-19 can be viewed as negative or positive for the printing industry. Negative impacts are primarily financial, such as increased costs and declining demand. Meanwhile, on the operational side, Covid-19 disrupted certain operations and existing business directions. On the positive side, we found that the pandemic allowed PSPs to diversify and improve their product and service offerings and explore new market segments. This has led most PSPs to become resilient and innovative and to strategically manage their businesses and adapt quickly to change.

The issue of adapting the printing industry to the age of automation and digitization could be usefully explored in further research. Furthermore, if the printing sector embraces digitization to a substantial degree, it would be worthwhile to conduct a similar study of the resulting outcomes. All productivity indicators should therefore be quantified to statistically reflect the benefits that the printing industry accrues across all or parts of its sectors.

Future research may extend this work by focusing on the printing industry's employees as well. Workers in this industry have always been a vital component in its growth. It is therefore essential to investigate not only if these individuals have the appropriate background to enter the digitization process, but also whether and how the printing industry's digitization will integrate them into this new working environment.

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TOPICALITIES

Edited by Markéta Držková

CONTENTS

News & more

A brief overview of patents granted to printing press manufacturers during the last five years

When looking back at the article dealing with the patents granted to leading printing press manufacturers in 2017, which was presented in this section in JPMTR Vol. 7, No. 1 (2018), not much changed among the companies that are the most active and successful when considering filed patent applications and granted patents. However, the numbers of published patents for Manroland Sheetfed and Manroland Web Systems, since 2018 Manroland Goss Web Systems, are significantly lower compared to Koenig & Bauer and Heidelberger Druckmaschinen. When considering each Manroland company individually, Komori outperformed both in the period in question. In the case of all these companies, the most common classification among their patents is B41F (Printing machines or presses). Selected inventions of the three leading companies are presented in the following sections, and those of the remaining two are in the side column, where some of the patents related to printing machines or presses and granted to other assignees are also mentioned.

Koenig & Bauer

Since 2018, the overall number of patents granted to Koenig & Bauer worldwide is about a hundred each year, usually above one hundred (documents deduplicated by family). The majority are German and European patents comprising 75 % and 15 %, respectively, followed by the U.S. and Chinese, with a few granted in Japan, Spain and the United Kingdom. Many inventions deal with various solutions improving the construction of the offset or hybrid printing presses, for instance, in terms of different features related to substrate transport, such as DE 10 2013 208 754 B4 for drawing a substrate web into a printing unit, EP 2 714 408 B2 for controlling web tension, EP 2 829 401 B1 for compensating a fan-out induced transverse substrate stretching, and EP 3 448 682 B1 for shingling the sheets to ensure optimum working speed in a hybrid printing machine, particularly suitable for the production of packaging materials. Another example is the possibility of improving the processing quality of cutting or punching in a sheet-fed machine by controlling the gap between the two driven processing cylinders using a distance sensor presented in DE 10 2018 219 715 B3. Some inventions concern flexographic printing of corrugated cardboard, such as EP 3 894 225 B1, which describes using sensors and inspection devices with corresponding image elements in combination with the possibility to change the print length by changing the speed of the forme cylinder relative to that of the respective impression cylinder. Among the patents related to security printing, the U.S. patent 11,220,101 B2 describes the drying unit following an intaglio printing unit and suitable for high printing speeds and the U.S. patent 11,440,312 B2 deals with gravure printing units having special inking units that include one cylinder with recessed elements and another cylinder with raised elements, both corresponding to recessed elements of the printed motif at the printing forme, and preferably a cylinder common for multiple inking devices and transferring the collected ink to the forme cylinder. Another solution is presented in EP 3 781 403 B1, which describes devices, a machine and a method for aligning magnetic or magnetisable particles on a web or sheet substrate, which make use of three magnetic cylinders.

More on the recent patents on printing presses and methods

Manroland Goss Web Systems

The total number of patents granted over the last five years to this joint company or one of the two separately is less than a hundred. This includes the European, German, U.S. and Chinese patents comprising 45 % to 12 %, with a few Spanish and French. The inventions deal, for example, with a device for forming book blocks (EP 2 876 070 B2) or a web-fed rotary printing system for multi-width webs with a single-width folder (DE 10 2009 029 572 B4). The most recent documents, filed in 2021, are the U.S. patent 11,358,192 B2 describing the folding roller with a compressible coating, which allows the processing of different products without changing or adjusting the nip, and the U.S. patent 11,535,024 B2, which presents the 3D-printable wear indicator for components that are in contact with the printed substrate to allow recognising the degree of wear for a timely procurement of replacement part.

Manroland Sheetfed

The yearly number of patents granted in the given period to Manroland Sheetfed is about a dozen on average. The majority are German patents that are complemented by the European and Chinese; the ratio is approx. 6:3:1. Among the recent ones, EP 3 402 678 B1 presents a compact device unlocking a coupling of a double gearwheel in perfecting printing presses, EP 3 463 888 B1 deals with a feeding unit, which provides improved sheet guidance with a longer alignment time to significantly reduce or avoid several problematic aspects of previous constructions, and EP 3 497 045 B1 describes a solution improving the lateral sheet alignment while at the same time simplifying its setting and automatic control during printing.

Patents of other companies

When looking for more companies having recently granted several patents with the B41F classification (Printing machines or presses), one significantly represented group comprises the manufacturers of digital presses, such as Xerox, Ricoh, Fujifilm and Canon. That might be a subject of an overview in one of the future JPMTR issues. When considering innovations involving conventional printing techniques, Boe Technology Group can be mentioned. The patents assigned to this supplier of semiconductor display and sensor technologies, some jointly with partner companies, include EP 3 263 351 B1 presenting the screen-printing method and apparatus with a well-controlled squeegee pressure as needed in the production of OLED screens, the U.S. patent 10,052,863 B2 describing printing screen suitable for printing uniform display sealant layer and the U.S. patent 10,166,758 B2 dealing with the anilox roller for producing an alignment layer in a liquid crystal display panel, which has a liquid carrying capacity adjustable through modifying the surface area. Further, the U.S. patent 10,303,004 B2 presents the method for manufacturing a quantum dot display device, and the U.S. patent 11,351,803 B2 covers the production of a touch panel. Several patents dealing with screen printing were also granted to Panasonic, such as the U.S. patent 10,850,498 B2 aimed at electronic component manufacturing. As another example, the U.S. patent 10,549,564 B2 of Nike combines screen printing, inkjet printing and application of the sublimation dye to provide quality print on garments made of polyester blends. In a different application area, EP 2 432 699 B1 of Procter and Gamble describes flexographic printing of various materials and graphic images onto a water-soluble film and feeding it into the unit producing detergent pouches. As the last example from yet another application area, EP 2 958 749 B1 of Crown Packaging Technology and the U.S. patent 11,130,331 B2 of Ball Corporation present innovations concerning printing on cans.

Heidelberg

The yearly number of patents granted across the world from 2018 to 2022 to Heidelberger Druckmaschinen is similar as for Koenig & Bauer, being the highest in 2018 and then decreasing and stabilising close to one hundred. The distribution is more even, with the German, Chinese, European, U.S. and Japanese patents comprising 36 % to 13 % and complemented by a few Spanish and Danish patents. Besides the construction features, the inventions deal with various tasks in other areas. To name a few examples among the U.S. patents, 11,288,793 B2 introduces a dynamic adaptation of the print inspection process to match the available time frame, and 11,294,610 B2 presents a method for flexible processing of a job queue when reaching the sufficient number of jobs while considering printed pages or products or print jobs, as well as the available machines for offset, electrophotographic or inkjet printing; unlike these software solutions, 11,453,223 B2 deals with controlling opaque white inline in printing machines and 11,500,595 B2 describes the setup for generating security elements preventing the risk of later conversion into another colour profile and thus impairing the validity of the security element. The most recent patent, DE 10 2022 102 523 B3, granted at the end of 2022, presents an improved method of compensating the defective nozzles to further increase the inkjet print quality. It makes use of the test pattern with a large number of test fields with a suitable range of tonal values, where unprinted lines are intentionally produced and compensated with different strengths of the neighbouring nozzle at several locations within the sheet. The optimal compensation is evaluated from the image, which is captured preferably with an industrial line-scan camera under bright field illumination, and applied in production printing.

Komori

The overall number of patents granted to this company in the given period is approximately five times lower than for the two major manufacturers, and the yearly numbers show a decreasing trend. The difference is even more evident when comparing the number of applications filed during the last five years; in this case, it is roughly 15 times lower for Komori than for Koenig & Bauer or Heidelberger Druckmaschinen. Considering the territorial coverage, it naturally differs from the Germany-based companies; the largest share belongs to Japanese patents (45 %), followed by the European, U.S. and Chinese, with some granted in Taiwan, Germany and Canada. Despite the relatively low number of patents, the inventions concern a wide range of production aspects for different processes, printing techniques and products. For example, the U.S. patent 10,071,392 B2 presents the apparatus for manufacturing flexible electronic devices, such as thin film transistors, using one impression cylinder rotating in forward and reverse directions, various coating and printing units for depositing conductive, insulating or other functional layers, as well as a drying or curing unit. Another application area is covered by EP 3 517 299 B1, which deals with measuring the thickness of varnish film on a printed product. In particular, the solution is intended for security printing. It employs non-contact detecting film thickness of varnish coated directly on the metallic foil with a smooth surface – a hologram or security thread – incorporated onto the base material. Also, security printing is in focus in the case of EP 3 517 300 B1. It describes the solution for print quality inspection in an area including the so-called motion threads in which positions of patterns change depending on the angle of view. Therefore, only the colour of the same hue as the colour of the motion thread is considered to avoid false positives, while the full-colour data are evaluated in the other areas.

Bookshelf – J. Print Media Technol. Res. – Vol. 12 No. 1 (2023), 39–44

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Bookshelf

4D Printing
### Volume 1: Between Disruptive Research and Industrial Applications
Volume 2: Between Science and Technology

The authors review and explain the state of the art of 4D printing in the text supported by rich literature references and numerous quotations. They share their expert opinion on future research and development directions in this field and put them into the perspective of the interaction between – and integration of – science and society. Due to a large number of publications, which deal with 3D printing objects responding to external stimuli, and their exponential growth seen in past years, the content is divided into two volumes.

The four chapters of the first volume deal with the questions if 4D printing is disruptive or incremental or a bit of both, if there is external creativity to support 4D printing, who would prevail today, from Lamarck or Darwin, to help the controlled evolution of 4D printing, and whether the transition from 3D to 4D printing is heading toward possibly programmable self-organisation. The text discusses, for example, the potential development of 4D innovations, financial and organisational aspects, a general public survey on the perception of 4D printing and vision of the future, complexity induced by the stimulation, spontaneous self-organisation, stimulated self-organising systems, and a possibility to envisage a "learning" 4D system.

The main content of the second volume is also organised into four chapters. One examines 4D printing with respect to main stimulation modes, which cause a spatial or functional change. It describes actuators, their types, properties and the requirements specific to 4D printing, characteristics of programmable matter, materials for 4D printing, activation by physical stimuli, swimming robots as a transition to 4D printing, current developments and possible applications, as well as the related difficulties. The following short chapter deals with energy stimulation, an area with many questions open. The next chapter is focused on industrial 4D printing, namely the routes from research to innovation, from matter to 4D form, and from 4D form to function. This includes the role of 4D printing in future projects and gaps between research and profitable applications, with the challenges of getting beyond the proof-of-concept stage. The last chapter is dedicated to designing for 4D printing. It discusses the design approaches, a strategic roadmap for research, the evolution of technological solutions and associated challenges, a methodological framework for the design of energy-sensitive structures, capturing and reusing of 4D printing knowledge, functional modelling and solution principles, selection of smart material and stimulus and planning of processing, the definition of design spaces and CAD representations, voxel-based modelling, behaviour simulation and distribution of active materials, digital chain for 4D design and prototyping, claims and practical constraints.
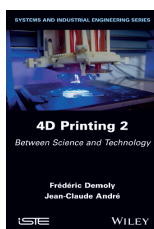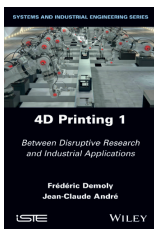
Authors: Frederic Demoly, Jean-Claude Andre

Publisher: Wiley-ISTE
1ˢᵗ ed., September & October 2022
ISBN: 978-1-786-30731-6 & 978-1-786-30810-8
368 & 320 pages
Hardcover
Available also as an eBook

Advances in Fashion and Design Research

Editors: Ana C. Broega, Joana Cunha, Hélder Carvalho, Bernardo Providência

Publisher: Springer
1st ed., October 2022
ISBN: 978-3031167720
816 pages, 260 images
Softcover
Also as an eBook

This volume presents a selection of 67 peer-reviewed papers presented at the 5th International Fashion and Design Congress, CIMODE 2022, which took place in Guimarães, Portugal. It covers seven major themes in fashion and design, which comprise communication, identities and cultures, product design, marketing and consumption, teaching and education, sustainability, and emotional design and fashion. The topics include, among others, 3D printing applied on painting canvas, transforming polyamide mesh waste into 3D printer filament, and digital transformation in purchasing print and pattern designs in the textile and apparel industry.

Smart Manufacturing The Lean Six Sigma Way

Author: Anthony Tarantino

Publisher: Wiley
1st ed., May 2022
ISBN: 978-1119846611
464 pages
Hardcover
Also as an eBook
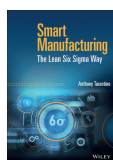
The methods and approaches explained in this new book have gained even higher importance due to COVID-19 and other challenges recently faced by manufacturers. The first three chapters provide the background on the industrial revolutions up to Industry 4.0 and the key components and advantages of smart manufacturing and detail lean, six sigma and continuous improvement tools. In the remaining chapters written by the main author and other contributors, the book deals with the use of smart technologies

Fibrous Structures and Their Impact on Textile Design

The objective of this book was to fill the gap in the literature on textiles, which usually focuses on either technical or aesthetic aspects while the mutual understanding of the relevant context is beneficial to both technical specialists and fashion designers. The book begins with a chapter that outlines textile development concerning clothing and technical applications, including the trends in functional and smart textiles. It discusses the future challenges related to the textile industry's changes towards greater sustainability and their implications for designers. The following three chapters discuss recent trends in textile structures and the importance of end-use considerations when developing innovations in the field of textiles, the desired properties of fibres, yarns and fabrics with their impact on design, as well as the specific features of colour and design for textiles based on the interaction of light with different types of fabric. Light is in focus also in the next chapter, which presents the development of side-emitting plastic optical fibres and the autonomous line illumination system along with the practical use of lighting and colour effects for contemporary design, safety or other special purposes. Then, one chapter deals with haptic perception and methods for evaluating and indirectly predicting the fabric handle. The next one is dedicated to business aspects in the textile industry; it reviews the business models and marketing strategies that reflect the changes in consumer behaviour and technological progress. The last chapter presents examples demonstrating new design possibilities opened by smart materials and advanced processing technologies.
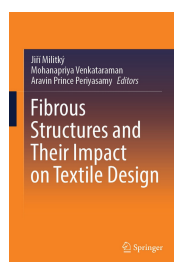
Editors: Jiří Militký, Mohanapriya Venkataraman, Aravin Prince Periyasamy

Publisher: Springer
1st ed., September 2022
ISBN: 978-981-19-4826-8
266 pages, 211 images
Hardcover
Available also as an eBook

Raman Spectroscopy in Cultural Heritage Preservation

This book describes the theory and instrumentation of Raman spectroscopy, a method that enables nondestructive and noninvasive characterisation of both organic and inorganic components of – often unique – specimens at the laboratory or on-site. Its combinations with other analytical techniques are also mentioned. Among other applications, the text covers analyses of pigments, dyes and colouring agents, including the identification of organic dyes in paper, prints and inks. Further, the authors present several case studies and the outlook for Raman spectroscopy development and utilisation.

Authors: Howell G. M. Edwards, Peter Vandenabeele, Philippe Colomban

Publisher: Springer
1st ed., October 2022
ISBN: 978-3-031-14378-6
531 pages, 1 image
Hardcover
Available also as an eBook
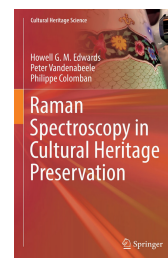
Cut/Copy/Paste
Fragments from the History of Bookwork

The author defines the task of this book as tracking how the past is constantly being de- and re-composed by the present. The work investigating the potential of changing media environment for the future of writing and publishing in the humanities uses case studies from England between the 1630s and the 1710s. In particular, the focus is on the so-called radical bookwork – the assemblages of cut and pasted materials. The first chapter deals with the elaborate collages of pieces sliced from printed Bibles made by the women at Little Gidding, a religious household, examining the typographical means and navigation tools used to enhance the reading experience. The second chapter is dedicated to books of poetry assembled in the domestic printing atelier of Edward Benlowes. The third one explores the History of the Book by John Bagford, with exemplary specimens of early text technologies acquired through an extensive gathering of waste books and their fragments. In all three cases, the present book also points to past misinterpretations of the subjects, drawing on archival evidence and scholarly works. The open-access online edition includes numerous digital assets and resources.

Author: Whitney Trettien

Publisher: University of Minnesota Press
1st ed., February 2022
ISBN: 978-1-5179-0408-1
328 pages, 70 images
Hardcover
Available also as an eBook

Building Science Graphics
An Illustrated Guide to Communicating Science
through Diagrams and Visualizations

The approaches to creating informative graphics presented in this new book with well-chosen illustrations and many real-life examples are of interest to all who need to visualise scientific facts and results, whether they are designers or researchers. The first part explains all fundamental concepts and principles related to science graphics and visual communication, from perception and storytelling strategies to layout and style, up to suitable tools and their use. The second part discusses special considerations for science graphics and their types. The third part guides the reader through the process of building graphics, from setting the goal and researching content to creating sketches, up to the final illustration, its review and possibly later adaptation for different purposes. The fourth part clarifies the possibilities and benefits of creative and critical collaboration.

Author: Jen Christiansen

Publisher: CRC Press
1st ed., December 2022
ISBN: 978-1-03-210940-4
357 pages, 265 images
Hardcover
Available also as an eBook
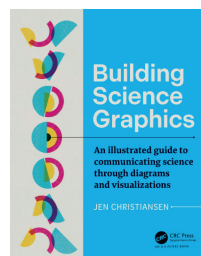
to improve supply chain resiliency, cybersecurity, logistics and life on the factory floor and describes big data, sensors for the industrial Internet of Things, artificial intelligence, machine learning, computer vision, networking for mobile edge computing and edge computing as such, 3D printing and additive manufacturing, and robotics. Also, it discusses growing opportunities for women in smart manufacturing and provides eight case studies.

Nordic Design Cultures in
Transformation, 1960–1980
Revolt and Resilience

*Editors: Kjetil Fallan,
Christina Zetterlund, Anders V. Munch*

Publisher: Routledge
1st ed., August 2022
ISBN: 978-1032290423
244 pages, 55 images
Hardcover
Also as an eBook

This work shows how discourses, institutions and practices transformed in the studied period due to profound changes in virtually all conditions relevant to the design, including the transition from traditional layout and typesetting to computerised processing in the printing industry.

Engineering Psychology
and Cognitive Ergonomics

Editors: Don Harris, Wen-Chin Li

Publisher: Springer
1st ed., May 2022
ISBN: 978-3031060854
523 pages, 204 images
Softcover
Also as an eBook

These proceedings include almost 40 papers from the 19th International Conference on the title topic, for example dealing with the eye-tracking study of the effect of typesetting applications on user manipulation of fractions, aesthetic preference in the composition ratios and the influence of font size, contrast, and weight on text legibility for wearable devices.

Materials for Additive Manufacturing

Authors: Yusheng Shi, Chunze Yan, Yan Zhou, Jiamin Wu, Yan Wang, Shengfu Yu, Chen Ying

Publisher: Academic Press
1st ed., February 2021
ISBN: 978-0128193020
774 pages
Softcover
Also as an eBook

This extensive volume covers the composition, preparation, properties and processing considerations of polymers in powder, liquid and filament forms, as well as metallic and ceramic materials. Also, it discusses application cases for additive manufacturing materials and materials for 4D printing.

Nature-Inspired Structured Functional Surfaces
Design, Fabrication, Characterization, and Applications

Author: Zhiwu Han

Publisher: Wiley-VCH
1st ed., July 2022
ISBN: 978-3527350216
320 pages
Hardcover
Also as an eBook

The author of this book briefly introduces the advanced bionic materials, definition and classification of nature-inspired functional structural surfaces, typical prototypes with such surfaces and methods for their characterisation, analysis, modelling and fabrication. Each of the following chapters deals in detail with an individual type of bio-inspired structural materials: light-trapping surfaces, transparent antireflective surfaces, antifogging surfaces, structural colour surfaces, oil–water separation materials, underwater superhydrophobic multifunctional surfaces, and responsive surfaces toward multiple organic vapours. Many of these materials are inspired by insects, often by butterfly wings; other natural models include fish scales or gecko feet, among others.

3D Printing of Sensors, Actuators, and Antennas for Low-Cost Product Manufacturing

This book tracks recent development and innovations of 3D-printable smart materials concerning their potential application for the manufacturing of sensors, actuators and antennas using low-cost 3D printing processes, highlighting those that are commercially available or can be easily prepared. The book comprises eight chapters. The text introduces 3D-printed antennas, reviews the related research published in the last few years and presents suitable materials, processes and different types of antenna design. Further, it discusses polymer-based solutions for low-cost product manufacturing, where also screen printing and inkjet printing can be used among fabrication methods, and economic and environmental justification of lab-scale solutions for sensors, actuators and antennas. The remaining chapters deal with flexible and wearable patch antenna using additive manufacturing for wireless applications, 4D-printed smart devices and a case study on developing polymer composite for sensors, actuators, and antennas.

Editors: Rupinder Singh, Balwinder S. Dhaliwal, Shyam S.Pattnaik

Publisher: CRC Press
1st ed., February 2023
ISBN: 978-1-03-204680-8
170 pages, 87 images
Hardcover
Available also as an eBook
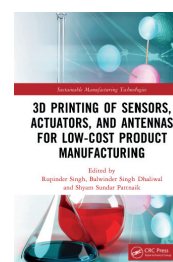
Thermally Activated Delayed Fluorescence Organic Light-Emitting Diodes (TADF-OLEDs)

This volume brings a comprehensive overview of the devices in focus. It begins with the early history of organic light-emitting diodes and the materials enhancing their efficiency through the mechanism of thermally activated delayed fluorescence. Then, it explains its fundamental theoretical principles and concepts and also introduces the aggregation-induced delayed fluorescence. Three chapters detail the advanced devices emitting in different spectral ranges, namely the highly efficient and stable blue thermally activated delayed fluorescent organic light-emitting diodes and the recent progress in thermally activated delayed fluorescent emitters for the long-wavelength region (orange, red and near-infrared) and high-performance white organic light-emitting diodes. Further, the text discusses the advantages of using materials with thermally activated delayed fluorescence for sensitising different types of dopants, formation and use of exciplexes and their use as emitters and hosts, applications of thermally activated delayed fluorescence aside from organic light-emitting diodes and future outlook.

Editor: Lian Duan

Publisher: Woodhead Publishing
1st ed., October 2021
ISBN: 978-0-12-819810-0
488 pages
Softcover
Available also as an eBook

Bookshelf – J. Print Media Technol. Res. – Vol. 12 No. 1 (2023), 39–44

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Bookshelf

Academic dissertations

On Droplet Microfluidics and Security Feature Microfabrication with Scalable Electrohydrodynamic Nanoprinting

This thesis deals with electrohydrodynamic nanoprinting, seen as a promising technology with great potential thanks to its high resolution and additive material processing. In particular, the thesis explored its application for microfluidics and security printing of novel multi-material ink systems. Further, it contributed to upscaling the process by developing a chip-based multi-nozzle printhead.

The introduction briefly reviews the micro- and nanostructuring techniques, which employ resist-based lithography, direct writing or inkjet printing, and provides the background on electrohydrodynamic printing. That includes the typical modes of the liquid ejection, applications for high-resolution manufacturing and microfluidics, and fabrication of glass capillary nozzles for electrohydrodynamic printheads with their limitations and the need for better-defined and more efficient multi-nozzle printheads. The main body of the text is divided into three chapters presenting the individual areas of work. First, the research focused on the coalescence dynamics of the sessile droplets to demonstrate an open-atmosphere microfluidic platform with omnidirectional droplet propulsion. The chapter describes the observed behaviour, provides theoretical analysis and presents the results, including the supplemental videos with self-propelled droplets travelling through a maze and picking up, transporting and merging solid particles. Further, the electrohydrodynamic technology was used for fabricating radiative, lifetime-encoded security tags with nanoprinted colloidal perovskite nanocrystals. Besides other details, the chapter presents the preparation of special quantum dot inks and the detection method for the decryption of resulting quick-response codes. Finally, to overcome the throughput limitations, the work dealt with the development of printheads based on a micro-electro-mechanical system (MEMS). The corresponding chapter describes the proposed design and microfabrication, characterisation of the printing behaviour of a single nozzle on MEMS printhead, and printing of fluorescent nanoparticle inks and silver conductive lines using both single-nozzle and multi-nozzle array printing. Also, it discusses the issues and challenges encountered with the MEMS printhead chip.

Development of a Method for Bio-Inspired Colouring of Surfaces by Imitating Structural Colours

The research focus of this thesis was on the optical properties of biological structural colours, with the goal of using them for the development of functional surfaces with such properties. Structural colours have intense colourfulness, multi-colour, metallic, and iridescent effects, as well as the ability to achieve a matt or glossy appearance. These properties result from the interaction of the incident light with the special nanoscale structures of the surface. The aim was to develop a method to make existing research on biological structural colours accessible for interdisciplinary transfer into technical applications of bionic structural colours. This method enables an efficient implementation of the optical properties for bioinspired colouration

of surfaces. It is based on the imitation of the physical properties of the biological structural colours. For the implementation, the method instructs in choosing technical processes, such as printing and finishing. The dissertation describes how bionic structural colours can be systematically developed and how to find suitable processes for technical implementation. First, it summarises the fundamental concepts related to light, colour and its perception by the human visual system and the reproduction of colour by printing technology, including special colour effects produced by dedicated finishing processes. Next, it analyses the literature on structural colours in biology and the usage of these in product and process development. The possibilities of functionalisation by surface structuring and the current state of the art, in general and specifically for structural colours, are also discussed. Then, a classification of biological structural colours is presented, which serves as a basis for the biologically driven development of bionic applications. Finally, the method for bionic structural colours is introduced, with the example of colouring surfaces inspired by the colour system of butterflies of the genus Morpho. An abstracted model is introduced and used for the technology transfer. The proposed system for the Morpho example combines diffuse reflection, multilayer interference, diffraction, and absorption in a suitable layered composite, to create the desired blue colour effect.

A History of the Kano Book Market, c. 1920–2020

This thesis studied the history of the book market in Kano, one of the oldest cities in northern Nigeria, during the last hundred years. Drawing on archival evidence, comprising research, public and private records, and in-depth interviews, the presented work contributes to the research on Arabic printing and book distribution beyond the global centres of Islamic literature while also dealing with popular literature in the Hausa language.

The main content of the dissertation is organised into eight chapters. The first introduces the Kano book market, reviews book history in Western and African scholarship, presents the approach of the work and outlines the history of book production in sub-Saharan Africa. Two chapters describe the traditional reading community in northern Nigeria, its reshaping due to colonial policies and the evolution of the modern reading community. The fourth chapter examines the geography of the Kano book market in the pre-colonial period and under the British administration that introduced the dual city project, with Arabic and Islamic book markets mainly within the walled city and the English and Hausa book markets in the township. Also, it discusses distribution channels of Islamic, English and Hausa book markets and the current growth related to the increase in the population and the number of schools. The following three chapters are dedicated to the Kano Islamic book market, focusing on the role of authors, copyists, distributors, publishers and printers, including background on the Kano printing industry from the appearance of printing presses by the beginning of the 20th century to the recent expansion thanks to the Hausa booksellers. Besides the local perspective, the text deals with the transnational book trade between the Middle East and sub-Saharan Africa. The last chapter details the transformation of the Hausa book trade in the period studied. That includes the state control during the colonial era, which continued after independence through the state-owned publishers, the changes induced by the growing demand for Hausa popular literature in the 1980s and the emergence of Kano as the centre of the new literature. The text also mentions the challenges suffered in the late 1990s, overcome in the new millennium, the gradual dominance of female authors, and the impact of new media.

Events

Optical & Digital Document Security

Prague, Czech Republic
17–19 April 2023

Held for the second time, this technical conference for physical, digital and virtual document security successfully combines two former Reconnaissance events. This year's programme opens the afternoon seminar discussing the use of smartphone solutions for digital transactions, authentication and related services, addressing the balance between their efficiency, convenience and security and also considering emerging technologies in this application area. The sessions on the next two days focus, for example, on new approaches to document security and protecting identity. The topics include novel magnetic codes, new techniques improving the process of banknote design, such as the software assessing the perception performance, robust micro- and nano-security elements, experiences with counterfeits of digital security features, and new security features protecting the portrait against manipulations. Two sessions are dedicated to new optical techniques for security, presenting the structural colours, anti-counterfeiting imaging device based on microlens array, NIR-induced colour and fluorescence changing inks, design of diffractive optically variable image devices in a non-orthogonal, spiral-based coordinate system, licence plate authentication with liquid crystal printing, and more.

GlassPrint 2023

Düsseldorf, Germany
25–26 April 2023

The presentations announced for the 2023 edition of this conference deal with hybrid machines for direct-to-shape printing, product personalisation options, prerequisites for standardisation and consistent quality in screen printing and inkjet printing on glass, the direct exposing technology for efficient screen making, new opportunities for screen printing on glass, functional inkjet printing, advanced patterning techniques, including magnetic print patterning, important process parameters and benefits of the UV-LED curing technology, decoration materials for hollow glassware, and also special solutions for bird-friendly glass.

IMI events

In the spring months of this year, IMI Europe offers the Inkjet Ink Characterisation Practical Course (17–20 April 2023 in Harston, UK) with an option to register for the additional open lab session to test the own samples and the event providing an overview of the progress in materials, technology and other solutions, the Inkjet Development Conference 2023 held on 10–11 May in Hamburg, Germany. A week later, as the American counterpart, the Inkjet Innovation Academy (16–17 May) and the Inkjet Conference 2023 (18–19 May) take place in Orlando, Florida, USA.

Forum & INFOFLEX 2023

Columbus, Ohio, USA
16–19 April 2023

The topics discussed in 2023 at this traditional event of the Flexographic Technical Association encompass the strategic aspects related to sustainability, effective collaboration and finding new employees, as well as the essential elements of flexographic production, from colour management to mounting tapes.

ICC Meeting

London, UK
25 April 2023

The open, free-to-attend session organised during this International Color Consortium meeting offers invited lectures dealing with colour matching functions, colour naming for colour management, colour management for 3D printers, iccMAX, and bridging the gap between image quality and image aesthetics.

Innovations in Publishing, Printing and Multimedia Technologies 2023

Kaunas, Lithuania
26–27 April 2023

This established international event is organised by the Department of Media Technologies at the Kauno kolegija Higher Education Institution. The 2023 edition is held in a hybrid format. It combines the conference sessions on the first day with the activities for students on the other day, which are this year led by experts from Belgium, Portugal, Mexico and USA. The plenary talks look into the future of media communication and education. Other topics range from the printing of conductive ink to the video editing speed up to the artificial intelligence impacts.

INMA World Congress of News Media

New York City, New York, USA
22–26 May 2023

The World Congress week begins with the two days reserved for the study tours of New York, which is followed by one day offering workshops on product innovation, digital advertising, subscriptions growth, smart data, and newsroom leadership. The sessions of the Media Conference are scheduled for the last two days, ending with the Global Media Awards Dinner.

Now23

Paris, France
3 June 2023

This new annual conference on typography and design is organised by TypeParis and replaces the TPTalks launched in 2015. The announced topics deal, for example, with handwriting fonts, rediscovering Greek letterforms, and reasons for developing more typefaces.

Print Matters for the Future

Riga, Latvia
9 June 2023

This annual Intergraf event is this time organised jointly with the Nordic Printing Association. Besides developments in different market segments and countries, the talks address web printing challenges, carbon footprint, and more.

IS&T events

The upcoming events presented by the Society for Imaging Science and Technology include Archiving 2023, which takes place on 19–23 June in Oslo, Norway, and London Imaging Meeting held jointly with the Institute of Physics a week later (28–30 June) in London, UK.

CPES2023

Montreal, Canada
17–18 May 2023

The programme announced for this event organised by the intelliFLEX Innovation Alliance consists of four sessions with oral and poster presentations dedicated to basic and applied research, commercialisation of innovative solutions and future markets. The topics include special solution-processed organic sensors, the printing of fine lines, micro-solid printing technology, sustainable electronic products design, upscaling and more. The 2023 edition is held in a hybrid format.

Color Impact 2023

Rochester, New York, USA
11–16 June 2023

This event of the Inter-Society Color Council is held in conjunction with the 40th Anniversary Celebration of the Munsell Color Science Laboratory at RIT. The theme of the conference is 'Color and Human Experience'. The main programme is scheduled from Monday to Thursday, and each day starts with a keynote. The speakers are Domicele Jonauskaite sharing the scientific findings from the international colour–emotion association survey with over 15 thousand participants, which reveal the links between colours and emotions across cultures and individuals, Kory Stamper exploring the communication gap between the colour specialists and the public with a focus on the role of the 20th-century American dictionaries, Peter Donahue presenting 'TikTok as Color Theory's One-Room Schoolhouse', and Roy Berns providing the digital photography and imaging software essentials helping to reproduce the artwork in good quality. The topics of presentation sessions include colour response, history, art and design, education, technology, colour experience, colour in the environment, printing and reproduction. The programme offers a variety of short courses, tours and other activities in the afternoon, as well as special evening events.

HOPV23
15th Conference on Hybrid and Organic Photovoltaics

London, UK
12–14 June 2023

The three-day programme of this established event again features numerous contributions documenting the progress in the field. The lectures and poster presentations review the past development of next-generation solar cells and share the recent advances, such as the novel printable conductive graphene electrodes for highly efficient perovskite solar cells, the chiral low-dimensional perovskite and bifacial fully printable perovskite solar cells. Several sessions deal with upscaling; the papers present, among others, the self-assembly strategy, the benefits of iplementing the in-situ optical analysis of the printing process and different approaches to roll-to-roll compatible and all-printed designs.

Call for papers

The Journal of Print and Media Technology Research is a peer-reviewed periodical, published quarterly by iarigai, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries.

JPMTR is listed in Emerging Sources Citation Index, Scopus, DOAJ – Directory of Open Access Journals, Index Copernicus International, NSD – Norwegian Register for Scientific Journals, Series and Publishers.

Authors are invited to prepare and submit complete, previously unpublished and original works, which are not under review in any other journals and/or conferences.

The journal will consider for publication papers on fundamental and applied aspects of at least, but not limited to, the following topics:

Printing technology and related processes
⊕ Conventional and special printing; Packaging; Fuel cells, batteries, sensors and other printed functionality; Printing on biomaterials; Textile and fabric printing; Printed decorations; 3D printing; Material science; Process control

Premedia technology and processes
⊕ Colour reproduction and colour management; Image and reproduction quality; Image carriers (physical and virtual); Workflow and management

Emerging media and future trends
⊕ Media industry developments; Developing media communications value systems; Online and mobile media development; Cross-media publishing

Social impact
⊕ Environmental issues and sustainability; Consumer perception and media use; Social trends and their impact on media

Submissions for the journal are accepted at any time. If meeting the general criteria and ethic standards of scientific publishing, they will be rapidly forwarded to peer-review by experts of relevant scientific competence, carefully evaluated, selected and edited. Once accepted and edited, the papers will be published as soon as possible.

There is no entry or publishing fee for authors. Authors of accepted contributions will be asked to sign a Licensing agreement (CC-BY-NC 4.0).

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