Aalto University
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Technology

Inkjet Printed Reaction Arrays on Pigment Coated Substrates

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Background

Background 1/4:
Aims of the research

- **New platforms for paper-based analytical devices, such as**
  - Paper-based reaction arrays
  - Paper-based microfluidic devices
- **Based on local hydrophobisation of hydrophilic substrate**
- **Possible applications**
  - Medical diagnosis
  - Environmental monitoring
  - Laboratory research tools
- **Previous research on cellulosic papers**
  - Novelty: custom paper coatings

Background 2/4:

Paper-based reaction arrays

Contained liquid spreading

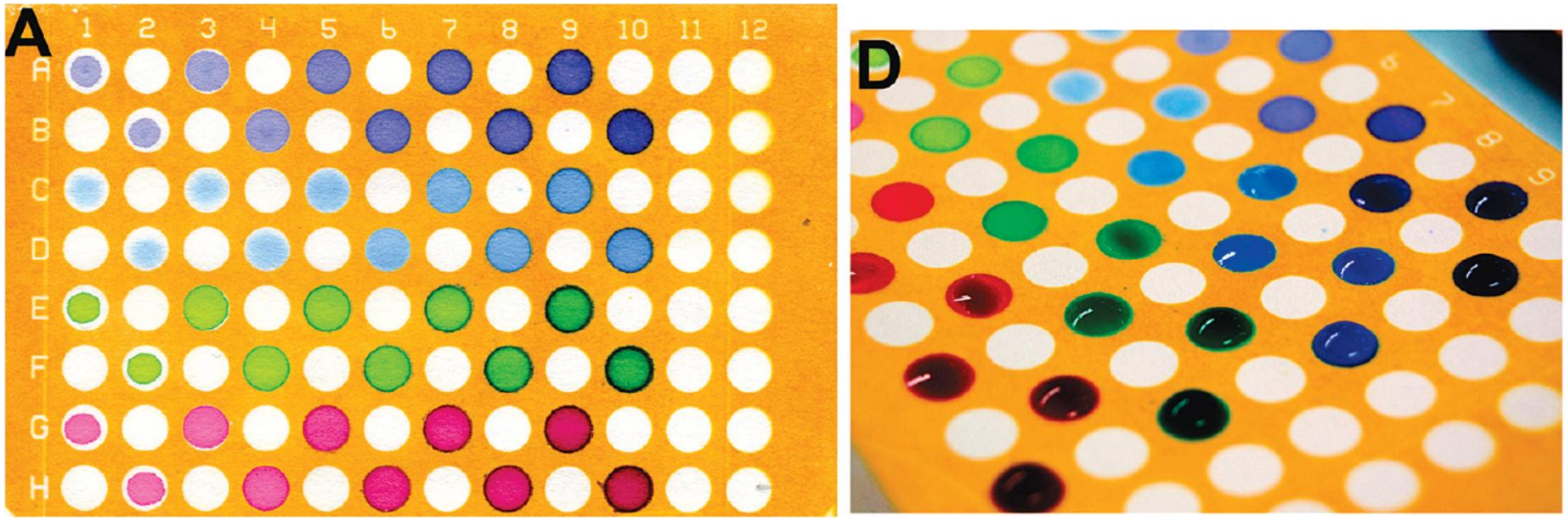


Figure: Carrilho *et al*. *Paper Microzone Plates*, Analytical Chemistry 81 (15) 2009, pp. 5990-5998.

Background 3/4:
Paper-based microfluidics

Directed liquid flow along channels

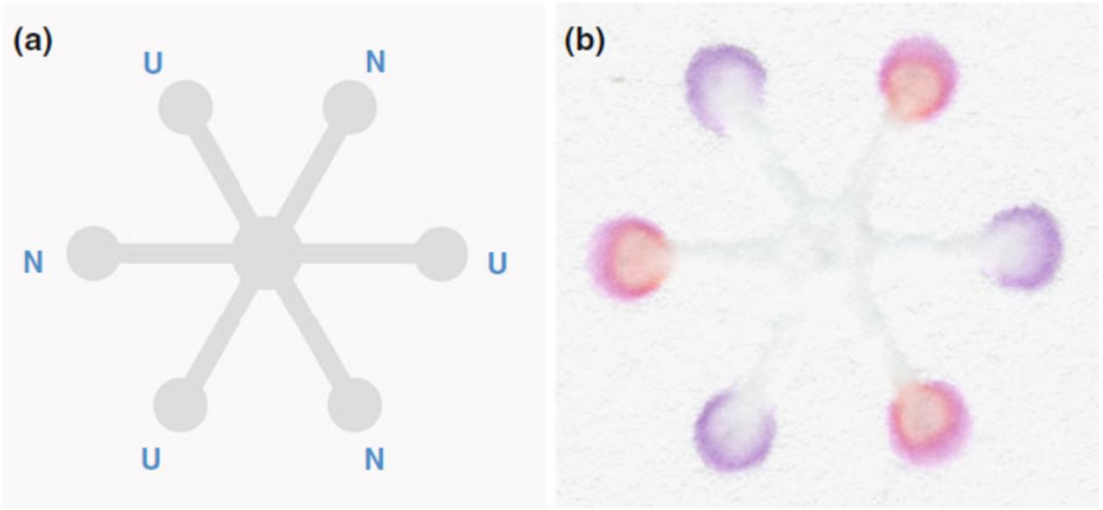
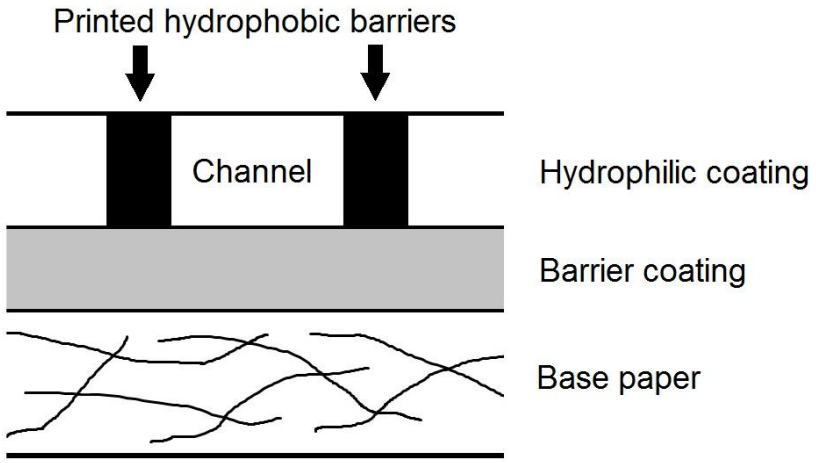


Figure: Li *et al*. *Progress in patterned paper sizing for fabrication of paper-based microfluidic sensors*, Cellulose 17 (3) 2010, pp. 649-659.

Background 4/4:
Paper vs. coating

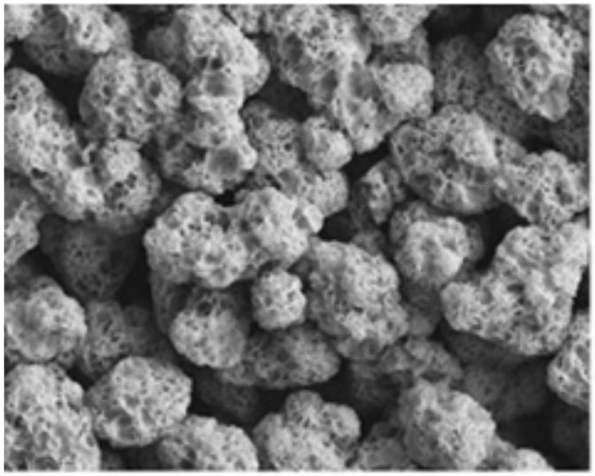
- **Advantages of paper**
  - Highly porous, wicking
  - Cheap
  - Disposable
- **Benefits of coatings**
  - Variable thickness
  - Isolated layers
  - Fine particles and resolution
  - New surface chemistries (immobilisation, separation)



Experimental

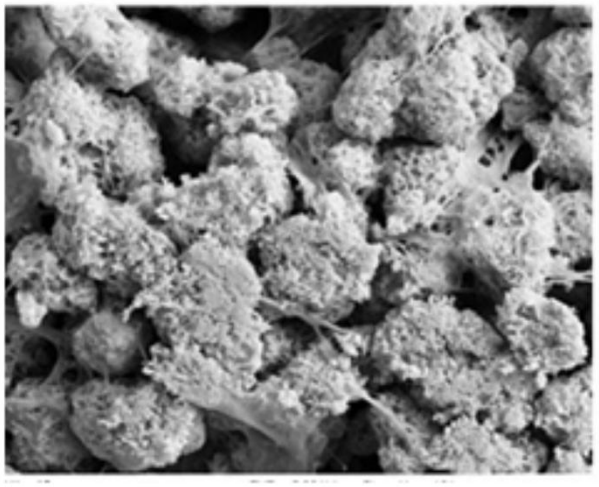
Experimental 1/4:
Pigment coatings

- **Applied with laboratory rod coater**
  - 100 µm wet thickness (27-76 µm dry)
  - Pigmented polymer film substrate (impermeable)
- **Functionalised calcium carbonate (FCC) pigment**
  - Hydrophilic surface chemistry
  - High surface area (105 m^2g^{-1})
- **10-50 pph binder**



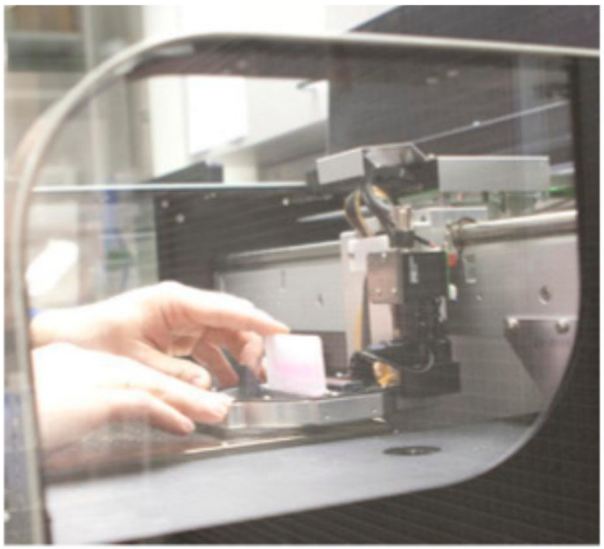
Experimental 2/4:
Pigment coating binders

- **Micro-fibrillated cellulose (MFC)**
  - Arbocel MF-40-7 (J. Rettenmaier & Söhne GmbH + Co KG)
  - 22.3462 CMCX-TYPE (Omya International AG)
- **Polyvinyl alcohol (PVOH)**
  - BF05 (Omya International AG)
- **Styrene acrylic latex**
  - Acronal S 728 (BASF)
- **Sodium silicate**
  - Product 1056212500 (Merck KGaA)



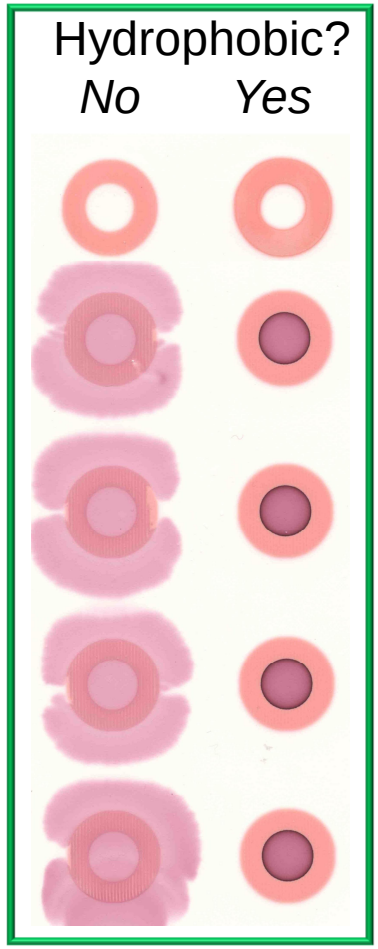
Experimental 3/4:
Hydrophobic inks

- **Two custom inks containing**
  - Solvent (p-xylene)
  - 5 % hydrophobising agent, either
    - *Polystyrene (PS) or*
    - *Alkyl ketene dimer (AKD)*
  - 0.1 % colorant (Sudan red G)
- **Inkjet printing**
  - Dimatix material printer DMP-2831
  - Ink cartridges with 10 pl nominal drop volume
- **AKD ink heat-treated post-printing (100 ˚C for 10 min)**



Experimental 4/4:
Test pattern

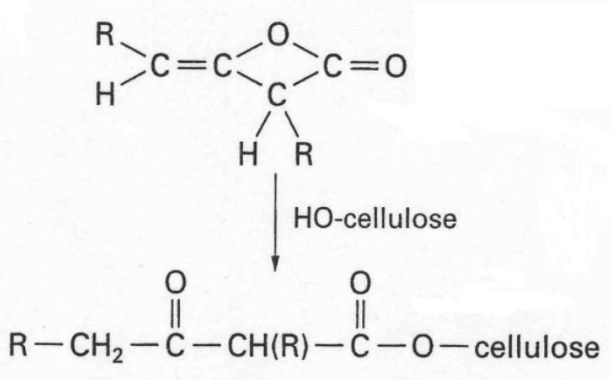
- **Arrays of printed rings (reaction array)**
  - 5 mm inner diameter
  - 9 mm outer diameter
- **Printing parameters varied**
  - Ink applied per unit surface area
  - Number of ink layers
- **Tested with liquid drops dosed at centres**
  - Coloured water
  - Water-ethanol solutions (select coatings)



Results

Results 1/3:
Barrier properties against water

- **PS ink as barrier against water**
  - All coatings could be successfully hydrophobised
  - Multiple layers of ink required in most cases to form full barrier
- **AKD ink as barrier against water**
  - All coatings hydrophobised, except those sodium silicate -bound
    - *Hydrophobising the binder required*
  - In most cases 1 ink layer sufficed
  - Lower ink volumes compared to PS ink



Results 2/3:

Ink layers to form water barrier

Ink	Coating	Nominal ink volume / cm^3m^{-2}		
		100	44	25
AKD	FCC + MFC A	1 layer	1 layer	2 layers
AKD	FCC + MFC B	1 layer	1 layer	1 layer
AKD	FCC + PVOH	1 layer	1 layer	1 layer
AKD	FCC + SA latex	1 layer	1 layer	1 layer
AKD	FCC + sodium silicate	-	-	-
PS	FCC + MFC A	2 layers	5 layers	Not tested
PS	FCC + MFC B	1 layer	2 layers	4 layers
PS	FCC + PVOH	3 layers	-	Not tested
PS	FCC + SA latex	1 layer	1 layer	-
PS	FCC + sodium silicate	3 layers	-	Not tested

Results 3/3:
Barrier properties (other)

- **Water-ethanol solutions**
  - Lower surface tension than plain water
  - Can penetrate barriers that contain water
  - AKD barrier penetrated with 30 w/w% ethanol
  - PS barrier penetrated with 20 w/w% ethanol

- **Surfactant solution (1 w/w% Tween 80)**
  - Has higher surface tension than 20 w/w% ethanol
  - But still penetrates both AKD and PS barriers
  - Permanent effect (adsorbs to barrier)

Summary

Summary and future work

- **AKD and PS inks could hydrophobise coatings**
  - Hydrophobising the binder was required
  - AKD was more efficient in most cases
- **Barrier effectiveness**
  - Dependent on liquid surface tension
  - Surfactants penetrate by adsorption
- **Future work**
  - Characterising channels
  - Practical applications
- **Question time!**