Printed and Hybrid Integration

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Printed Electronics Limited (PEL)
General Overview

• PEL was founded in 2006 – idea formed within a conventional electronics manufacturing business (PCB).

• An SME with main facility in Tamworth UK and materials formulation in Cambridge

• Partnership with Amphenol Invotec Circuits, the UK’s largest manufacturer of PCBs.

• Work closely with CPI in Sedgefield

• PEL is an integration, process, materials and product development company
  – product development for clients: prototype through to production quantities. Includes system development with partners.

• PEL Training courses: Inkjet Electronics and Integration
• Inkjet-electronics and material deposition expertise:
  – Direct circuit printing, Material deposition, Composite device fabrication
PEL Locations

• Tamworth, Birmingham
  – Main facility
    • Inkjet Centre
    • Electronics / design
    • Screen Printing
    • 3D digital deposition
    • PCB manufacture - Invotec

• Cambridge
  – Ink development lab

• Sedgefield - CPI
  – Close partnership
Using printed methods to form circuits and then to attach conventional components using (ideally) digitally deposited conductive adhesives.

Much of the work that PEL undertakes is related to printing interconnects: the conductive lines that form the circuits, antennae, passive components etc.
The idea of Printed @ Home

- Home inkjet printer with no modifications
- Uses a PEL nano ink (Ag)
- Commercial inks also work
- Print silver, copper, gold etc using nano inks
Desktop Printing
Room Temp Cure Ag nano ink
Printing of interconnects using Industrial Inkjet systems
Inkjet process

1mm Print Distance

Low viscosity fluid

High speed ejection (7m/s)

1mm travel distance

Susceptible to surface imperfections etc

(Drops from a binary head deposited on a copper surface. Courtesy of Cambridge University Inkjet Research Centre (joint project))
Inkjet Systems for circuitry
Inkjet rapid prototyping

- Inkjet printed circuitry
  - Manufactured in minutes
- SMT placement
  - ~minutes to complete
  - Using conductive epoxy (not solder)
- Pictured design Included
  - Printed switch
  - Printed Battery
  - OLED

- Design to Manufactured Prototype Product in << one day.
Pixdro LP50 – Printing Etch Resist

- We design circuits...
- Therefore we need various revisions of PCB design
- Although we are based in a PCB facility we often use the LP50 for ultra quick turn printed etch resist
• Thin substrates (as thin as 12um) have been printed successfully.
• Make use of both surfaces: print on 2 sizes of material
Long & Large Area Electronics

- Conventional Circuits are limited in size by manufacturing formats
- Using digital system one can print “unlimited” length
- Sensors, cable printing etc

Highest Potential Areas for P.E.

- Very long (R2R) circuits
- Large Area
- Smart Integration
- Ultra Fine Features
- 3D
- Others...

Interconnection and Fan Out

Examples of applications for miniaturization

Chip-on-foil interconnect

Source: Tampere University
Device level interconnects

e.g.

Using digital printing to form “chip-scale” modules (or attachment)

I will say now that printing an equivalent to wirebonds is very challenging – so we focus here on other packaging areas.
Printing the interconnect onto the device

Printed Ag lines are 50um in width
Printed drop size is 1pl = line @ ~50um
Inkjet Nano Silver Ink
PragmatIC transistor device
So what is the downside to Inkjet?

- Printing acuity
- Accuracy
- Materials

- Drops are quite big (~50um)
- Viscosity and Surface Tension – capillary action
- The ink is mostly solvent actually...
Jet-printed Interconnects
Integration – *Package* to Flex

- **Use modular approach**
- Print large low cost substrates (P.E.)
  - Low density & complexity
  - High Yields
- **Attach small modules of high density circuitry for functionality**
  - Conventional electronics
- **Uses Pick and Place with e.g. conductive epoxy**

**Highest Potential Areas for P.E.**

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- Others…
Hybrid Device Integration

Printed EC Display

Screen Printed & Inkjet Traces

Dispenser – conductive adhesive
Interconnection - integration
Inkjet Scale vs “Silicon” scale

**Inkjet Scale**
- 50-150um printed lines are usual in inkjet circuits.

**Silicon edge interconnection**
- Connections to silicon are at micron scale
Super Ink Jet (SIJ)

Key Points:

- Sub-femtolitre drop size
- Electrostatic drop ejection
- Line widths of 1μm or less are possible

Figure 1 Standard Inkjet Droplet (left) and Super Inkjet Droplet (right) Size Comparison
SIJ Examples

Silver ink, L/S=1 μm

Circuit pattern

Microlens (resin ink)

Protein material (albumin)

Microbump
Diameter=5 μm, Height=20 μm

Micro QRcode (750 μm × 750 μm)
Fanout features (~10um)
Real time view of printing

On Si substrate, Silver Nanopaste,

Line pitch 15μm

Line pitch 15 μm
Vertical structures using super inkjet

Real time video
In air atmosphere, (no chamber)
At room temperature

PEL
**TSV structure**: tapered vias with bottom diameter of 10 μm, top diameter of 23 μm and depth of 36 μm.

**Research Level Work**

![Top View](image)

**Figure 8.** SEM picture from the vias completely filled by 3rd trial

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**Metallization of High Density TSVs using Super Inkjet Technology**
Behnam Khorramdel, Mika Matti Laurila, and Matti Mäntysalo
Tampere University of Technology
Department of Electronics and Communications Engineering

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3D interconnection
3D Inkjet System

PEL-developed proof of concept inkjet printing system for curved surfaces.
Embedded electronics – on a curved surface
Capability

- **What capabilities can printing technology offer today?**
  - Digital (e.g. inkjet) is strong but inks are still imperfect. New printhead systems overcome many problems - but not all.
  - Sometimes inkjet is not suitable (e.g. for finer features or thicker layers)
  - In this case other techniques are essential (Screen, Aerosol Jet, SIJ etc)
  - Lithography is still a big part of the picture.

- We need to work with hybrid interconnection
Reduce time to market

• *How to combine technologies from a system integration perspective, to rapid prototype applications and allow quicker customer trials and shorter time-to-market?*

  – Needs a creative approach on all sides.
  – E.g. We may need to persuade customers to accept a “different type of interconnect” from that which they are used to.
  – New techniques will push this e.g. combination of 3D printing and additive circuit printing.
Thank you