Aerosol Jet® technology opportunities

Jiří Navrátil
1. Introduction – history and formation
2. Aerosol Jet system
   2.1 System components
   2.2 Inks and substrates
3. Application of Aerosol Jet technology
4. Conclusion
• Printing technologie used for creating electronics (1950)
• Screen / stencils printing, inkjet
• Technologies limitation, low flexibility
History

- **DARPA** (Defence Advanced Research Program Agency)
  - project **MICE** (Mesoscale Integrated Conformal Electronics) (1990)
    - Developing a tool for printing of the electronics
      - Ability to use CAD systems
      - Fast and easy to use
      - Wide range of printed materials
      - Wide range of substrates (including low-temp <200 °C)
    - **Success** – *invention of the Aerosol Jet technology*
      - Established company - **Optomec Inc.** (1997)
• Optomec Inc.
  – Established 1997
  – Headquarters in Albuquerque (USA)
  – LENS a Aerosol Jet
  – Investments in research 30 mil. $
  – Close cooperation with
• **Aerosol Jet**
  – Selective deposition technology
  – Contactless printing technology
  – Fast creating or changing toolpath → optimal for **Rapid Prototyping**
  – Tisk aerosolu
    • Ink droplets 1 – 5 µm
    • Droplets nozzle outcoming velocity up to 50 m/s (180 km/h)
    • Minimal printed line width **10 µm** (Ag ink)
    • Minimal printed layer thickness **10 nm** (CNT ink)
Aerosol Jet vs. Screen Printing

• Pros
  – Fine lines printing
  – Easy printing on 3D substrates
  – Easy change of printed motive!!!

• Cons
  – Not (yet) suitable for high volume manufacturing
  – High ink prices
  – Not suitable for covering large areas
Aerosol Jet vs. Inkjet

• Pros
  – Fine lines printing
  – Nozzle - substrate distance – variable
  – Ink‘s viskosity range
  – Printing on 3D substrates

• Cons
  – More complex operation
  – Higher ink prices
• Bubbler, Atomizers, Print heads, …
Pneumatic atomizer (PA)

• Jar with ink
• Suction by Venturi effect
• Sputtering on the jar wall >> ink smashed to aerosol
• Viscosity 1-1000 mPa·s
• min 15 ml of input material
• Deposition of wider (25+ µm) or thicker lines
Ultrasonic atomizer (UA)

- PFA sleeve with ink
- Ultrasonic smashing of ink $\rightarrow$ aerosol
- Viscosity 1-5 mPa·s
- min 1 ml of input material
- Deposition of narrower lines (10+ µm) or thin layers
Bubbler

- Possible (not needed) to use
- Filled with solvent
- Nitrogen „bubbling through“
- Improves atomization
- Addition of solvent to ink
Deposition heads

• 2 types
  – Fine
  – Wide

• Nitrogen focusation – 3 advantages
  – No contact aerosol-nozzle >> resistent to clogging
  – Aerosol focused to thin stream >> fine lines printing (from 10 µm), easy line width management
  – Aerosol well focused 15 mm from nozzle tip >> possibility for printing on 3D/curved/stepped substrates
Fine deposition head

- Nozzle – stainless with ceramic tip
- Nozzle hole diameter 100, 150, 200, 250, 300 µm
- Shutter
  - stops aerosol deposition on substrate
Wide deposition head

• Stainless nozzles
  – Round (0,75 mm)
  – Oval (0,25x1,5 mm and 0,25x3 mm)

• Shutter
  – Stops aerosol deposition on substrate
  – Exhausted to waste jar
Printing - complex process

• Atomizer flow $\text{ATM} \ [\text{scm}]$
• Ultrasonic current $[\text{mA}]$
• Virtual Impactor exhaust flow $\text{EXH} \ [\text{scm}]$
• Focusation gas flow $\text{SHT} \ [\text{scm}]$
• Platen temperature $t_{\text{plat}} [^\circ\text{C}]$
• Ink temperature $t_{\text{ink}} [^\circ\text{C}]$
• Motion velocity $v \ [\text{mm/s}]$
• Etc.
Aerosol Jet function summary
Aerosol Jet inks

- Viscosity 1 – 1000 mPa·s
- Solid particle size up to 500 nm
- Compatibility with substrate
- Compatibility with systém (orings, metal)
- Capability of atomization??

- Possible ink modifications
  - Adding different solvents (even mixing them)
  - Functionalizing with different chemical groups (primary for organic materials)
• Compatibility with ink
• Broadly any substrate for printing
  (2D, 3D, platen max size, platen max load,…)

• Classic PCB, ceramics, Si wafer, metals, foils (PET, PEN, Polyimide…), plastic, paper, …. 
• Commercial usage – mobile devices printed antennas
  – Company - Lite-On
  – 24/7 Aerosol Jet Marathon series
  – 4 print heads, 5-axis motion system
Our application

• Printed electronics
  – Electrical circuits, passive components (R, L, C), RFID antennas

• Sensing application
  – Active layers - PEDOT, CNT, Graphene…
  – Auxiliary contacts, interconnections
  – Interdigital electrodes

• SMD chips interconnecting
  – Electronics
  – Power electronics

• Future ??
• Logo RICE
  Au ink
  10 µm line
• Miniature 3D objects (Ag ink), multilayer printing
• RFID antenna, IDE (Ag ink)
• Chip interconnections (Pt, Au and Ag ink)
• Our available materials: Ag, Pt, Au, CNT (carbon nanotubes), Graphene, PVP dielectrics, Polyimide,…
Optomec Aerosol Jet

- Unique, modern additive deposition technology
- Aerosol generation (atomization) + nitrogen focusation
- Printing on 3D or non-planar substrates
- Rapid Prototyping
- Using Inkjet, Aerosol Jet, Dispensing, Screen printing >> their synergy in manufacturing >> hybrid made electronics

- Wide range of inks, substrates >> huge capability of technology in R&D (research and development)
Questions are welcomed 😊
Thank you for your attention