3rd international workshop on IN-SItu study and DEvelopment of processes involving PORous Solids

New challenges for nanoporous materials

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# On the optimization of the microencapsulation process for the development of electrophoretic ink solutions for e-paper systems

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## Introduction

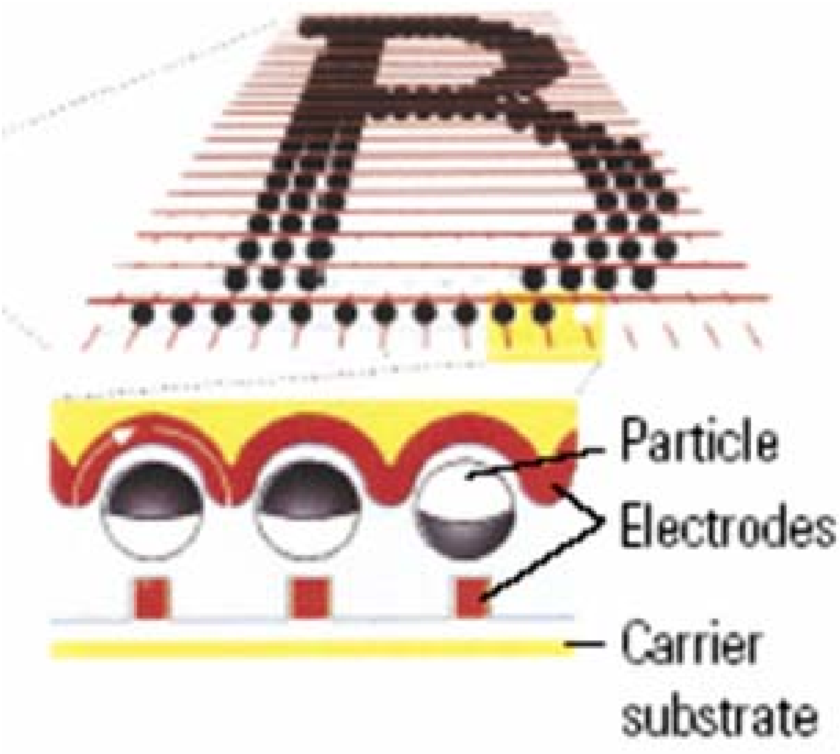
In the year 2000 the Nobel Prize in Chemistry* was given for the discovery and development of conductive polymers.

Conductive polymeric systems gave us the great opportunity to watch our lives differently.

**With the use of flexible, conductive and transparent polymeric films flexible multilaminated displays and E-paper solutions are able to be constructed.**

* Alan J. Heeger , Alan G. MacDiarmid, Hideki Shirakawa

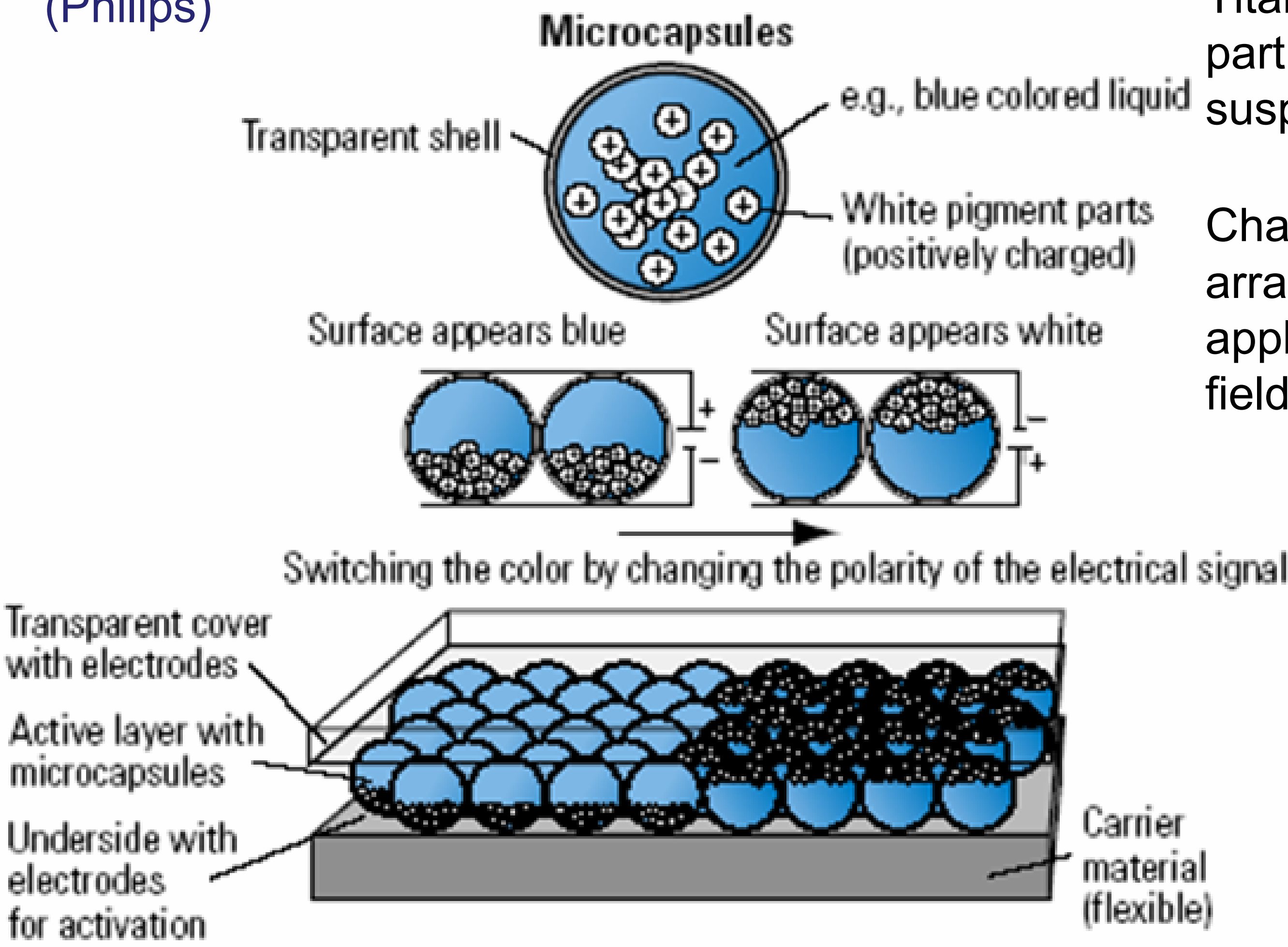
## **Basic operation principles of Gyricon** (Xerox)




Charged microspheres have two different colour sides, black & white.

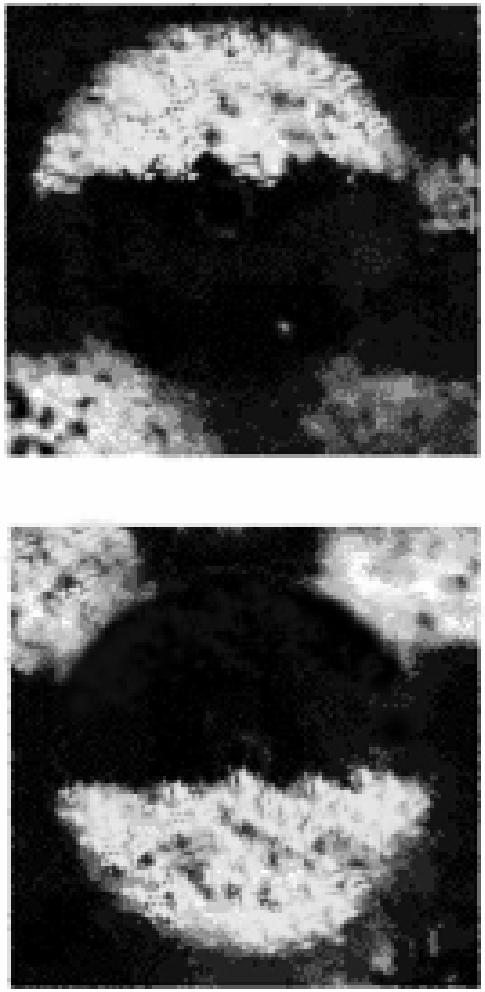
Upon application of the electric field, charged microspheres present -on demand their black or white semisphere as the microsphere is rotating freely under the applied forces.

## Basic operation principles of E-Ink
(Philips)

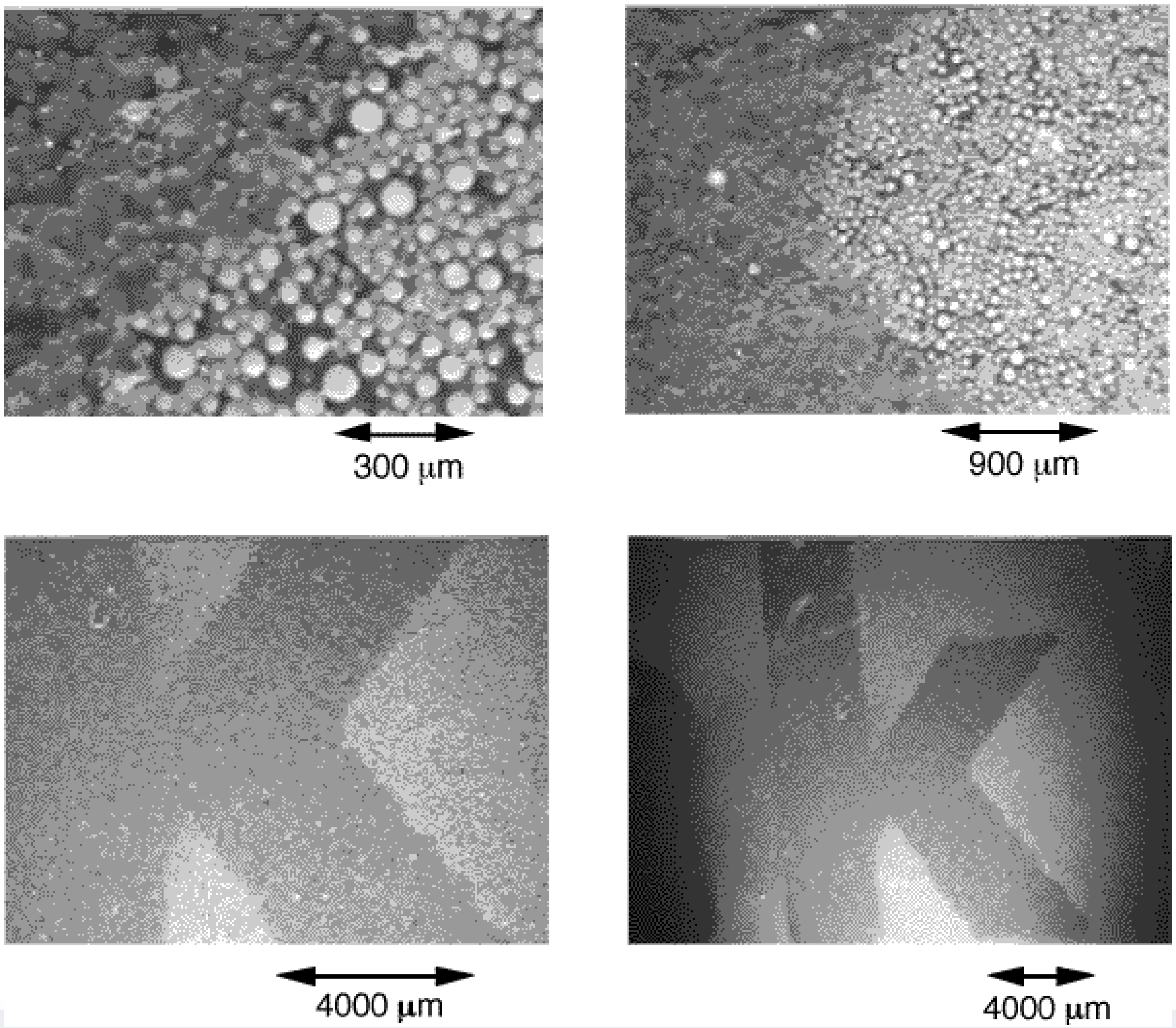



Titanium Oxide charged particles are held in suspension in the dye.

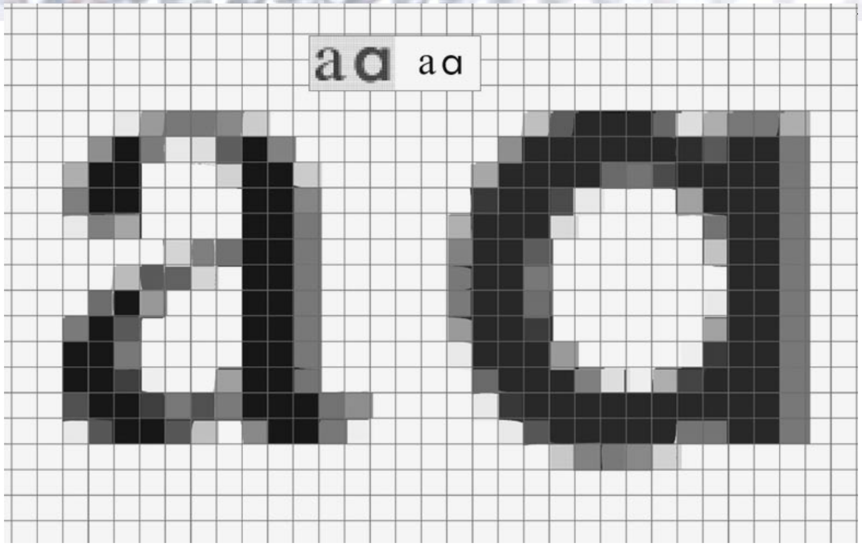
Charged particles are arranged by the application of the electric field .

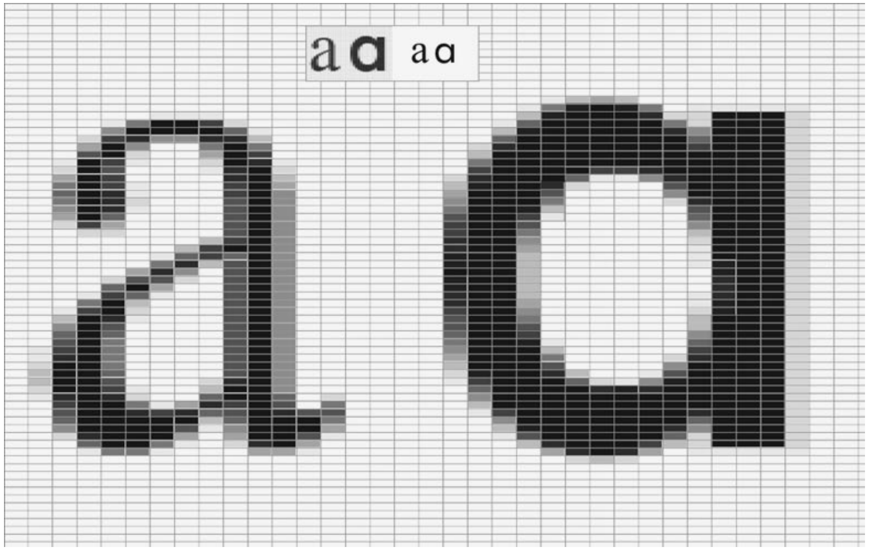


Photomicrograph of an individual microcapsule (200μm diameter) addressed with a positive and negative field (E-ink technology)




Photomicrographs of 200 μm-thick film of electronic ink ('white particles in dye' type) with a capsule diameter of 40 ±10 μm (top view). The electronically addressed letter "k" is white, other areas are blue.




Top (Gyricon) and bottom (e-Ink): simulation of the effect that the electronic paper pixel aspect ratio. Note the improved definition of the thinner parts of the characters

# 1st Preparation Method of Hollow Silica Microspheres

**Procedure A**

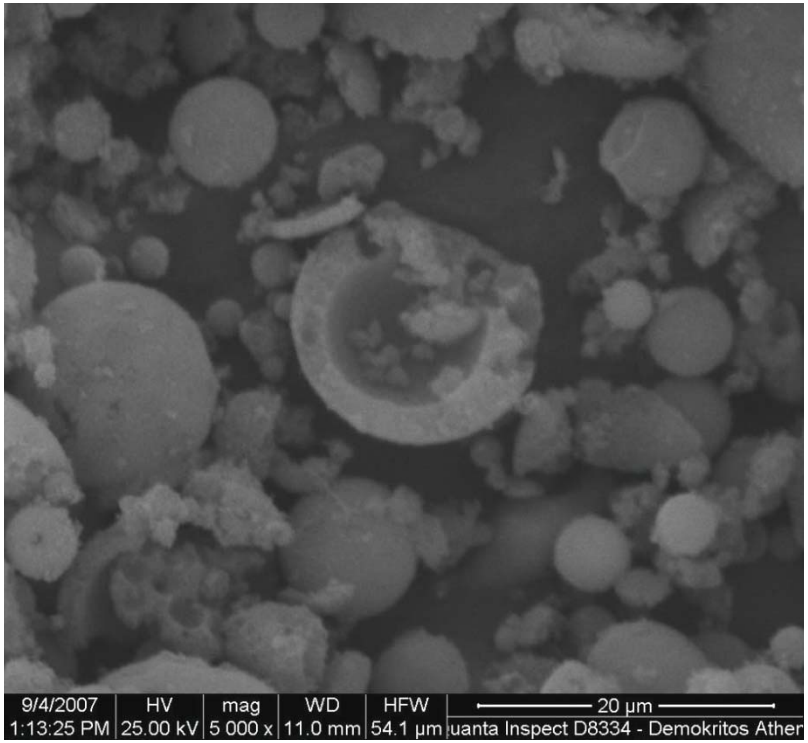
**Procedure B**

- 1- Octanol, HPC, 80 °C, 4 h
- Span 80 (Procedure A)
- $H_2O$, PEG, Tween 20, $NH_4OH$ (Procedure A)
- $H_2O$, PEG, Pluronic Acid, $NH_4OH$ (Procedure B)
- TEOS
- Washing with ethanol
- Centrifugation
- Drying
- Calcination

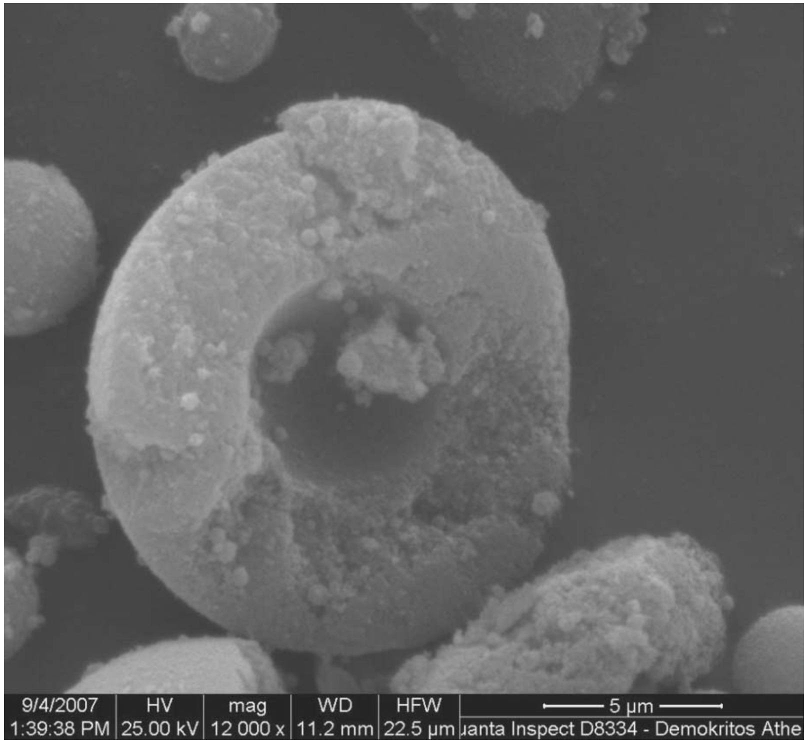
**The use of HPC with the use of tween 20 and span 80, as surfactants, results in a successful multiple emulsion encapsulating retinol.**

- **HPC** hydroxypropyl cellulose.
- **Tween 20** (polyoxyethylenen sorbitol ether is suitable as solubilising agent for membrane proteins and as blocking reagent in blotting applications – monoionic detergent widely used in biochemical applications).
- **Span 80** (sorbitan monooleate ester/non-ionic surface active agent used in food products and oral pharmaceuticals.

# Hollow Silica Microspheres




Procedure A



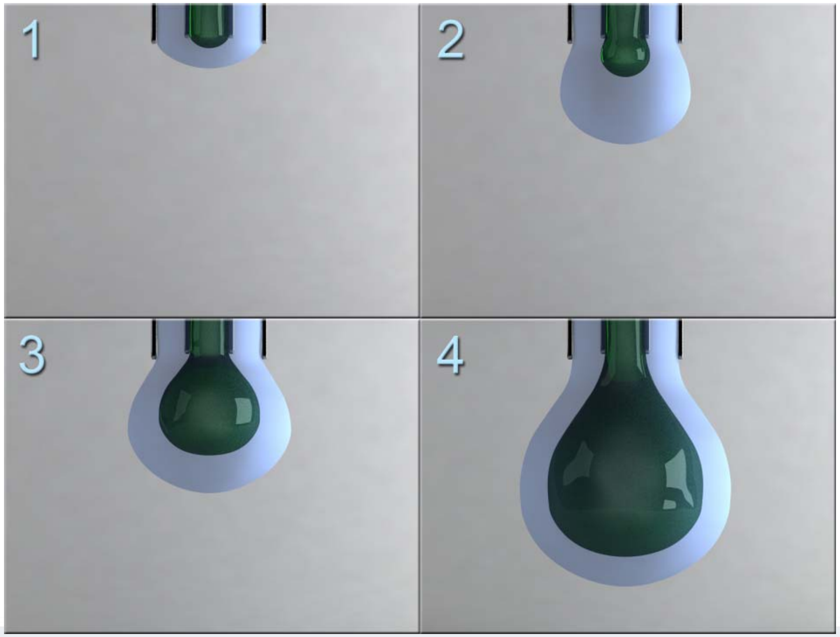

Procedure B

SEM images of hollow silica microspheres with porous shells

# 2nd Preparation Method for of Hollow Transparent Microspheres (Optimisation method)

Polymeric shell encapsulation by means of a multi-nozzle layout.

- Allow for different nozzle geometry.
- Achieve the reduction of the microcapsules dimensions down to 10-20 μm

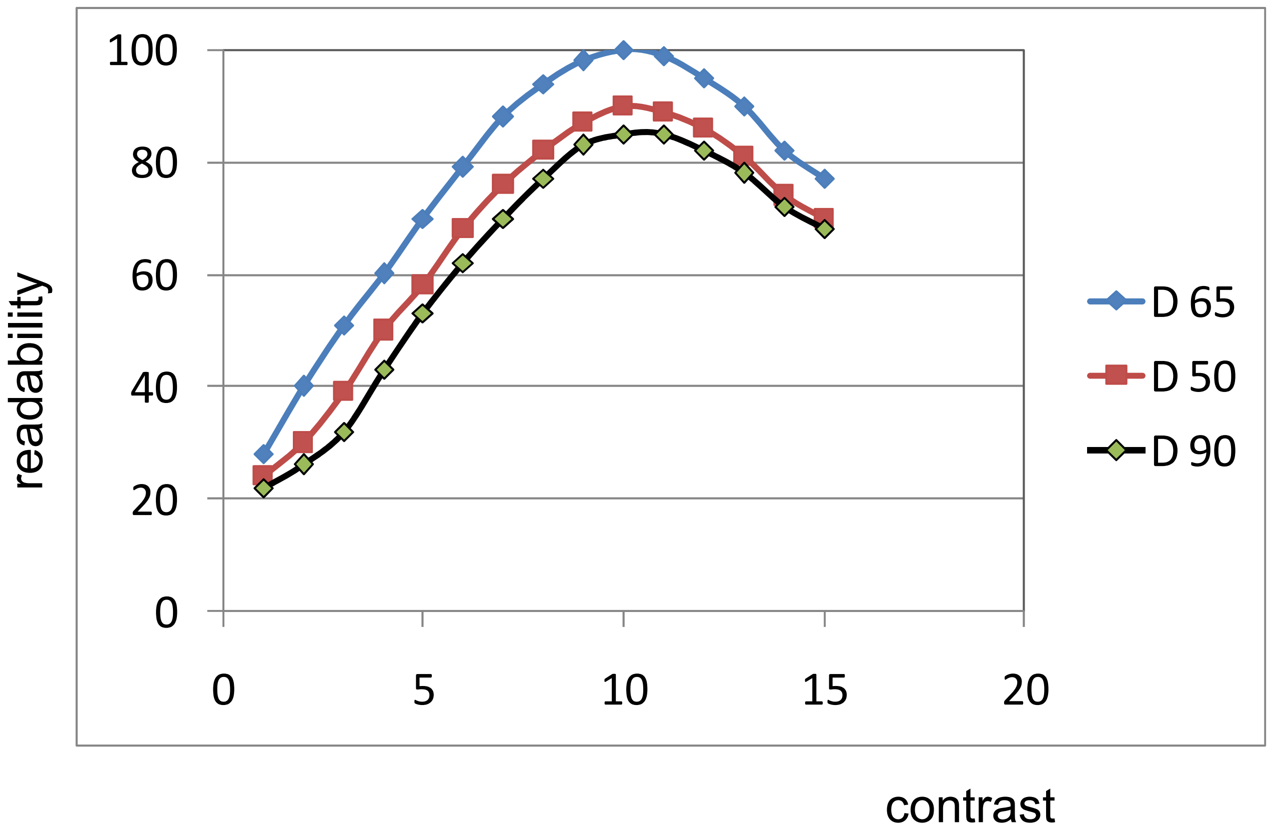


## A comperative presentation of paper and E-paper characteristics

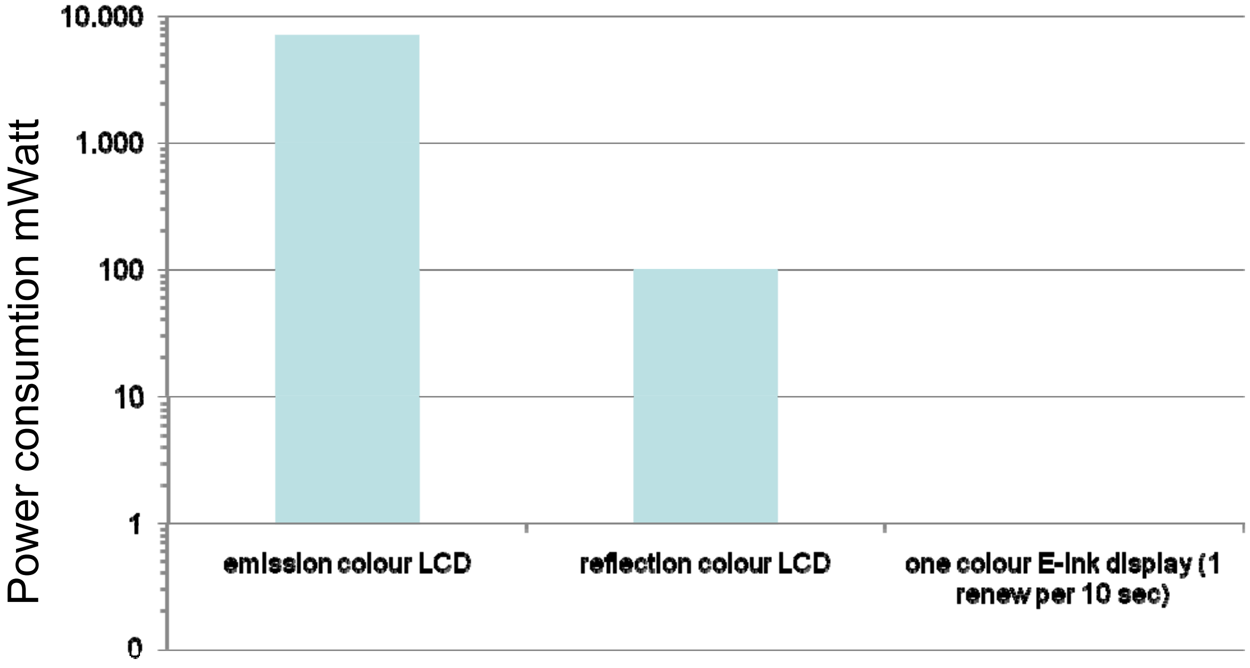
| | Paper* | Gyricon | E-Ink |
|---|---|---|---|
| Contrast | 10:1 | 10:1 | 30:1 |
| Reflectance | 50% | 20% | 40% |
| Reflection type | Lambertian | Lambertian | Lambertian |
| Viewing angle | All | All | All |
| Flexibility | Yes | Yes | Yes |
| Colour | Yes | No | No |
| Responce time | N/A | 80 msec | 100 msec |
| Voltage | N/A | 90 V (max) | 90 V (max) |

* Wall Street Journal News Paper

## Correlation of the document readalility and the substrate contrast



## Power consumption – LC Displays Vs E-paper



## Main problems of the current E-paper technologies

- Responce time of the display is proportional with the applied voltage.
- Titanium oxide nanoparticles agglomeration  reduces the life time of the dispays.
- Limitations for the construction of colour displays.

## Optimisation methods

- Change of the geometry: three proposed solutions

1) Transformation of the microcapsule geometry into cylindrical structures (micrograna)
2) Use of microfacoids (lens alike shaped structures)
3) Reduction of the microcapsules dimensions down to 10-20 μm

- Development of titanium oxide - surfactants systems with redused agglomeration ratios.

- Use of three colour dyes (R,G,B) within the microcontainers in order to deposit them in normal possitions by printing methods on the substrate.

- Use of fluorecent factors in the dye.

## Targeted - Investigated Benefits

- ➢ Display life-time increase.
- ➢ Significant potential for the construction of colour displays.
- ➢ Display luminosity increase.
- ➢ Reduction of responce time for the same voltage
- ➢ Even lower  energy consumption
- ➢ Increase of the resolution

## E-paper and future applications

- User-Interactive Application (Combination with biosensors and RFID (Radio Freqency IDentification) systems in order to develop integrated interactive products)

- Interactive Packaging (Integration into interactive environmental-friendly packaging  materials that could provide useful information to the consumer)

- Health & e_Health Applications (Intergration of intelligent systems that could register and analyse the patients health and monitor on the E-paper)

## REFERENCES


Barrett Comiskey, J. D. Albert, Hidekazu Yoshizawa and Joseph Jacobson, An electrophoretic ink for all-printed reflective electronic displays, Nature 394, 253-255 (16 July 1998) .

Murau, P. & Singer, B. The understanding and elimination of some suspension instabilities in an electrophoretic display. J. Appl. Phys. 49, 4820–4829 (1978).

Claus, C. J. & Mayer, E. F.in Xerography and Related Processes(eds Dessauer, J. H. & Clark, H. E.) 341–373 (Focal, New York, (1965)).

Fowkes, F. M., Jinnai, H., Mostafa, M. A., Anderson, F. W. & Moore, R. J.in Colloids and Surfaces in Reprographic Technology (eds Hair, M. & Croucher, M. D.) (Am. Chem. Soc., Washington DC, (1982)).

Wang, L., Fine, D., Sharma, D., Torsi, L. and Dodabalapur, A. (2006) Nanoscale organic and polymeric field-effect transistors as chemical sensors, Journal of Analytical and Bioanalytical Chemistry, Springer Berlin / Heidelberg 384 (2): 310-321 Jan.

Berggren, M., Kugler, T., Remonen, T., Nilsson, D., Miaoxiang, C. and Norberg, P. (2001) Paper electronics and electronic paper, In: Proceeding of the 1st International IEEE Conference on Polymers and Adhesives in Microelectronics and Photonics, pp. 300-303, Potsdam, Germany.

Chen, Y., Au, J., Kazlas, P., Ritenour, A., Gates, H. and Goodman, J. (2002) Ultra-thin, high-resolution, flexible electronic ink displays addressed by a-Si active-matrix TFT backplanes on stainless steel foil. In: Proceedings of the International Electron Devices Meeting, IEDM '02 (IEEE).

Rogers A. J., Bao, Z., Baldwin, K., Dodabalapur, A., Crone, B., Raju, V.R., Kuck, V., Katz, H., Amundson, K., Ewing, J. and Drzaic, P. (2001) Paper-like electronic displays: Large-area rubberstamped plastic sheets of electronics and microencapsulated electrophoretic inks. In: Proceedings of National Academy of Science, vol. 98, no. 9, 4835–4840.


**Thank you for your attention.**