Printed electronics: Definition of the printing parameters for the functionality of the prints.

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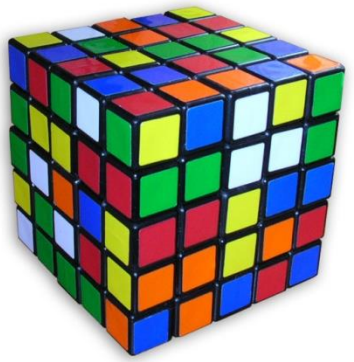
Presentation: Georgios Vlachopoulos

Ph.D. Printing & Coating Technology

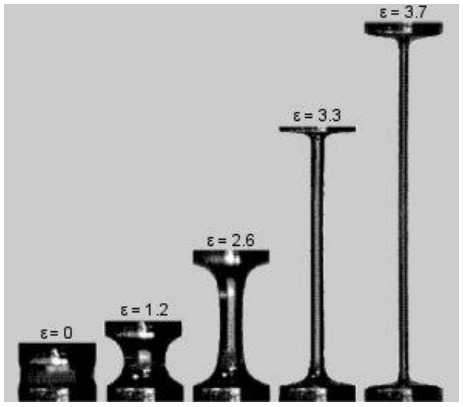
Overview

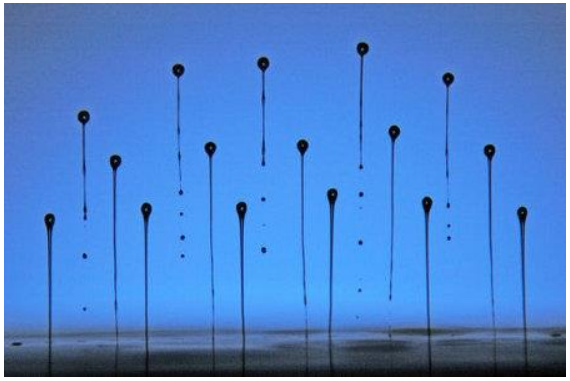
- Printing principles
  - Main techniques and characteristics
- Setting process parameters
  - Locate printing variables
  - Conductive materials
- Ink transfer instabilities
- Quality assurance
- Closure



Principles in printing

- Image
- Reproduction
- Printing
  - Conventional
    - Ink transfer by contact
    - Deformation mechanisms
  - Digital
    - Non contact techniques
    - Dispersion mechanisms





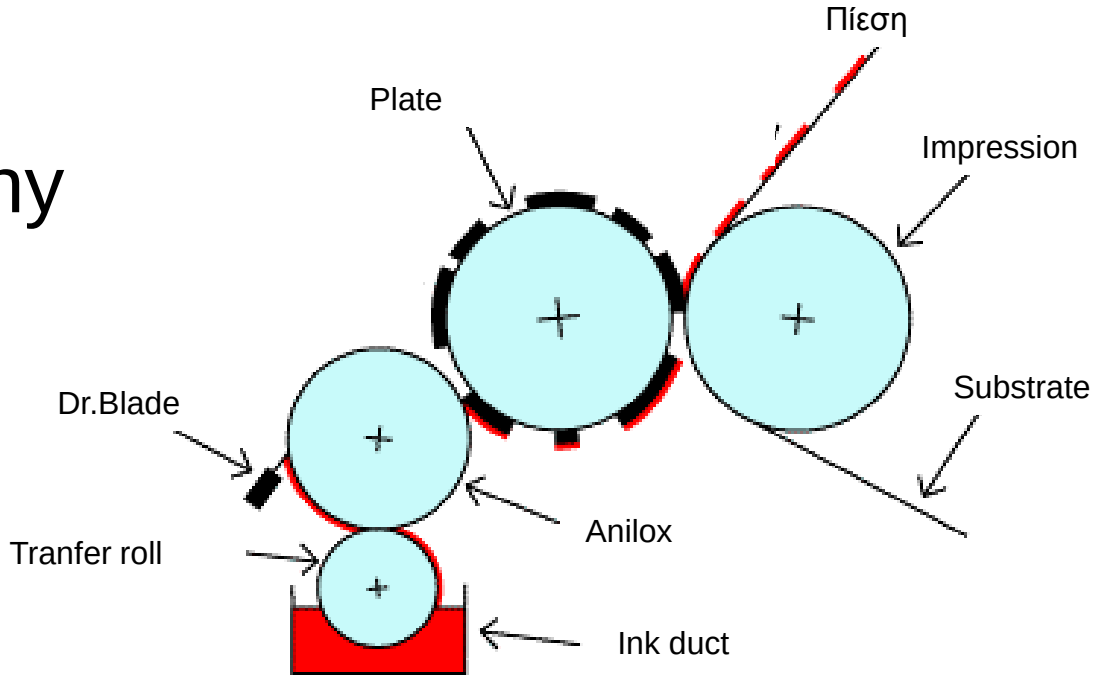
Principles in printing

- Flexography
- Offset - Lithography
- Gravure
- Screen printing
- Inkjet

Process	**Offset lithography**	**Flexography**	**Gravure**	**Screen printing**	**Inkjet**
Printing forum	Flat (Al plate)	Relief (polymer plate)	Engraved cylinder	Stencil +mesh	None (digital)
Substrates	Papers boards, polymers, metals	Papers boards, polymers, metals	Coated papers	All substrates	All substrates
Ink film thickness (μm)	1-2	6-8	8-12	20 to 100	Depends on ink
Ink viscosity in Pa.s	5-50	0.01-0.1	0.01-005	0.1-10	10^{-2}
Resolution (lines/em)	100(conv) 200 (waterless)	60	100 (conventional)	50	60 (continuous) 250 (DOD)

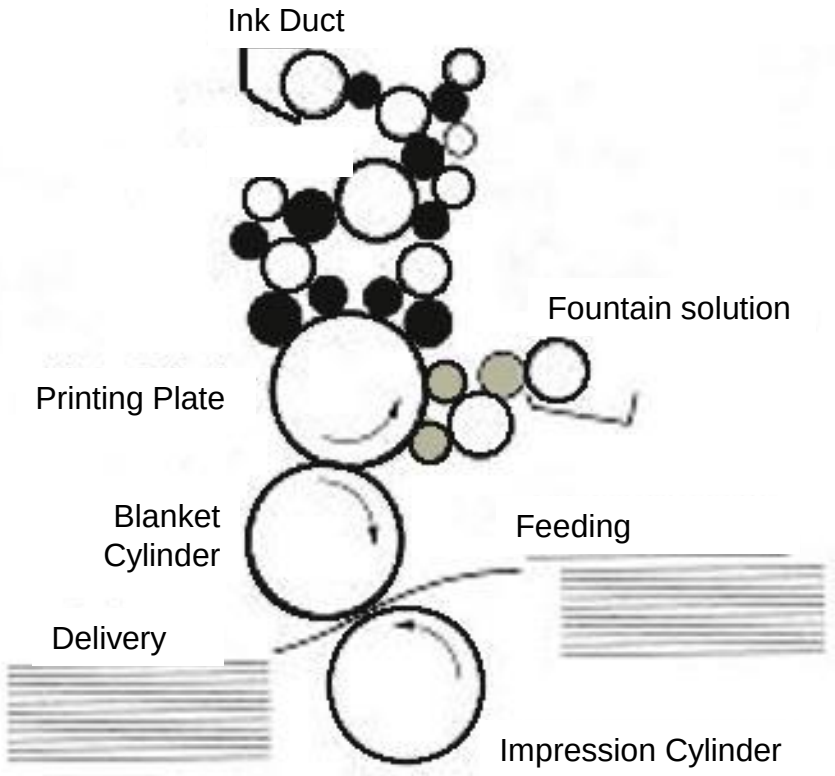
Conventional Printing

- Flexography
  - Deformable Plate
  - Anilox roll
  - Dr.Blade
- Offset - Lithography
- Gravure
- Screen printing



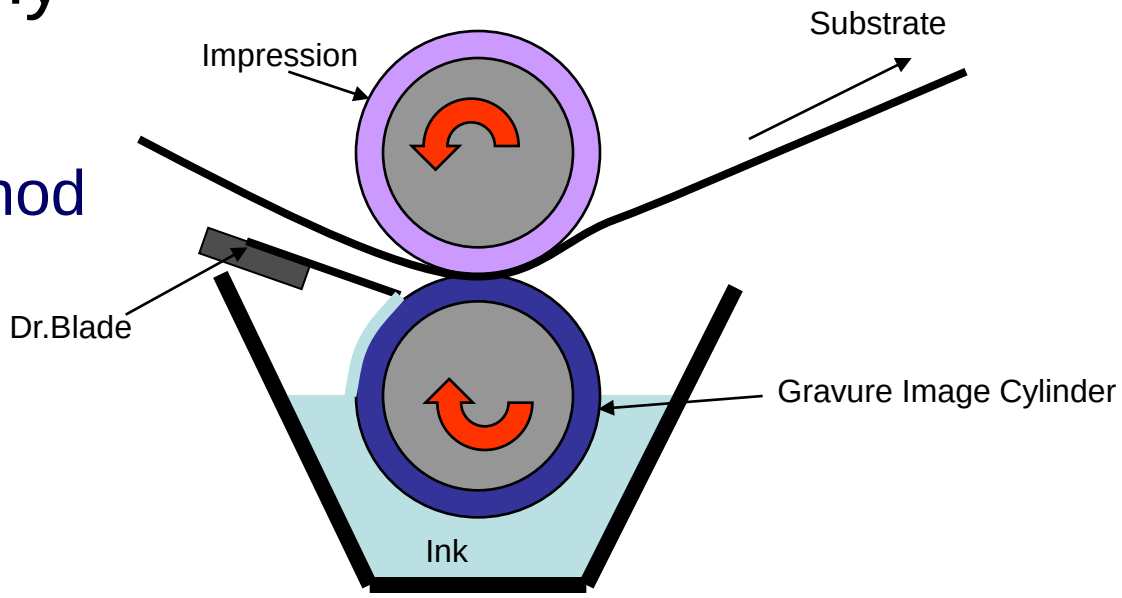
Conventional Printing

- Flexography
- Offset - Lithography
  - Plate
  - Blanket
  - Fountain solution - Ph
- Gravure
- Screen printing



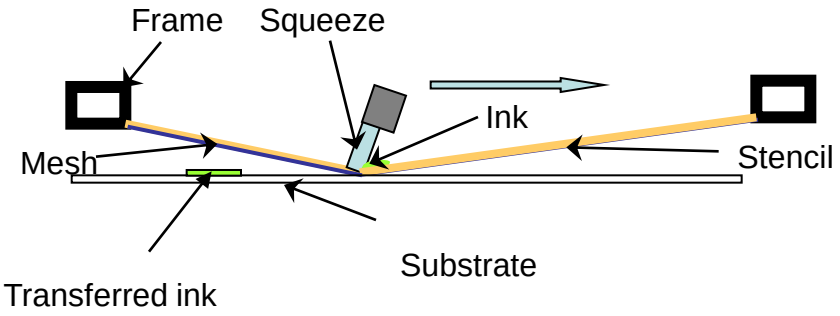
Conventional Printing

- Flexography
- Offset - Lithography
- Gravure
  - Cell engraving method
  - Dr.Blade
- Screen printing



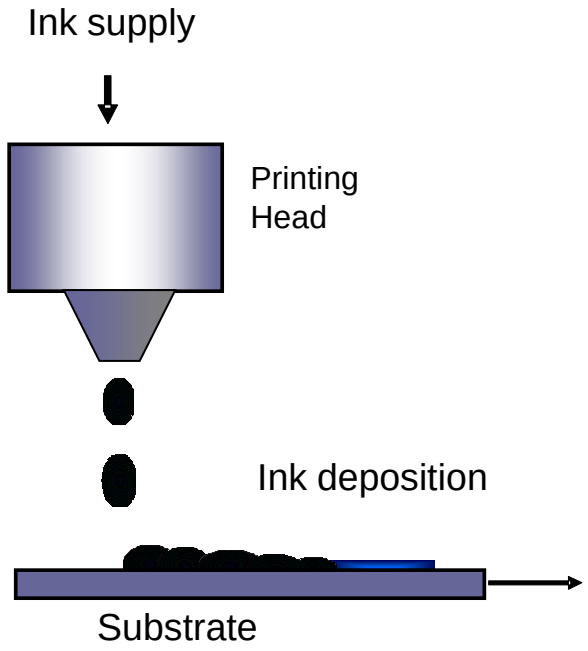
Conventional Printing

- Flexography
- Offset - Lithography
- Gravure
- Screen printing
  - Mesh analysis
  - Squeeze
  - Stencil thickness
  - Distance from substrate



Digital Printing

- Inkjet technologies
  - Thermal – Piezoelectric
  - Dependent ink volume
  - Printing Speed
  - Droplet volume
  - Signal noise



Printing electronics

- Why printing electronics;
  - Productive processes,
  - Wide range of printing methods,
  - Existed materials and presses,
  - Qualified people,
  - Good knowledge of materials,
    - Conventional
    - Nanotechnology
    - Organic – Inorganic
  - Decrease of production cost.

Printing electronics

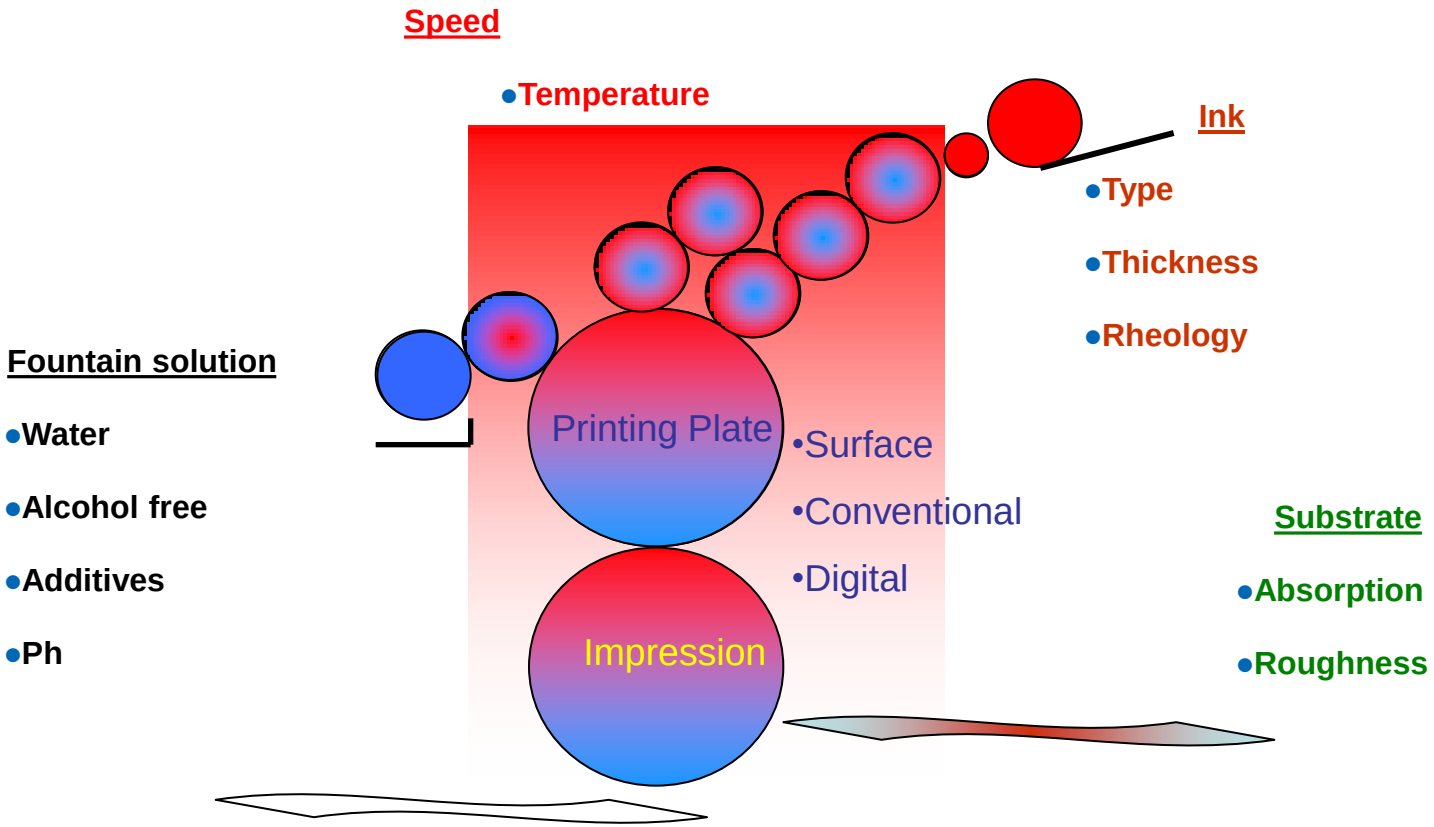
- What stands between straight away production;
  - Differential of materials
  - Combined or hybrid methods
  - Workflow
  - New data
  - Trusted printing product
- Search for printing parameters
  - Materials
  - Conditions

Setting Parameters

- System variables
  - Action level
  - Appearing limits
  - Appearance Stability
  - Twisting over time
  - Interactions
- Importing data
  - Production
  - Preliminary studies
  - Related Phenomena

Setting Parameters

- Dynamic printing system



Setting Parameters

- Drying - Polymerisation
  - Overall transfer on substrate
  - Durability in wide conditions range and stresses
- Direct reaction
  - Absorption
  - Cold-set
  - Heat-set
- Indirect reaction
  - Radiation use – IR - UV

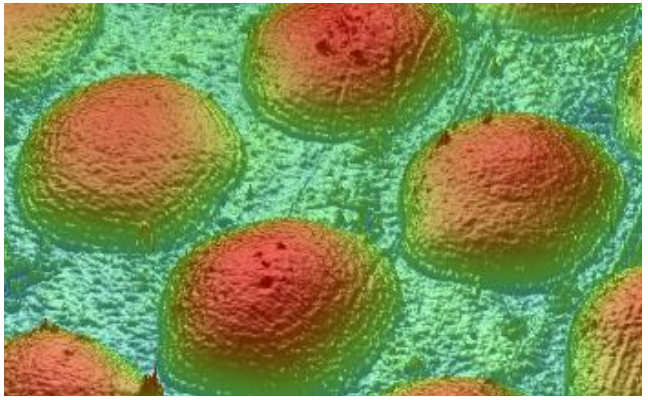
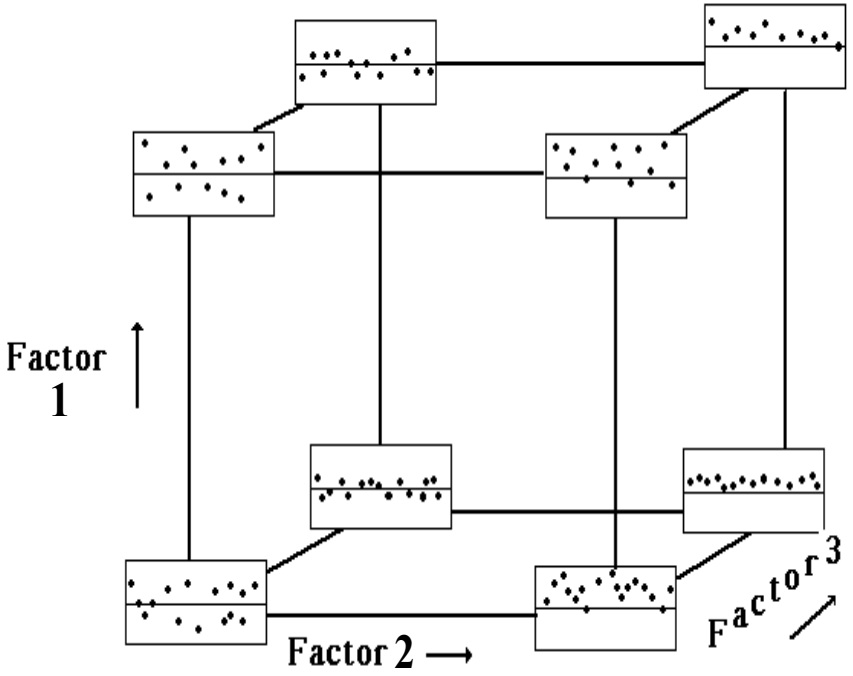


IMAGE - WCPC SWANSEA UNIVERSITY

Setting parameters

- Impression – Contact - Transfer
- Transfer method
- Speed
- Temperature
- Rheology
- Stresses
- Materials performance
  - Changes in quality over time



Conductive materials

- Printing Inks components
  - Resins, Pigments, Solvents and Additives
- Conductive inks components
  - Conductive materials, organic carriers, heat-set agents and rheological additives

	Units ICI-003	ICI-003
Resistivity	Micro ohm–cm	4.3
Sheet Resistance	milliOhm/Square	140
Bulk conductivity	Rho Film/Bulk Ag	2.4

Conductive parameters

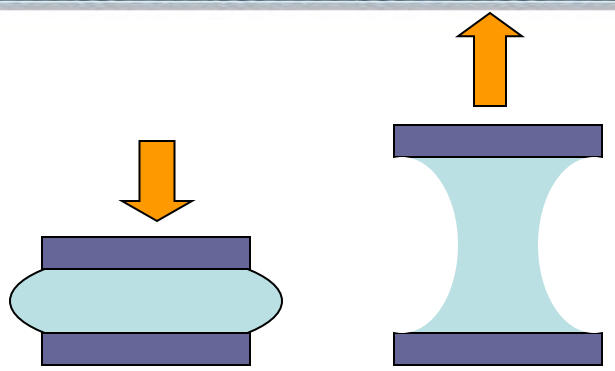
- Constant conductivity
  - Constant conductivity rates with temperature changes.
- Mechanical strength
  - Withstand to various mechanical stresses.
- Chemical resistance
  - Durability over oxidation and corrosion.
- Ability machining
  - Constant performance (e.g., torsion, bending, rolling, etc.)
- Weldability
  - Welded with welding materials

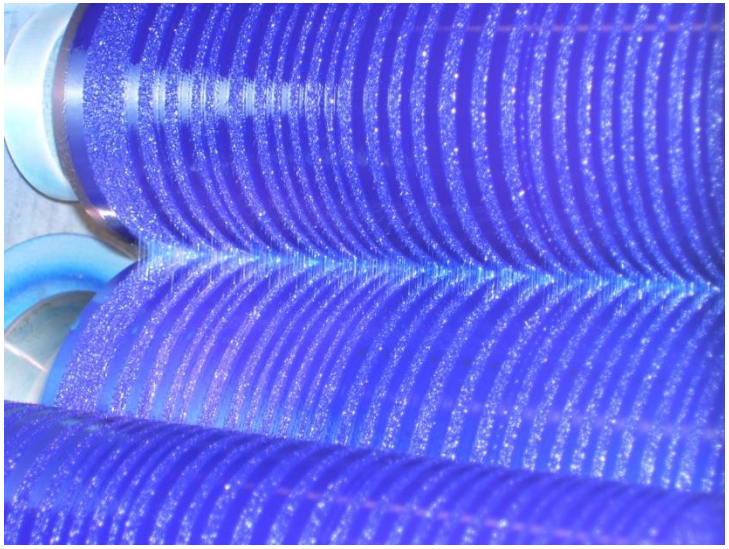
Conductive parameters

- Physical parameters
  - Line width, thickness, space between lines.
- Electrical parameters
  - Electrical conductivity, sheet resistance, longest electrically continuous path length, shorts between adjacent conductors, etc.
- Printing parameters
  - Number of impressions, registration, post treatment, substrate.

Ink Transfer instabilities

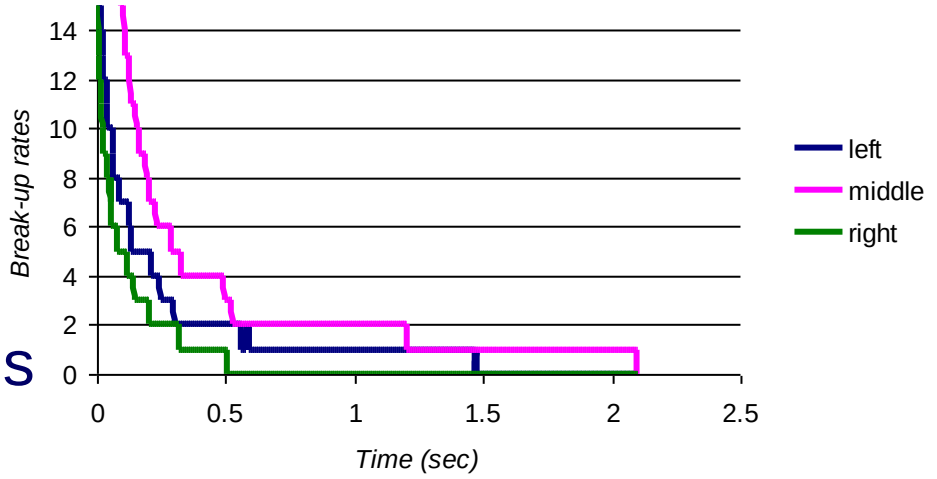
- Ink transfer mechanisms
  - Ink deformation during splitting
  - Tensile forces form filaments
- Ribbing
  - Non-uniform fluid spreading
  - Wave phenomenon
  - Rheological profile
  - Capillary number
  - Transfer mechanism
  - Gap (nip distance)





Ink Transfer instabilities

- Symmetric splitting
- Filaments thinning
  - Progressing thinning
  - Variation in break-up times



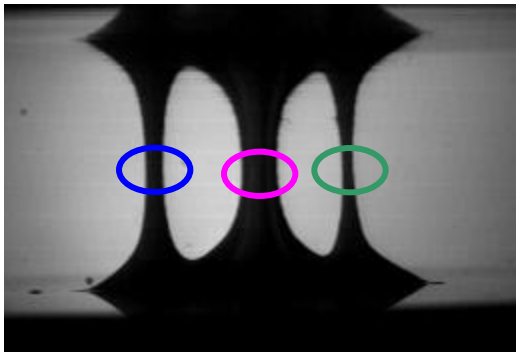
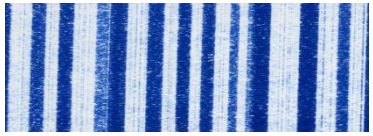
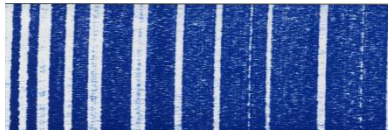
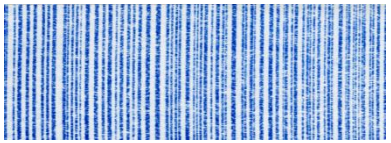


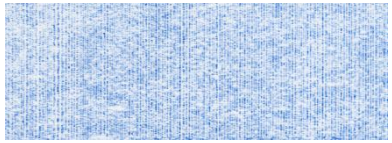
Image source: G.Vlachopoulos 2009

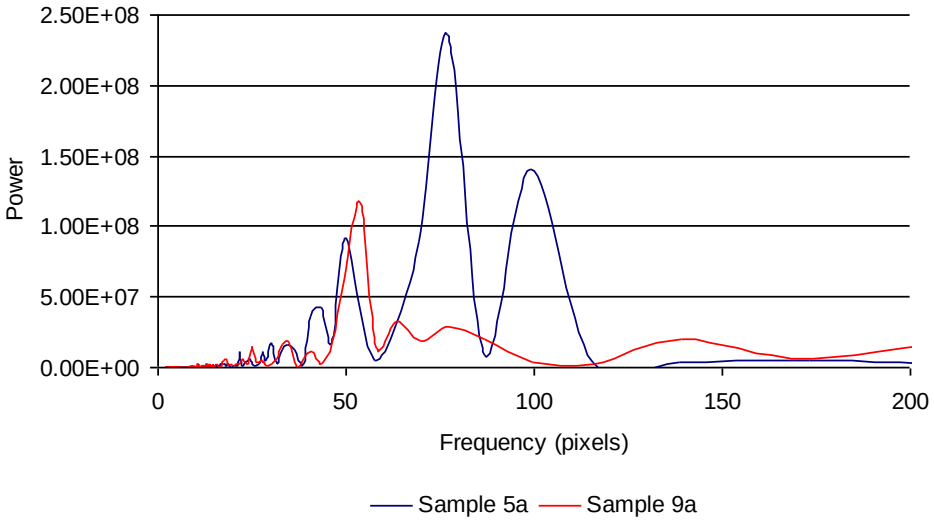
Ink Transfer instabilities

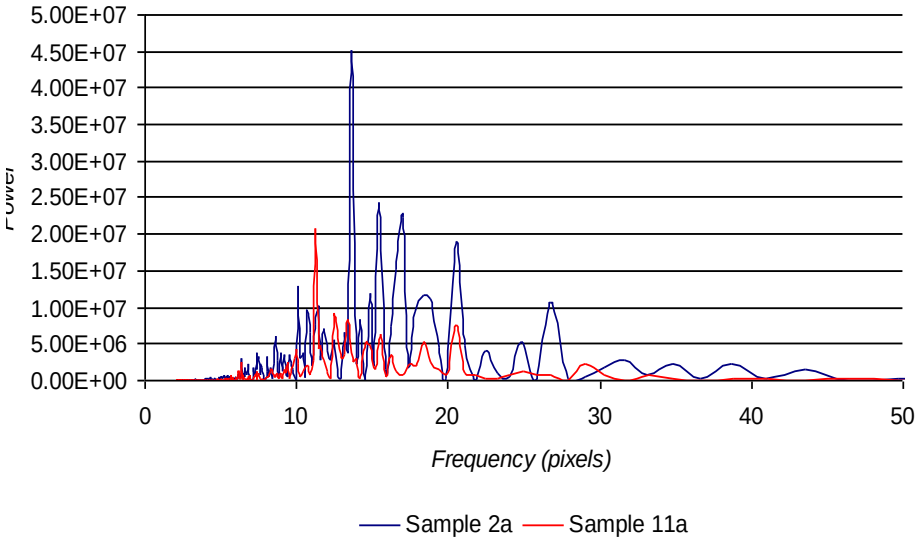

Sample 5a


Sample 9a


Sample 2a


Sample 11a

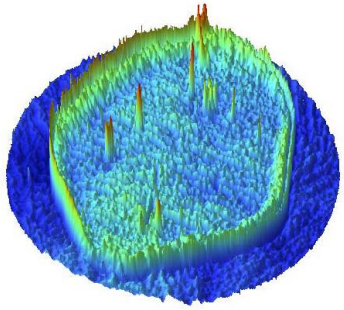




Images: G.Vlachopoulos 2009

Ink Transfer instabilities

- Gravure
  - Both scenarios?
  - Dr.Blade effect
    - Blade geometries
    - Printing speed
    - Cell volume



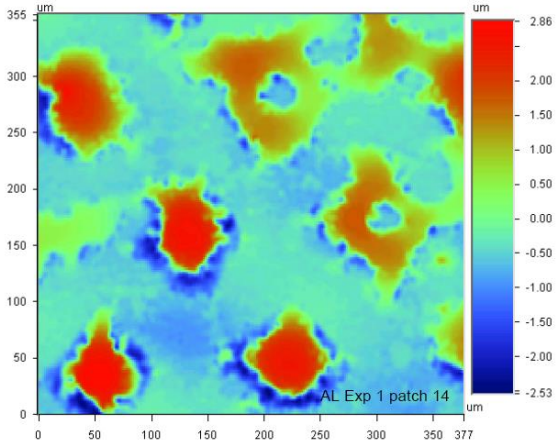
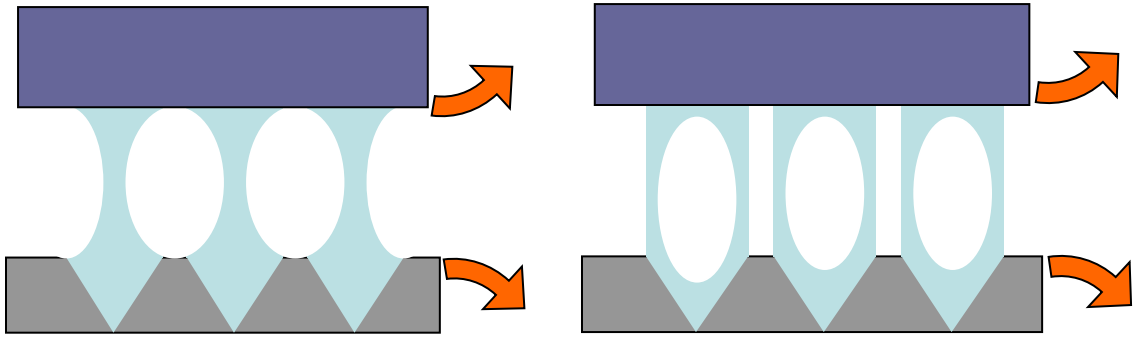
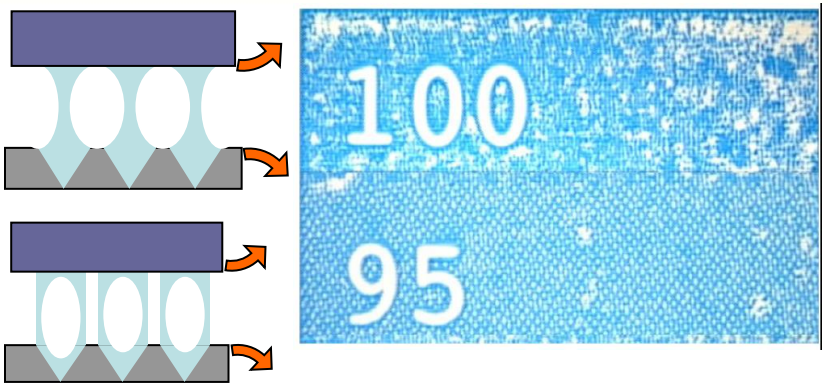


Image Swansea University - WCPC

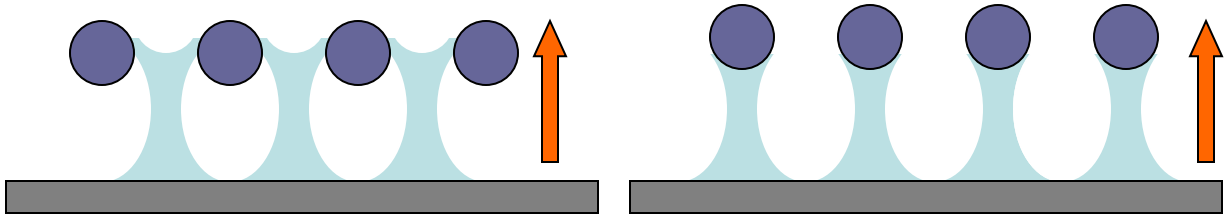


Ink Transfer instabilities

- Flexography
  - Anilox effect
    - Engraving and resolution
    - Contact nip
    - Plate and anilox charateristics

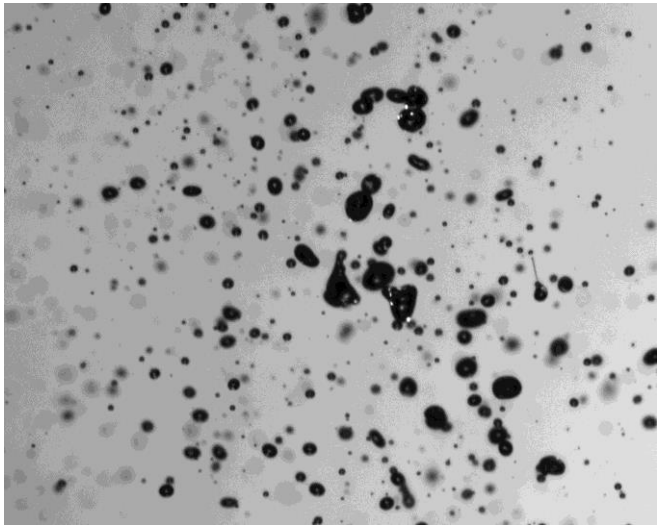


- Screen printing
  - Ink release
    - Squeeze speed
    - Distance
    - Mesh resolution



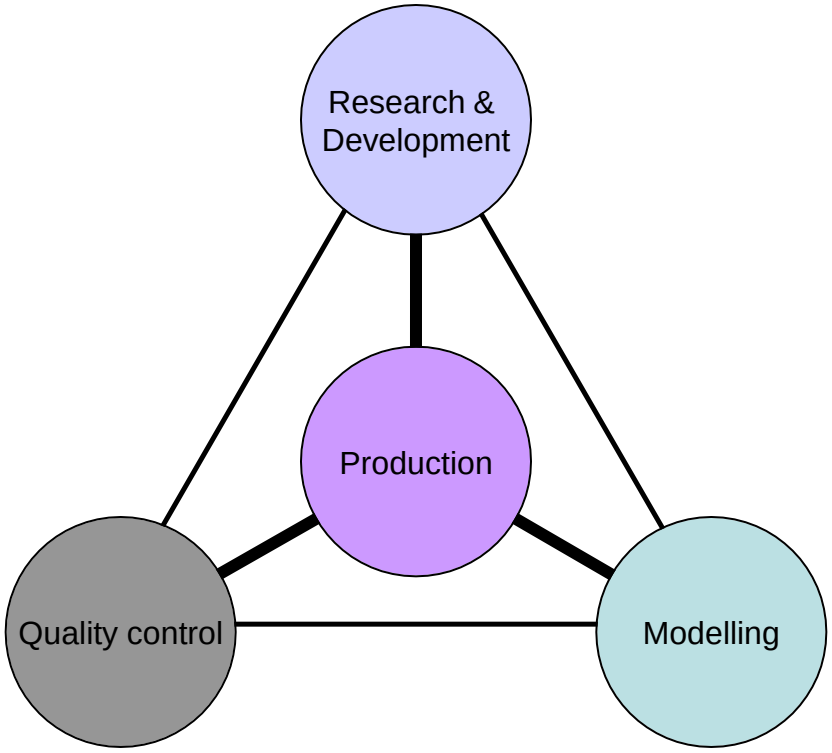
Ink Transfer instabilities

- Misting phenomenon
  - Micro-formation of droplets
  - Not fully understood
  - Tangential forces
    - Rollers rotation
  - Air contamination



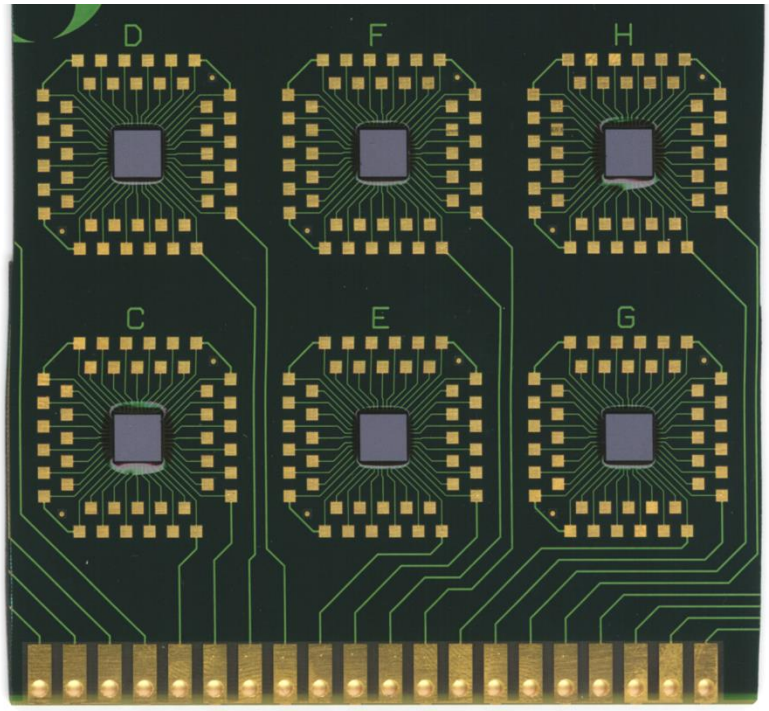
Quality assurance

- Production process evaluation
  - Communication
  - Exchange data
  - Applications
  - Quality
  - Evaluation
  - Modelling



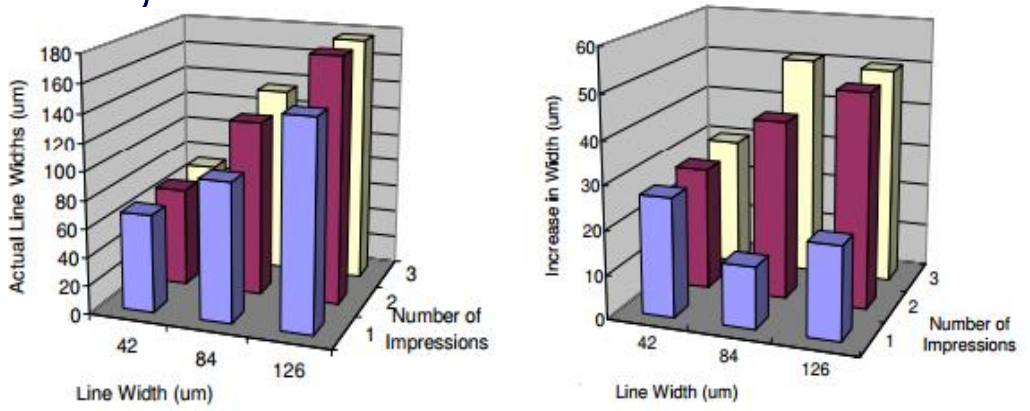
Quality assurance

- Printing electronics means:
  - Colour is not the main think
  - Trusted and reliable working
  - Durable product
  - Performance over time
    - Using conditions
  - Consistency of elements
    - Final product



Quality assurance

- Printing lines consistency:
  - Increasing with number of prints,
  - Decreases ribbing effect,
  - Increases conductor width,
  - Conductivity?



Actual Line Width Increase vs. Nominal Line Width and Number of Impressions

Absolute Line Width Increase vs. Nominal Line Width and Number of Impressions

Image:K.Anupama 2006

Quality assurance

- Post printing curing:
  - A. As deposited,
  - B Optimal cured,
  - C Reoxidised,
  - D Flaking circuit

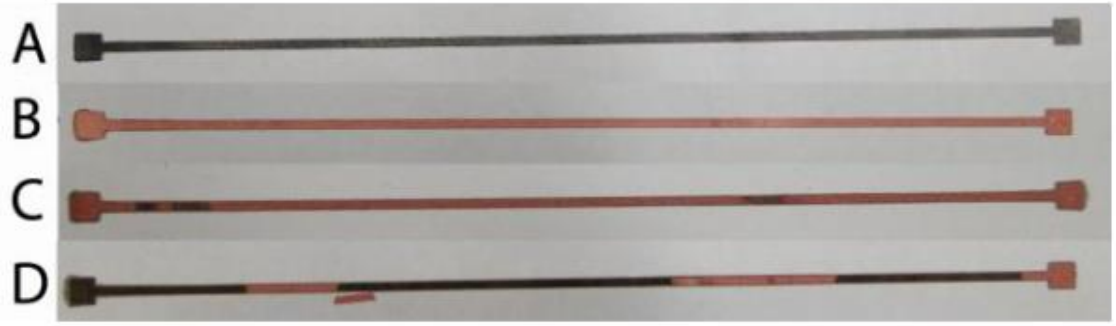


Image: *V.Akhavan et al, NovaCentrix*

Quality assurance

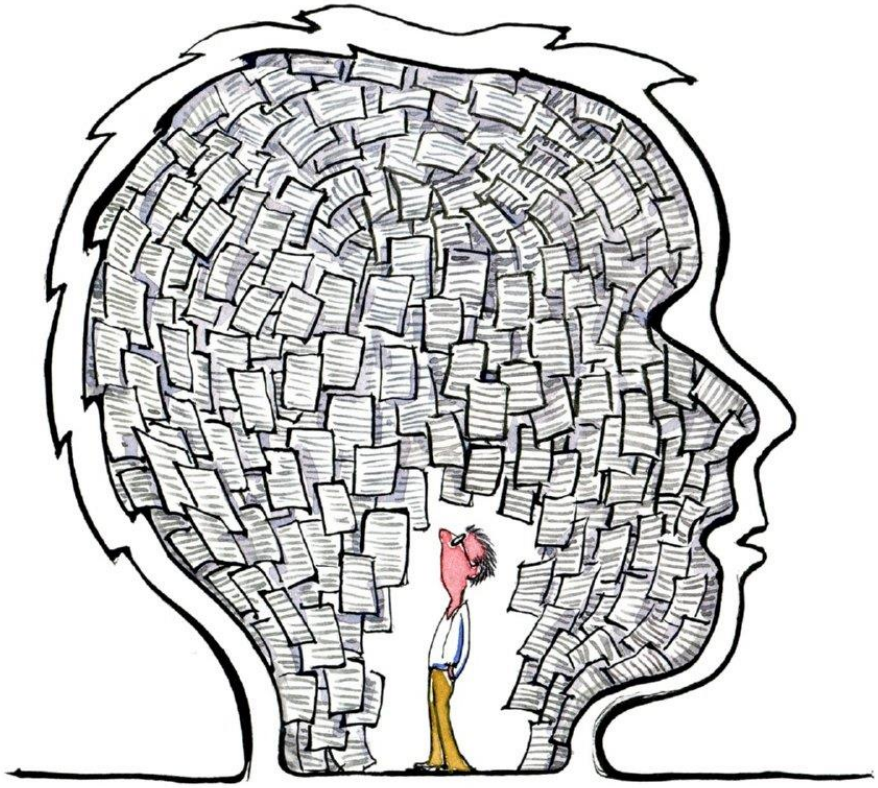
- Setting quality control
  - Limits – tolerance
  - Accuracy
- Conductivity
- Conductor design
- Materials quality tolerance
- Stress durability
  - Mechanical
  - Chemical

Quality assurance

- Definition of quality characteristics
- Measurement methodology
  - Accuracy
  - Tolerance
- Data analysis
  - Classification
  - Evaluation

Modelling

- Fast and low cost review
  - New materials
  - Geometries
- Product preview
- Faster results
- Locate instabilities
  - Variations
- Effective solutions



Closure

- Instabilities due to ink transfer mechanisms
- Printing electronics still under research
  - Conductive inks are not fully examined yet
  - Materials development
  - Post printing curing processes
- High product performance
  - High quality standards

Thanks for your attention

ΣΙΒΙΤΑΝΙΔΕΙΟΣ ΔΗΜΟΣΙΑ ΣΧΟΛΗ
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Any questions?