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Ink testing for industrial printers

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Presentation outline

1. Ink design
2. Ink testing strategy
3. Typical test equipment
4. It doesn’t jet!
5. Summary

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Ink design - Considerations

What do you need to know before formulating an ink?

- Type of printhead technology – e.g. DOD or CIJ, piezo or thermal?
- Application properties – e.g. colour, adhesion, lightfastness
- Restrictions – e.g. VOCs, food compatibility, regulatory compliance
- Process requirements – e.g. throughput, low energy consumption

These requirements will define the inks, and therefore the tests needed

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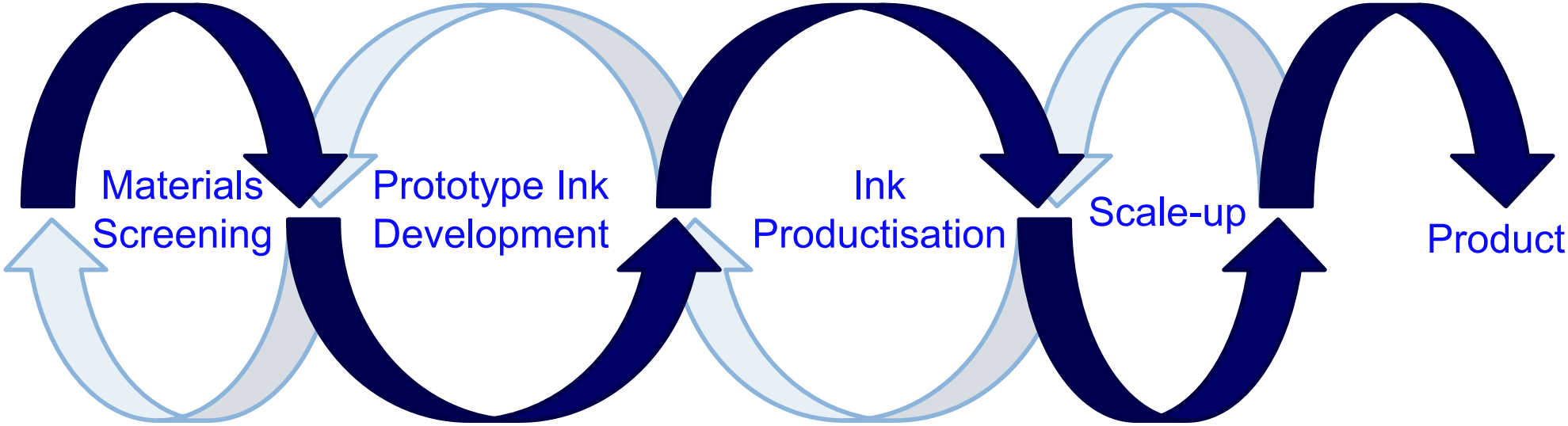
Ink design & test strategy



- Compatibility:
  - Printhead
  - Substrate
  - Process
  - Ink components
  - Restrictions
- Basic characterisation:
  - Viscosity
  - Surface tension
  - Particle size
  - Dry/cure speed
  - Printability
  - Substrate interaction
  - End-use properties
- Full characterisation:
  - As per prototype
  - Drop formation
  - Printing parameters
  - Reliability
  - Print quality
  - Process
  - Ageing stability
- Verify properties
- Define QC tests
- Quality testing:
  - Components
  - Inks

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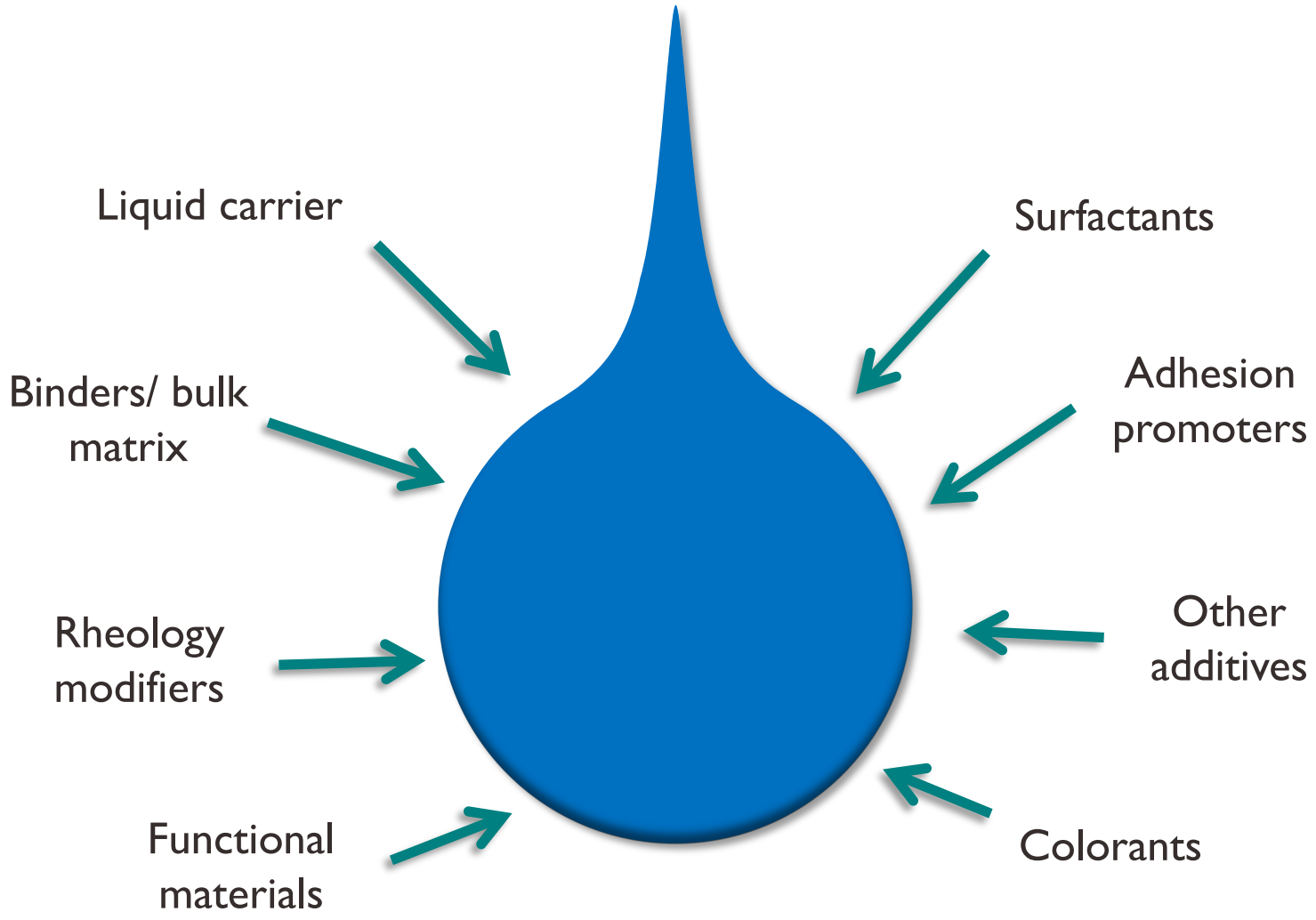
Ink Complexity



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Ink testing strategy
- materials screening

Establish type of printhead and its limitations

Establish type of ink, e.g. aqueous, solvent, oil, UV-curable, phase change

Establish main components of ink, e.g. solvents, colorants, reactive materials

Establish application requirements, e.g. speed, drying time, pre and post press sensitivities

Establish any regulatory requirements, e.g. OekoTex, Nestle standard, FDA, REACH

What are the ink contact parts of the system, e.g. printhead, ink delivery system, ink tanks, tubing, filters

- Test compatibility of parts with identified risky chemicals

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Ink testing strategy
- prototype ink development

Formulate prototype ink formulations

Perform basic characterisation prior to printing

- Viscosity
- Surface tension
- Particle size, sedimentation rate
- Drying or curing rate

Print if properties appear acceptable –

- Printing is only way to fully test an ink!
- Assess printability
- Assess interaction with substrate
- Assess end-user properties

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Ink testing strategy
- ink productisation

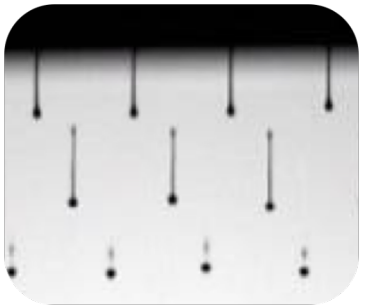
Inks demonstrate all targeted end-user properties

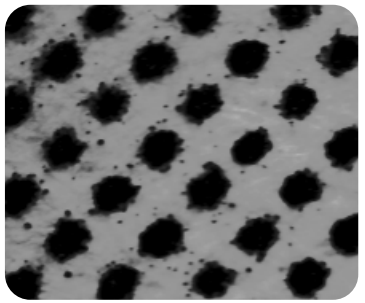
Optimise inks for production performance

Test under pilot production conditions:

- Drop formation properties
- Printing parameters, e.g. waveform, drive voltage
- Printing reliability
- Start/stop tests (latency/open time)
- Develop process parameters with sensitivity analysis
- Assess print quality
- Assess/estimate shelf life of inks through ageing studies

Repeat testing under production printing conditions





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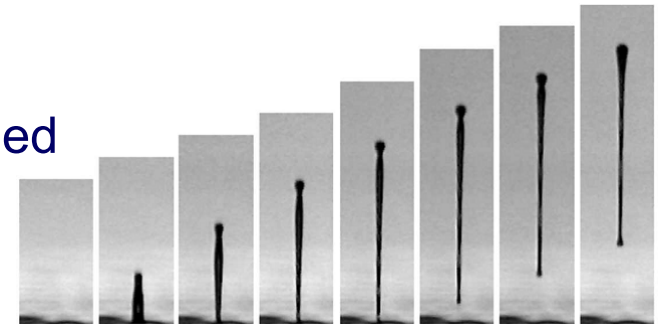
Viscosity/rheology

- Measure of the resistance to motion of a given fluid
- If viscosity is too high, ink will not flow out of nozzles
- If viscosity is too low, ink will eject with poor control
- Complicated by high shear conditions at nozzles
- Influenced by:
  - Types and concentrations of polymers used
  - Solids content
  - Compatibility of ink components



- Typically characterised using low shear Brookfield viscometers
- Rheometers for measuring low viscosity fluids at high shear available, e.g. ARES rheometer
- The inkjet printhead is the best rheometer to use!

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Surface tension

- Controls:
  - Jet break-up process, i.e. formation of drops
  - Faceplate wetting
  - Ink channel re-fill
  - Interaction between printed drop and substrate
- Dynamic process
- Typical tests:
  - Static surface tension: DuNouy ring methods
  - Dynamic surface tension: Maximum bubble pressure tensiometer (Kruss BP2)
  - Contact angle: Theta optical tensiometer (KSV Instruments)
  - Drop formation studies

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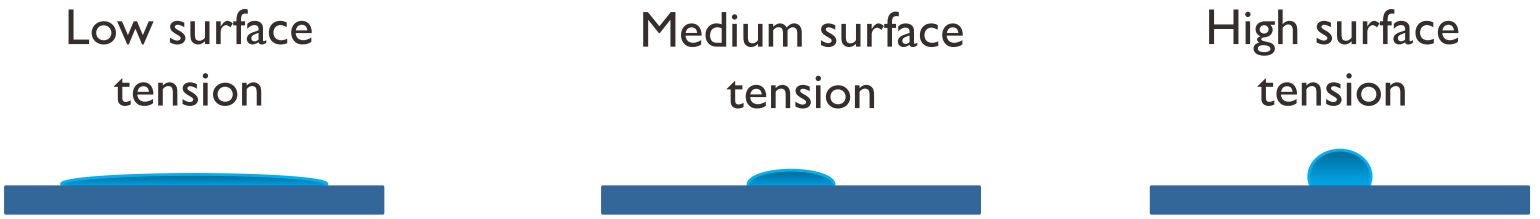
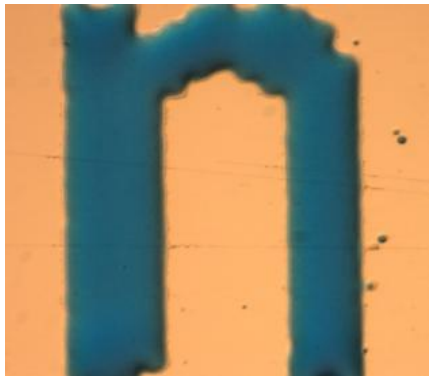
Impact of surface tension

Ink behaviour on substrate



- Drop behaviour on substrate controlled by
  - Surface tension of ink relative
  - Surface energy of substrate
- Tune morphology of printed features by adjusting ink properties

UV-cured ink on plastic



UV-cured ink on copper

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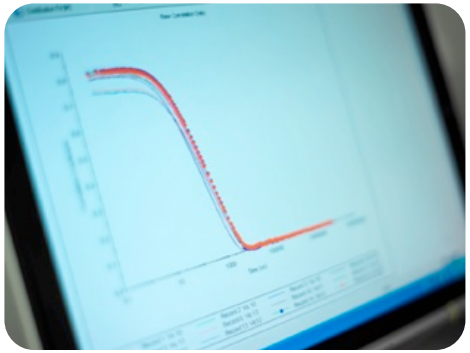
Particle size

- Particulate content in inkjet inks typically sub-micron
- Aggregation can cause blockage of nozzles
- Important to measure particle size over time for:
  - Dispersions
  - Inks
- Timed filtration of fixed quantity of ink
  - Does not give particle size
  - Provides quick indication of problems
- Light scattering systems used to measure particle sizes
  - e.g. Malvern Nanosizer
  - Important not to over-dilute samples



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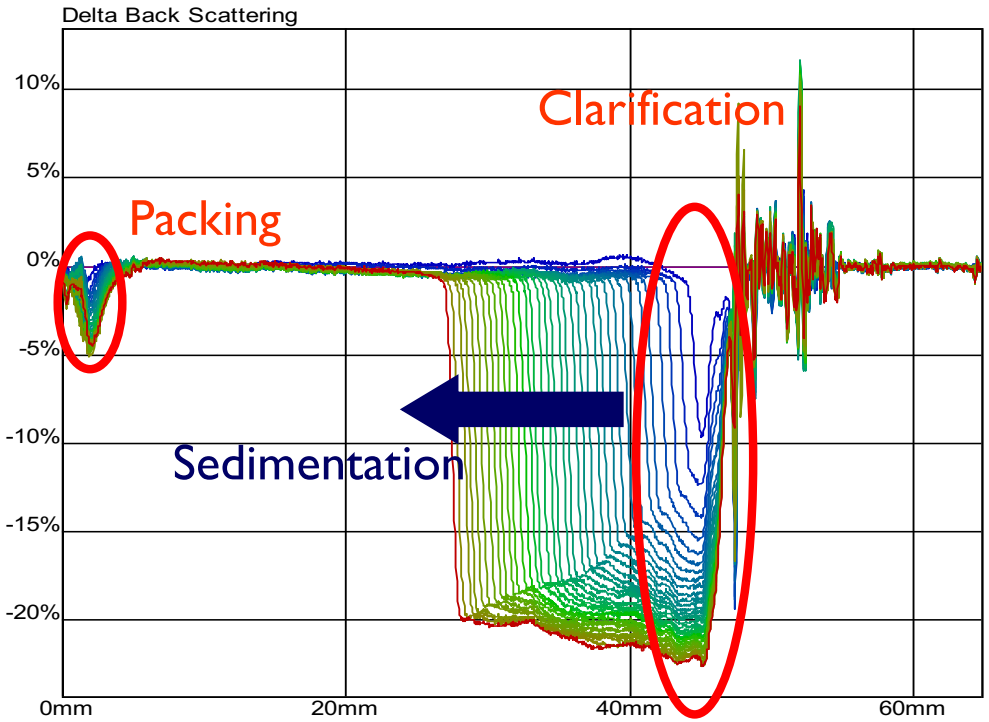
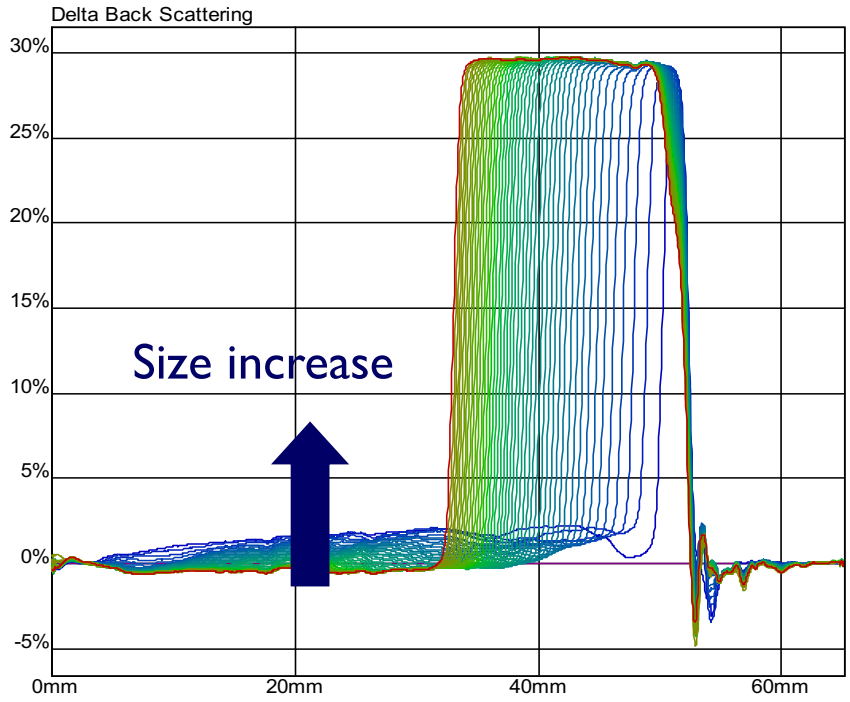
Sedimentation rate

- Increasingly important parameter as denser materials become more routinely used
- A Turbiscan system can give vital data on migration rates and rate of change of particle size





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Other fluid properties

- Other fluid property measurements include:
  - Conductivity
  - pH
  - Amount of dissolved gas
  - Degree and type foaming
  - Recirculating flow characterisation

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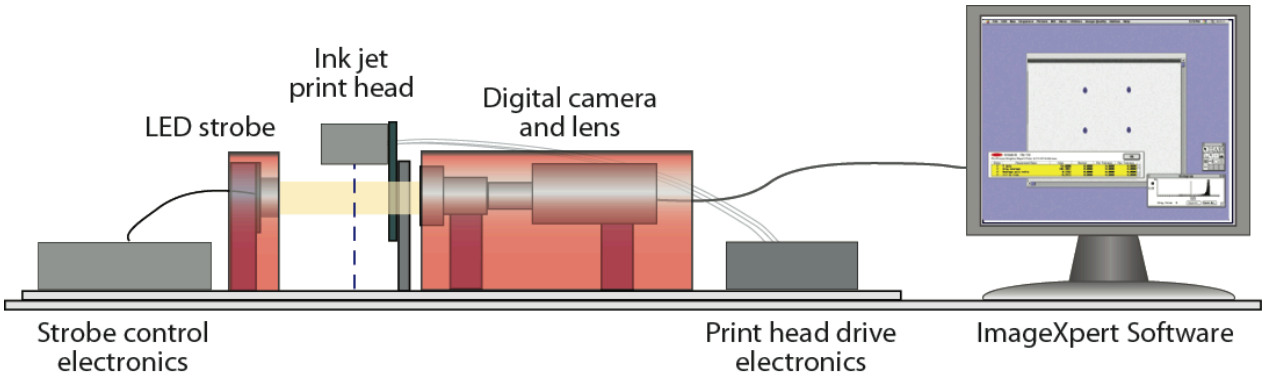
Drop formation

- Drop visualisation tools are key to successful ink development
- Enable:
  - Development and optimisation of printing parameters
  - Determination of window of printing reliability
  - Development of maintenance requirements
  - Diagnosis of printing failure modes
- JetXpert - stroboscopic system capable of single event capture for imaging single drops



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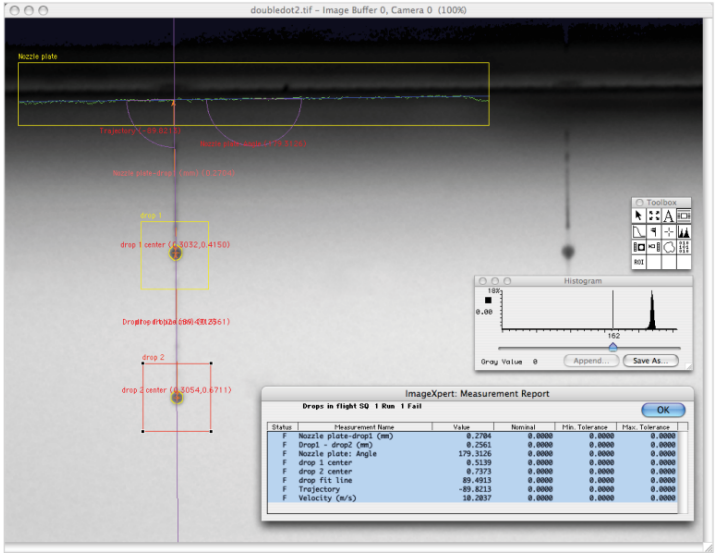
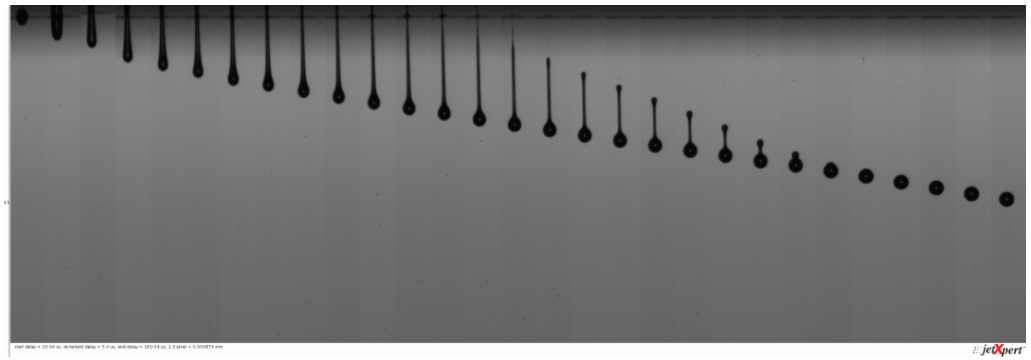
Drop formation 2

- Characterise:
  - Drop volume, velocity, trajectory
  - Ligament length, volume, break-off length
  - Satellites
  - Nozzle plate wetting





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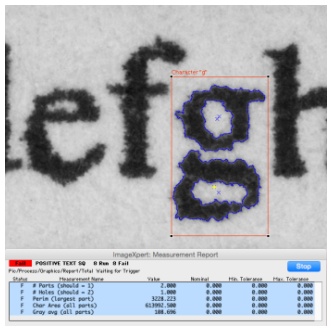
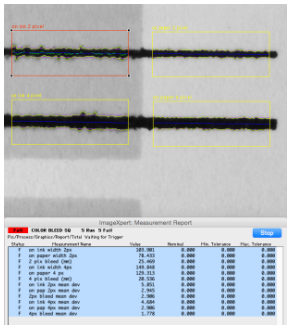
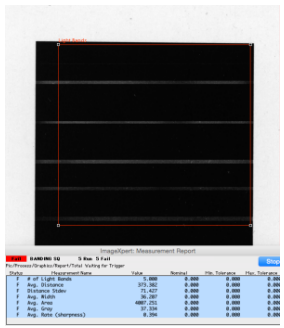
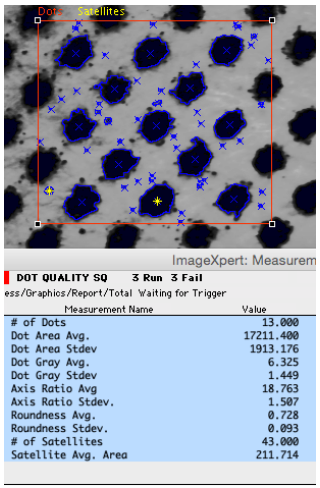
Print quality analysis

- Degree and type of analysis required highly dependent on application
- Typical measurements include:
  - Feature size/quality:
    - dot size, dot roundness, dot axis ratio
    - line width, line edge raggedness
  - Image attributes: satellites, contrast, colour bleed, mottle, pinholes
  - Dot placement accuracy: dot-to-dot spacing, relative displacement of dots from a datum point









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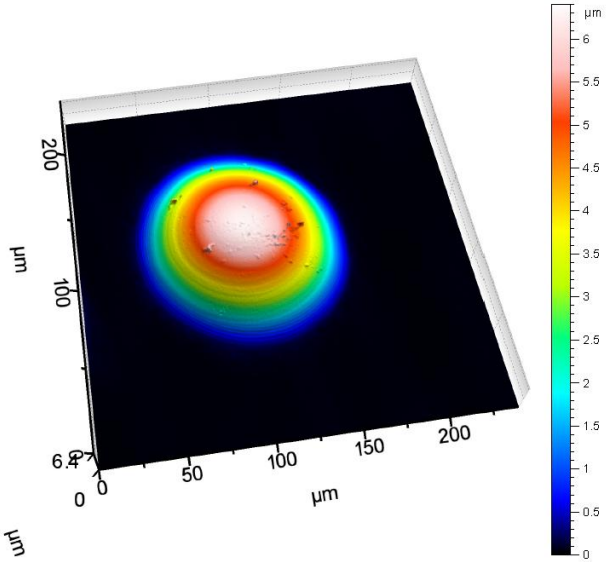
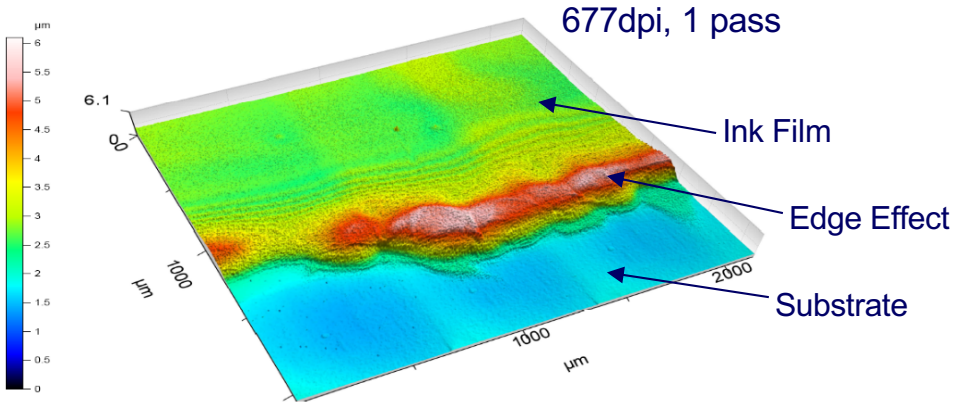
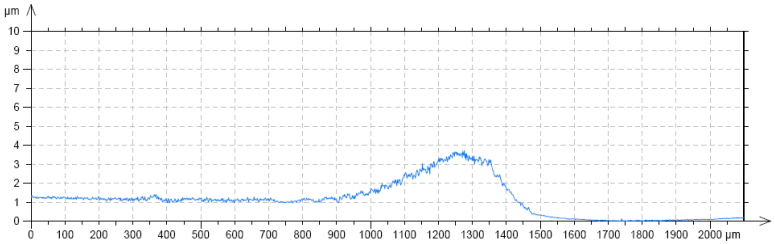
Metrology

- Crucial for materials deposition applications
- Measure 3D profiles to determine:
  - Film thickness
  - Aspect ratios
  - Uniformity over areas
  - Drying effects & profiles
- Stylus and optical systems available
- Profilometers include Nanofocus, Altimet, Veeco







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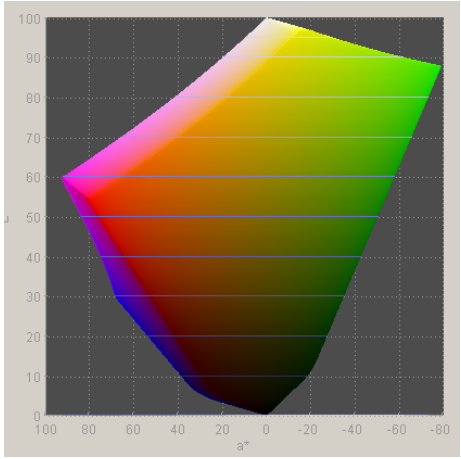
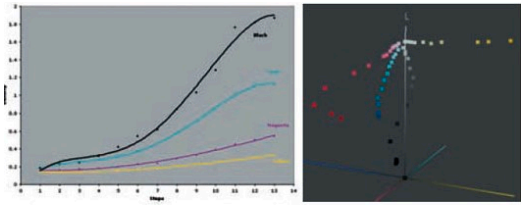
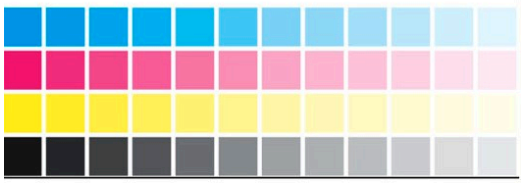
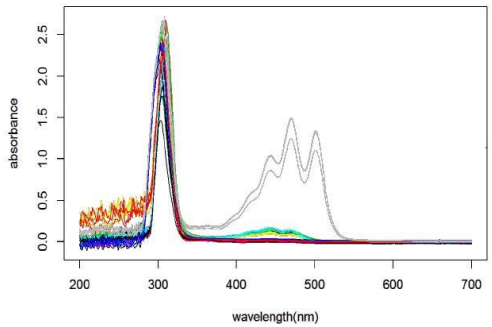
Colour measurement

- Measurement/definition of the colour gamut of great importance
  - 3D colour space
  - Choice of colorants determines region of achievable colours
- Measurements must always be performed on the real substrate/medium
  - Densitometer – Optical density
  - UV/Vis - Absorption characteristics
  - Spectrophotometer – Colour co-ordinates
  - Flop index - Metallic effect coatings
- Fastness - measure of resistance of chroma against environmental impact:
  - Light, Wash, Crock, Solvent etc.









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End-user properties

- How does the printed ink perform in the application?
- Commonly encountered measurements are:
  - Adhesion: cross-hatch tape test
  - Hardness: pencil hardness test
  - Flexibility: 180˚ bend test
  - Stress/strain curve: strain gauge
  - Degree of cure: smudge test
  - Conductivity/resistivity: 4-point probe
  - Refractive index: refractometer
  - Hydrophobicity: contact angle

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It doesn't jet!

- Or at least it doesn't jet well enough …
- Is it the:
  - Ink?
  - Printhead?
  - Something else, e.g. ink delivery system, motion system, environmental conditions?
- Inkjet is a complex multi-disciplinary area
  - Need understanding of all components of a printing system
  - Step-by-step testing and evaluation of ink properties during development minimises
    - time to product launch
    - need for excessive aftersales intervention

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Diagnosing issues

- Most printing issues can be diagnosed using:
  - A drop visualisation system
  - A nozzle test pattern
  - A microscope
- ALL printing issues can be diagnosed using:
  - Understanding of underlying chemistry of ink and substrate
  - Understanding of the characteristics of the printhead
  - Understanding the characteristics of the ink delivery system
  - Understanding of the product handling

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Summary

- Ink testing is crucial to the successful implementation of inkjet printing in an industrial production environment
- Different applications will require different types of testing
- Ink developments should be performed with industrialisation in mind

Test, test and TEST!

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