Manufacturing inks for industrial printers

IMI Europe Tech Talks

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LINKING TECHNOLOGIES AND MARKETS

Presentation outline

1. Ink design for manufacturing
2. Ink testing strategy
3. Typical test equipment
4. Problems
5. Summary

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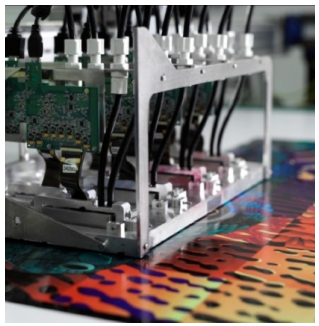
Ink design - Considerations

- Things to know before formulating an ink for an application
  - 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 define the inks, and therefore the manufacturing process and tests needed



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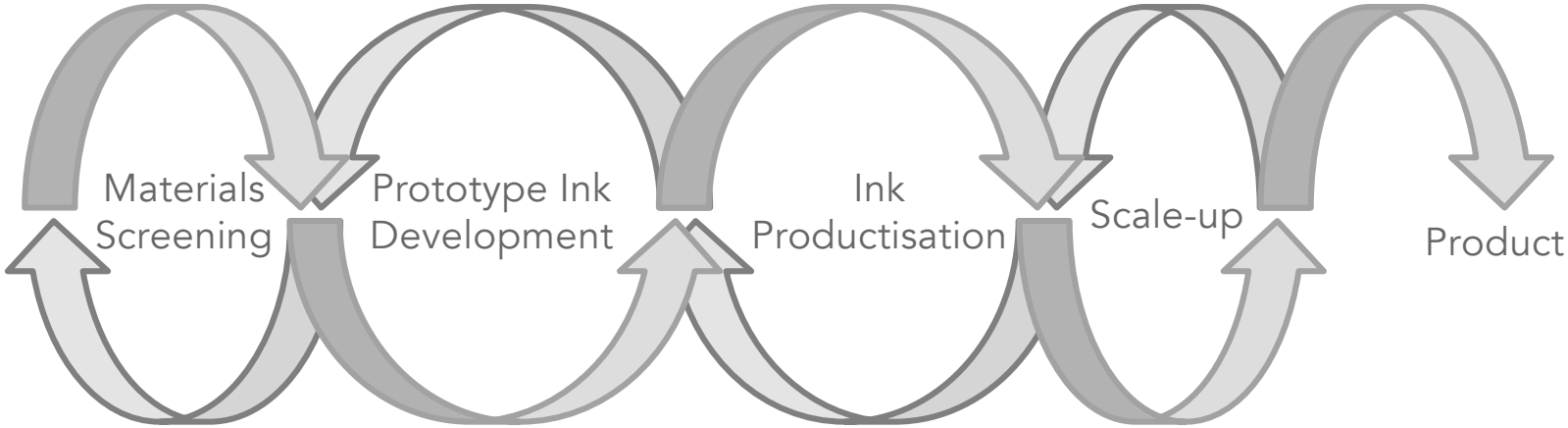
Ink design & test strategy



- 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
- Batch size tests
  - Verify properties
  - Define QC tests
- Quality testing:
  - Components
  - Inks

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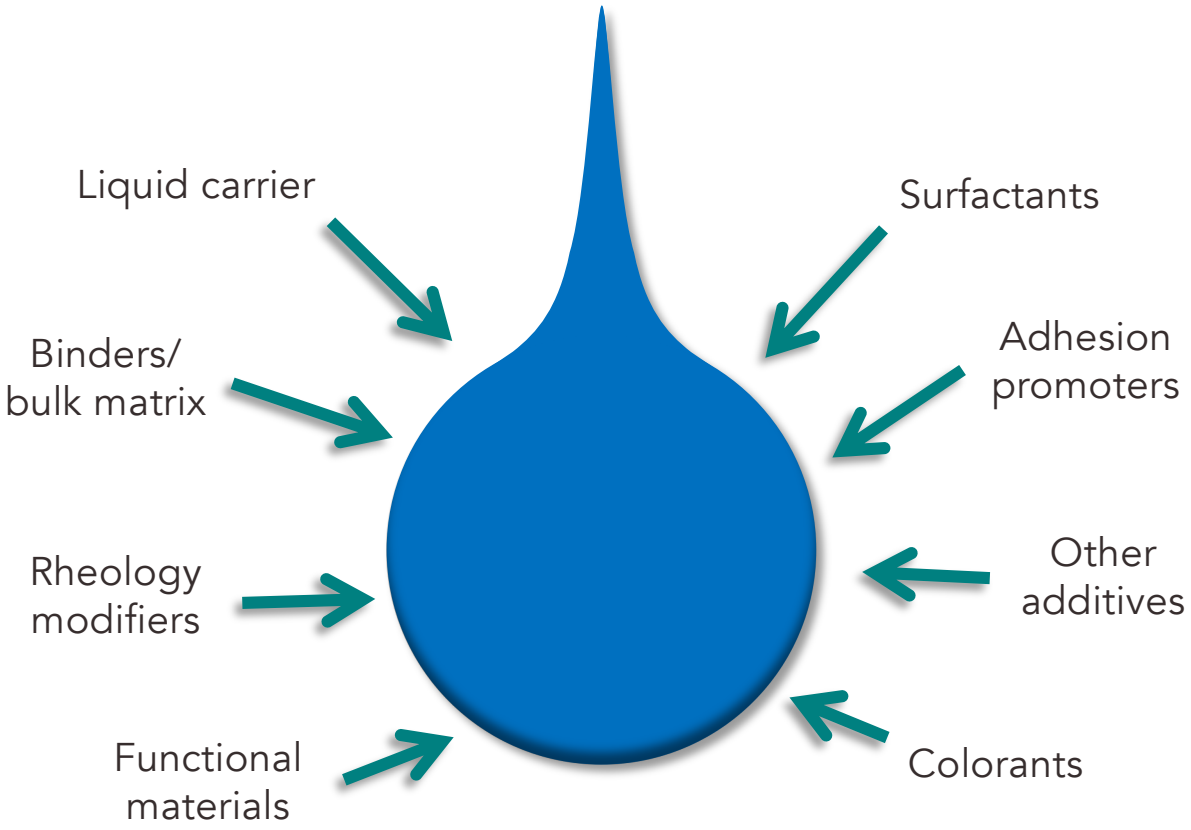
Ink Complexity



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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
- Test contact parts of the system, e.g. printhead, ink delivery system 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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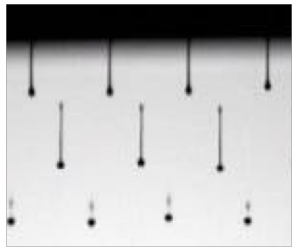
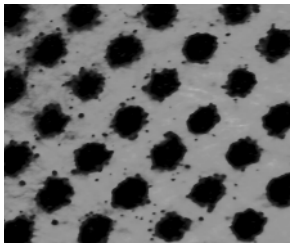
Ink testing strategy - ink productisation

- 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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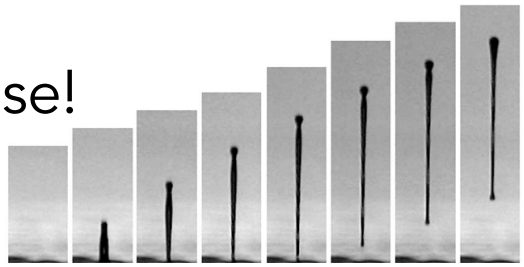
Viscosity/rheology

- 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
- Typically characterised using low shear viscometers (e.g. Brookfield)
- Rheometers for measuring low viscosity fluids at high shear available
- 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 (e.g. Kruss BP2)
  - Contact angle: Theta optical tensiometer (e.g. KSV Instruments)
  - Drop formation studies

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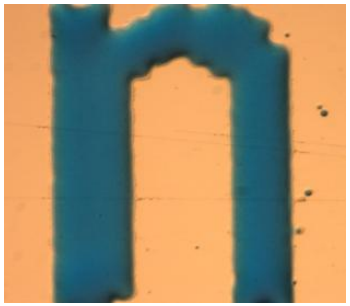
Impact of surface tension

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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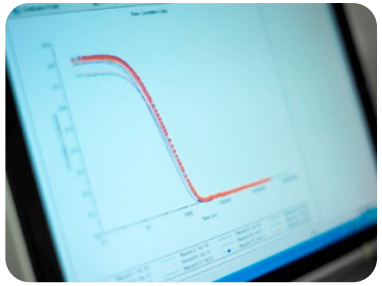
Particle size

- 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



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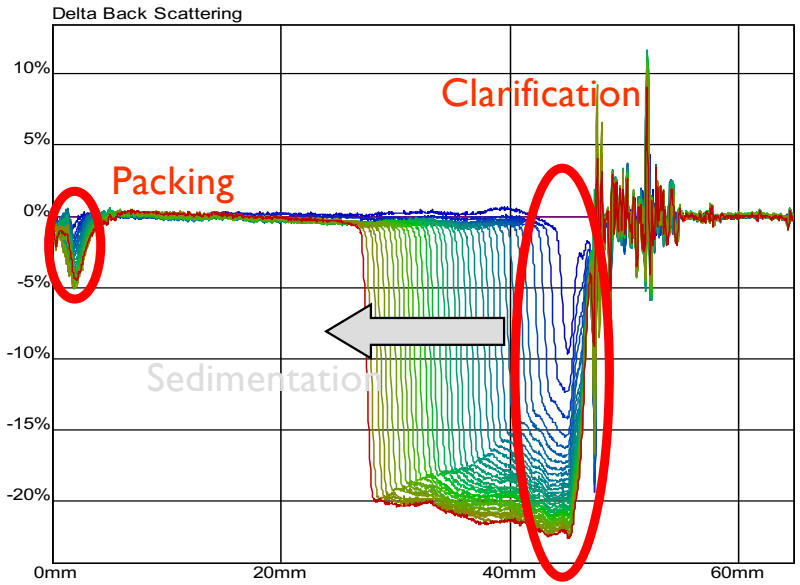
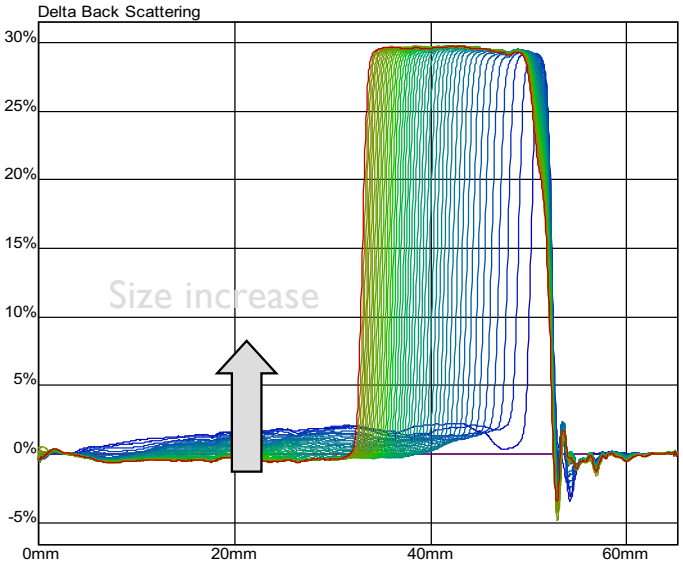
Sedimentation rate

- 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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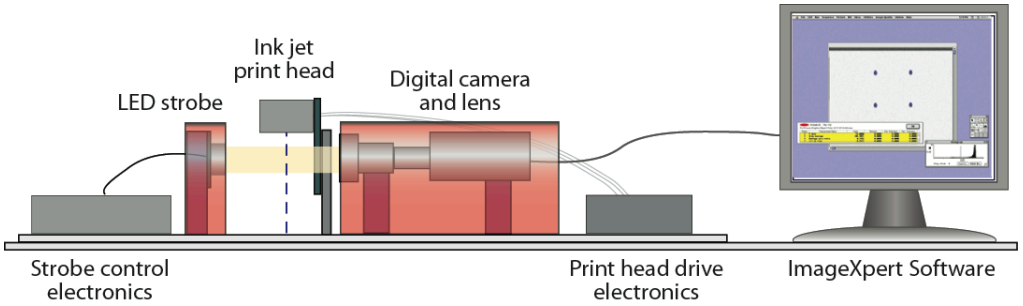
Drop formation

- 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
- Stroboscopic systems capable of single event capture for imaging single drops



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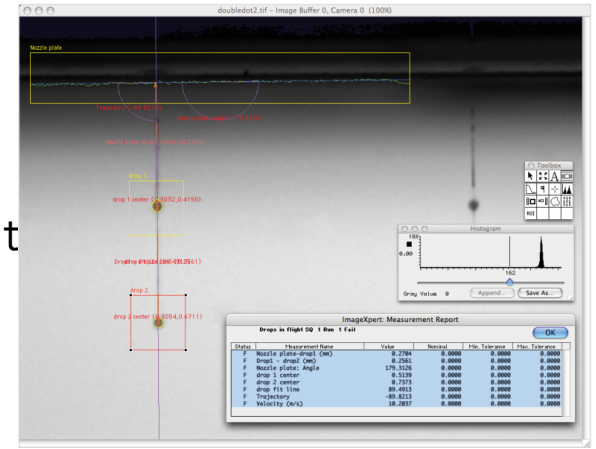
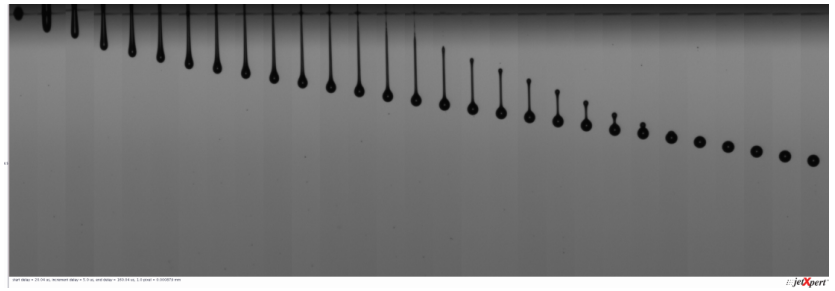
Drop formation 2

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





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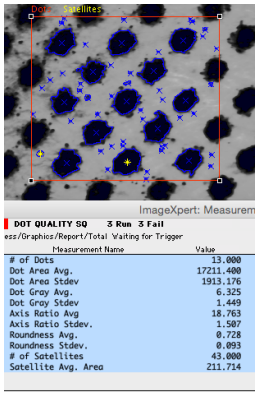
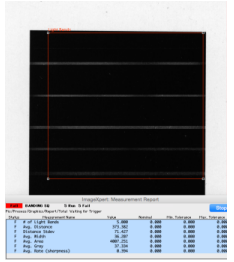
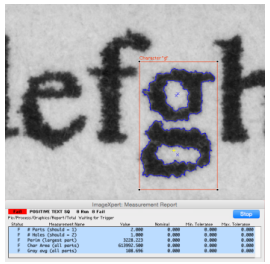
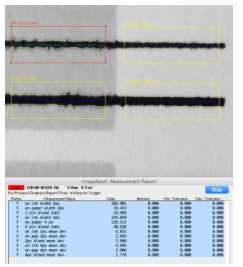
Print quality analysis

- 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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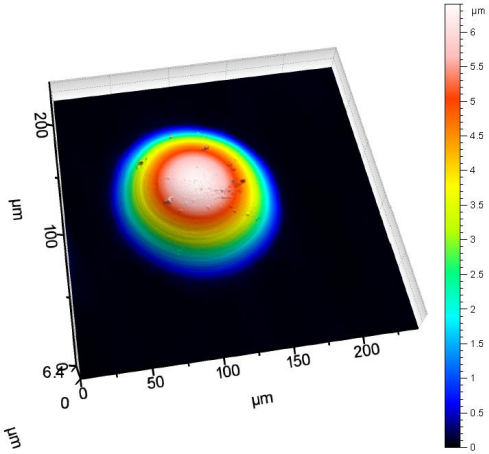
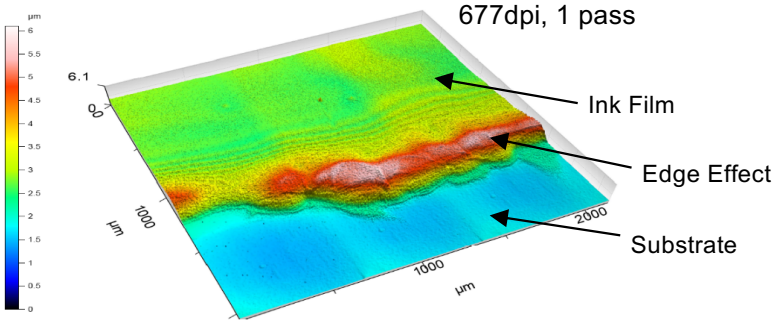
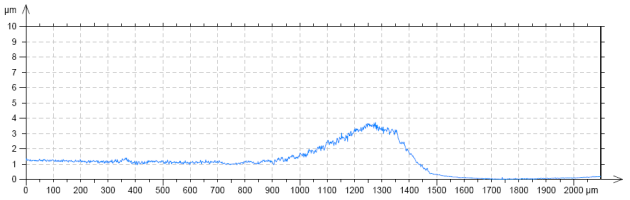
Metrology

- 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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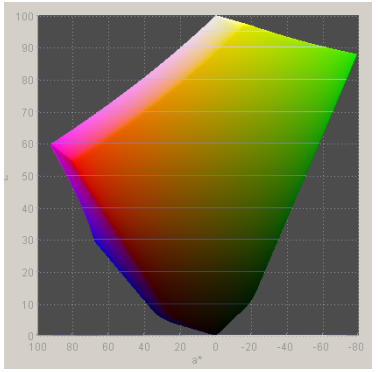
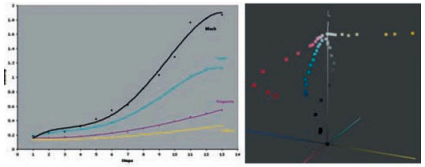
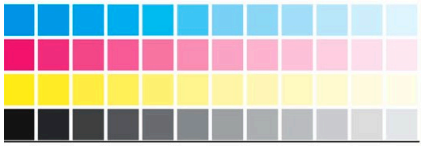
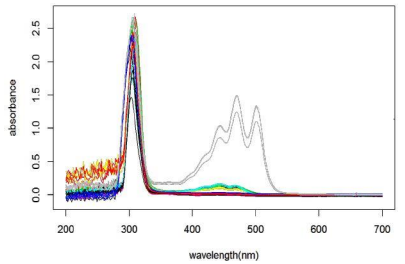
Colour measurement

- 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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Problem solving

- 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 issues before and after launch

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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 design for manufacture is crucial to the successful implementation of inkjet printing in an industrial production environment
- Inks need to be tested at all stages of design and manufacture
- Different applications will require different types of testing
- Ink development and manufacturing should be performed with industrialisation in mind

- Test, test and TEST!

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