R2i - Connecting Research to Industry

Session 3
Chair: N. Rix

Speakers:

1. Ashayer: Smart Conductive Textile
2. Sugden: Functionalisation of Metal Nanoparticles to Enable Electroless Metal Deposition in Electronics Manufacturing
3. Liu
4. Glover: High emissivity micro-particles sensors enabling high-accuracy, point, thermal profiling
5. Ashworth: TIn whiskers research at Loughborough University
6. Lewis: Carbon nanotube (CNT) composite surfaces for electrical contact interfaces
Smart Conductive Textiles

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- Unique additive technique for interconnect on fabrics
- Highly conductive, antibacterial, robust and stretchable
Why?

Increasing demand for wearable electronics from industries such as:

- medical and healthcare
- sport and fitness
- consumer electronics
- defence applications
- fashion

*Global Industry Analysts* has predicted the US market to reach US$1.8 billion by the year 2015.

*Smithers Apex* are forecasting the Compounded Annual Growth rate (CAGR) of 30% 2016-21.
Potential Applications

- **Wearable sensors and antennas**
  - Assisted living
  - Environmental data capture and feedback

- **Health and emergency**
  - Physiological monitoring
  - Triage

- **Leisure and fashion**
  - Looks good!!!

- **Sports**
  - Performance monitoring

- **Medical applications**
  - Antibacterial (surgical masks, wound dressing)
NPL Smart Conductive Textile

- Unique wet chemistry additive technique, developed at NPL (patent applied for).
- 100% silver encapsulation of fibres (typical thickness = 20nm).
- Results in a robust, extremely flexible, conductive coating with good adhesion.
- As well as being conductive, it is antibacterial due to the presence of Ag.

Coated cotton fibres
Conductive fabric

- The copper plated thickness is 1.25µm.
- Resistivity is Very low ($\rho = 0.188\Omega/$sq)
Summary

- Unique smart conductive technique developed by NPL
- Further work required to develop include:
  - Patterning techniques
  - Long term ageing and conditioning trials
  - Demonstrators
- Looking for partners for collaborative research
  - TSB or EC proposals
  - Textile producers or end-users
  - Technology integrators
Functionalisation of Metal Nanoparticles to Enable Electroless Metal Deposition in Electronics Manufacturing

Mark Sugden, David Hutt, Changqing Liu - Loughborough University
John Graves, Andy Cobley – Coventry University
**Proposed Idea**

**Current Process**

Sn⁴⁺ shell

Pd NP  Pd NP

substrate

Electroless Cu

**Proposed Idea**

Stabilizing Ligand

Cu  Cu  Cu

substrate

Electroless Cu

Cu  Cu  Cu  Cu

substrate
Rationale

- Reduces the amount of precious metal usage
  - Copper is much cheaper and much more abundant
- Wide range of materials are being used as substrates
  - Introduces problems with coating adhesion
- Aim to improve adhesion with functionalised copper nanoparticles
  - Remove the need for extensive substrate pre-treatments such as chromic acid
Particle Dispersion

- Particles have been dispersed in isopropanol using ultrasound
  - Appear to have 2 populations
- Adsorption of various surfactants has been confirmed by XPS
Initial Plating Trials

- Copper nanoparticles are shown to be able to activate the electroless plating process
  - Particles dropped onto substrate
  - Peel tests suggest good adhesion
- Further tests are being carried out after dip coating of the particles
Potential Collaborations

- High volume supplier of smaller metallic nanoparticles.
  - Initial work has been carried out using 25 nm particles but adhesion/activity will be improved by working with 5-10 nm particles similar to current Pd catalyst.
- End users who wish to investigate metallisation of novel substrate materials

For more project details contact the lead investigators:

- Dr David Hutt (D.A.Hutt@lboro.ac.uk)
- Dr Andrew Cobley (A.J.Cobley@coventry.ac.uk)
Microelectronics for Healthcare and Industrial Applications

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Why integrated circuits?
low cost, low power, high integration, intelligence, enhanced reliability, system-on-a-chip, high SNR, negligible maintenance
Rapid advance of technologies (integrated circuits, telecommunication, micro-packaging, low-power design) paves the way to many new applications of miniature and intelligent medical devices, system-on-a-chip and lab-on-a-chip.

### Medical applications
- disease prevention, diagnostic, therapeutic

### Industrial applications
- Environment monitoring

With 8 partner hospitals:
- Great Ormond Street Hospital
- University College Hospital
- Moorfields Eye Hospital
- Eastman Dental Hospital
- ...

**Dept. of Electronic & Electrical Engineering**

**Analogue & Medical Electronics Group**

**Elektra 2012 WINNER**

**London Centre for Nanotechnology**
• Microelectronics for Healthcare

The US implantable medical devices market was worth $43.1 billion in 2011 and is expected to reach $73.9 billion in 2018.

Neuromuscular stimulators are used to restore lost or impaired neural functions.
- spinal stimulators → bladder control and leg movements
- vagus nerve stimulator → epilepsy
- deep brain stimulator → Parkinson
Chip implant developed to help the paralysed exercise

A tiny, implantable chip that delivers electrical impulses to aid in exercising paralysed limbs has been unveiled by scientists.
Microelectronic devices and sensors for patients (diagnostic, therapeutic) for well-beings (disease prevention, athletics)
## Medical devices

### Microelectronic sensors

### Opto-electronics using silicon technologies

<table>
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<th>Funding schemes</th>
<th>Notes</th>
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<td>Research councils</td>
<td>EPSRC, EU-FP7, etc</td>
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<td>Technology Strategy Board (TSB) and Knowledge Transfer Partnership (KTP)</td>
<td>Up to 60% of the cost is met by KTP</td>
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<td>Charities and NGOs</td>
<td>Wellcome Trust, etc</td>
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<tr>
<td>Engineering Doctor (EngD)</td>
<td>PhD with a solid industrial base</td>
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| UCL-Cambridge Doctor Training Center (DTC)           | Call for mini-projects on photonic system and opto-electronics
                                    | Possibly a 3-year PhD project afterwards (funded by DTC!)             |
| Impact Studentship                                   | UCL makes 50% contribution                                            |
| Industrial Case Studentship                          | Company contributes one third of the fund, approximately £10,000 annum.|

Contact Dr Xiao Liu at [xiao@ucl.ac.uk](mailto:xiao@ucl.ac.uk)
High emissivity micro-particles sensors enabling high accuracy, point, thermal profiling

J. Glover, M. Maricar, and C. H. Oxley

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Thermal profile of GaN heater structure using conventional infrared (IR) measurement
Thermal profile of GaN heater structure with high emissivity coating

- Coating causes heat spreading
- Coating can not be easily removed from devices and may cause damage to the device
Thermal profile of GaN heater structure using micro-particle sensor

- Micro-particle sensors minimise heat spreading
- Can easily be removed from the device leaving it undamaged
- Resolution of the technique is determined by the optical resolution of the microscope
Planar gallium arsenide (GaAs) based Gunn devices supplied by the University of Glasgow
TIN WHISKERS RESEARCH
at
Loughborough University

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- WHISKERMIT - Manufacturing and In-Service Tin Whisker Mitigation Strategies for High Value Electronics
- Development of conformal coatings optimised for whisker mitigation
Introduction to Tin Whiskers

**Environmental legislation:**
EU RoHS directive prohibiting use of Pb, pure tin often the first finish to replace Sn-Pb

**Miniaturation in electronics**
- Whiskers can bridge components and tracks

**Lower voltages**
- Whiskers can sustain currents

**Environment**
- Electronics performing under harsher environments

C.Minter, DMSMS Conf., Charlotte, USA, 10-13th July 2006.
WHISKERMIT Research Programme

Modification of the Electroplating Process

- Process variables
- Pulse plating
- Incorporation of particulates

Conformal Coatings to retard whisker growth

- Commercial coatings
- Development of model coatings

In-depth understanding of the relationship between process parameters, deposit structure and subsequent whisker growth

Commercial and model conformal coatings evaluated

Insight into whisker/coating interactions
Although the electroplating process may be optimised to reduce whisker growth; it is not possible to eliminate it completely.

Current commercially available conformal coatings do not provide adequate levels of protection from long term whisker growth.

The development of new conformal coating materials is required whose properties are specifically optimised to prevent whisker growth.
We would like to invite partners to collaborate with us in a project whose aim is to develop new conformal coating materials with properties optimised to resist whisker growth.

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Carbon nanotube (CNT) composite surfaces for electrical contact interfaces

Adam P. Lewis, J. W. McBride, S. M. Spearing, L. Jiang, C. Chianrathabutra and M. P. Down
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- Novel CNT-composite surface for electrical contacts
- MEMS switch with lifetime >10^8 cycles (load current: >10 mA; load voltage: 4 V)

This work is supported by the IeMRC and EPSRC under grant number: EP/H03014X/1.
• **Problem:** Contact failure of metal-contacting micro-electromechanical system (MEMS) switches
  – Every cycle the contacts are physically brought together and pulled apart – resulting in contact wear → failure

• **Proposed solution:** CNT-composite surfaces
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WHY MEMS SWITCHES?
- Low contact resistance and power consumption
- Off-state: zero/low current leakage
- MEMS technology → batch fabrication → low cost

RF Performance
- Off-state: high isolation
- On-state: low insertion loss
- Improved frequency performance over alternative technologies (e.g., PIN diodes and FETs)
- Example applications:
  - switched antenna applications
  - switched filter banks
  - phase-shifters for multi-beam satellite communication
• **Key results:**
  
  – Controlled fabrication of Au-MWCNT composites
    
    • 10 – 50 µm height
  
  – Demonstrated >180,000,000 cycles
    
    • Load: 4 V, 50 mA, 1 mN
  
  – Fabricated MEMS cantilever beam switch:
    
    • investigate failure mechanisms
    
    • demonstrate advantage of using MWCNT-composites
  
  – Rig designed to investigate real contact area
Fine transfer model and experimental data for lifecycles of stable stage. Arrows link to SEM images of failed surface.

Fine transfer model:

$$\Delta V_{\text{fine}} = 4.78 \times 10^{-11} I^2$$
• **Current status of research:**
  – Investigated effect of load current on contact lifetime
  – Evaluated the wear evolution process over contact lifetime
  – Initiated testing with:
    • MEMS-cantilever switch
    • Real-contact area rig

![Graph showing contact resistance and contact lifetime](attachment:image.png)

**Bouncing behaviour during closing process in ‘rising’ stage**
• **On-going research:**
  – MEMS switch testing with Au/MWCNT composites
  – Modelling the failure mechanisms
    • Further the understanding and aid design optimisation
  – MEMS switch redesign:
    • Address specific applications

• Come see our poster to discuss further...
Thank you for your attention
Any Questions?

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