Printable Electronics at the Cambridge Integrated Knowledge Centre

UK Plastic Electronics Showcase, 3rd September 2009

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UNIVERSITY OF CAMBRIDGE
800 YEARS
1209 ~ 2009

CIKC CAMBRIDGE INTEGRATED KNOWLEDGE CENTRE
Advanced Manufacturing Technologies for Photonics and Electronics – Exploiting Molecular and Macromolecular Materials

What is an IKC?

- EPSRC vehicle to accelerate and promote business exploitation of an emerging research and technology field.
- Five years' funding
- Integrates
  - Skilled professionals from both academia and business
  - Researchers
  - Potential customers
  - Shared space
  - Entrepreneurial environment

CIKC Operating Model

Defined Technology Scope

Technology Platforms

Business Support

Technology Scope

- We are on the brink of a manufacturing revolution for photonic and electronic devices
  - Photovoltaics
  - Displays
  - Lighting
  - Smart Packaging
  - Smart Windows
  - RFID

Manufacturing Revolution

- Low temperature processing
  - Low-temperature substrates (paper and plastic)
  - Reduced energy consumption
- Additive processing
  - Reduced waste
  - Simpler processes
- Atmospheric pressure processes
  - Reduced energy consumption
- Continuous web-fed processes
- Low capex plant
  - Printing presses
  - Inkjet

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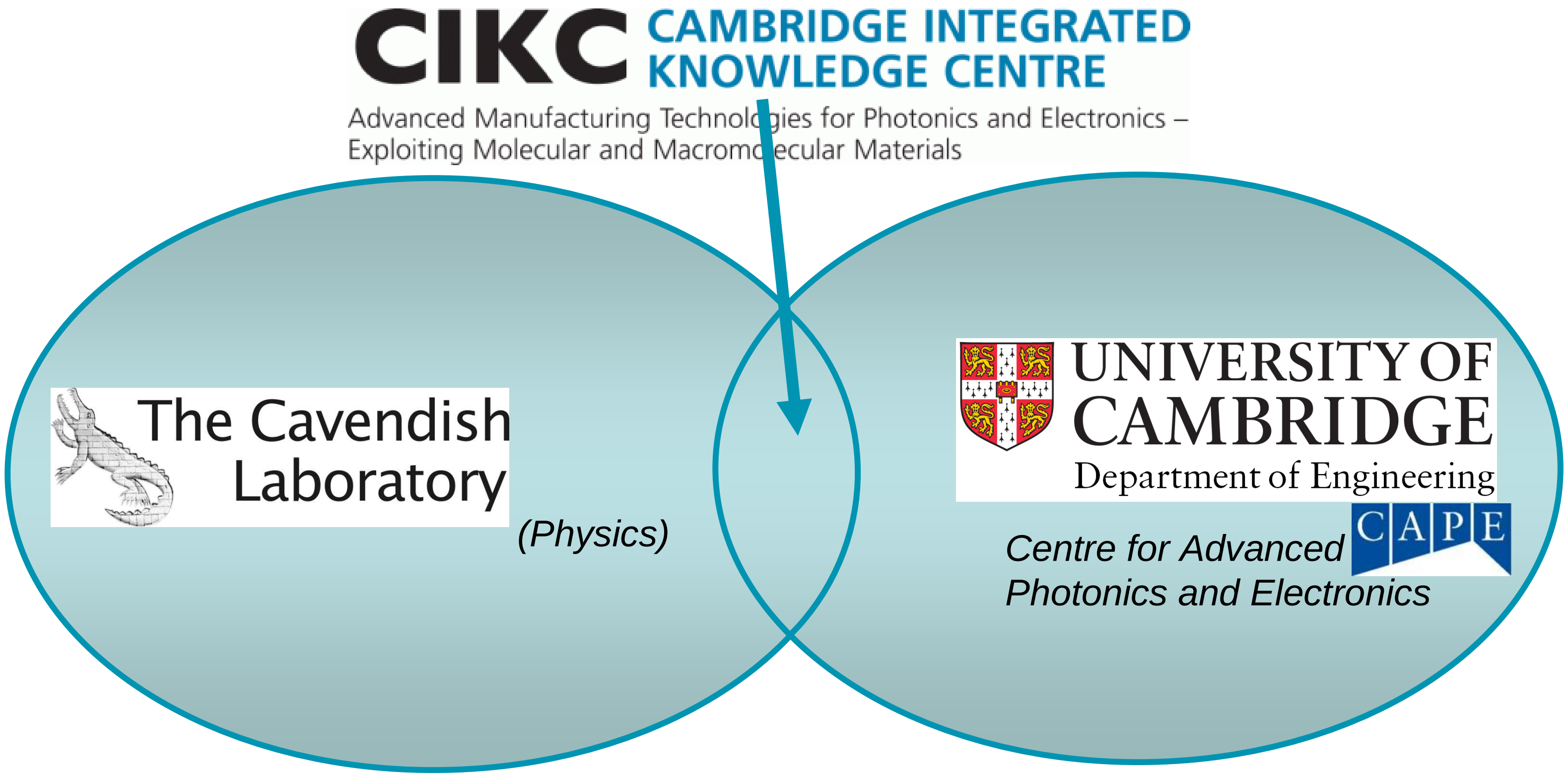
Enablers

- New printable/coatable functional materials
- New device architectures
- New manufacturing processes

Technology Scope

- CIKC Themes
  - Plastic (opto-)electronics:
    - flexible displays/electronics and
    - distributed electronics on rigid substrates at a “low” temperature budget
  - Augmented or additive processing on active substrates (e.g. LCoS)



Exploitation Approach

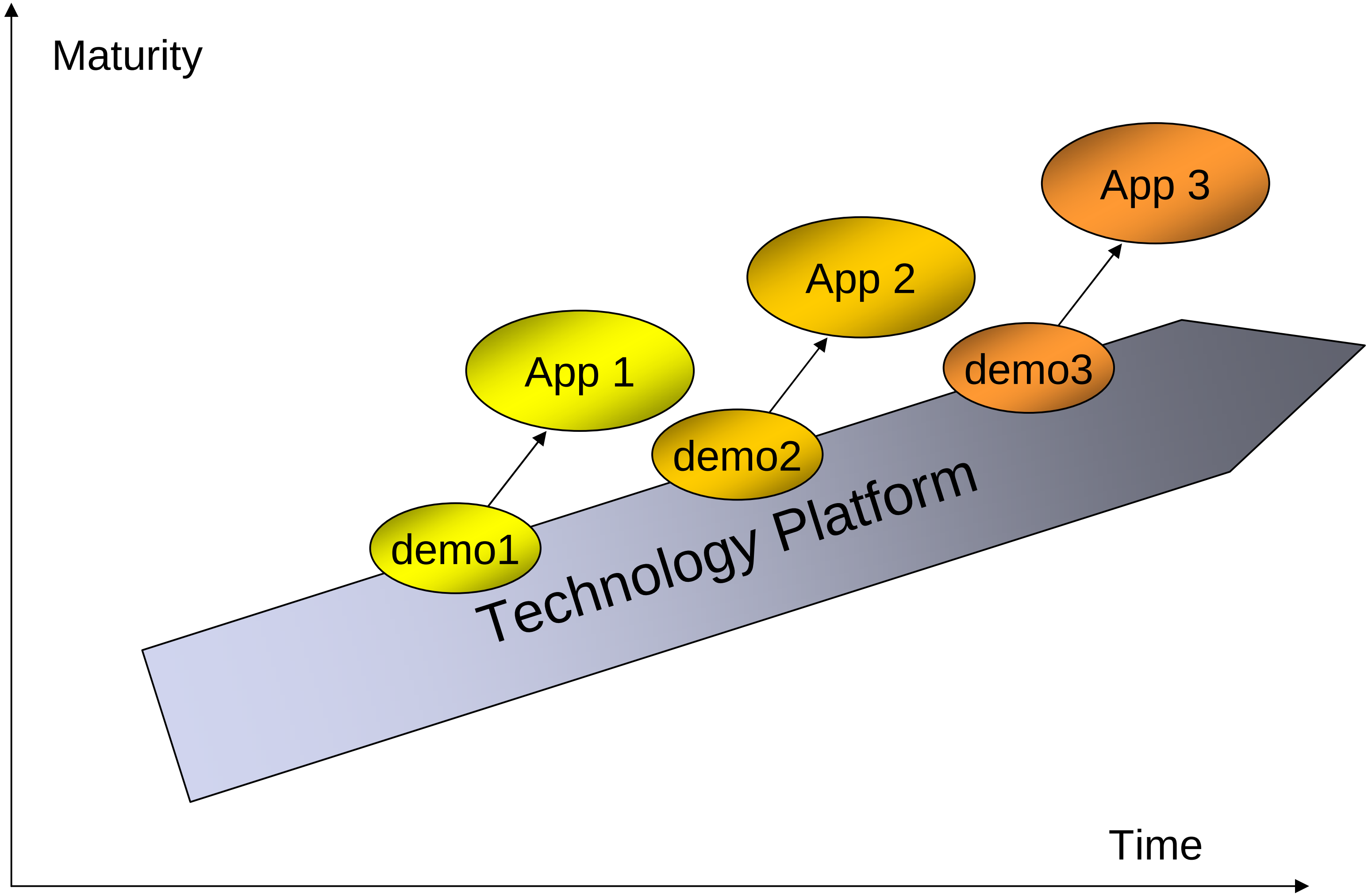
- Business support for technical teams
- Commercialisation Research
- Partnership with industry
- Open exploitation model based on technology platforms

CAMBRIDGE Judge Business School

Institute for Manufacturing

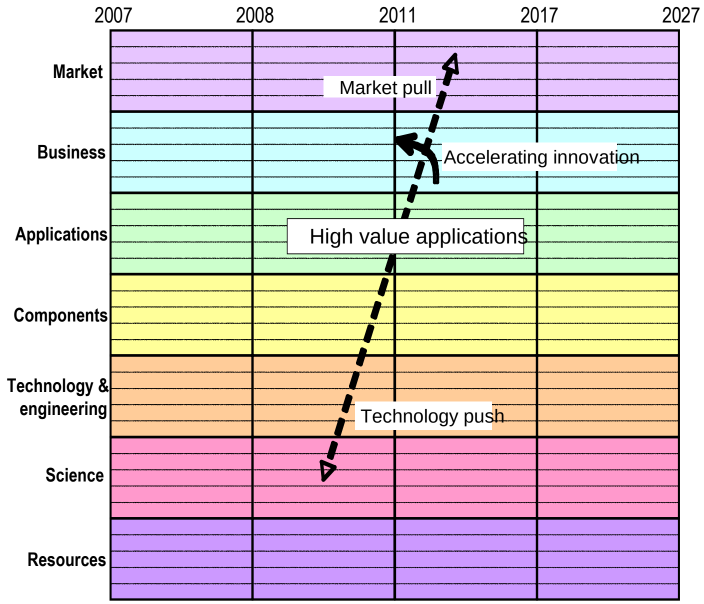
Centre for Business Research

Exploitation Approach



Commercialisation Support Tools

- Roadmapping
  - Opportunity exploration
  - Programme alignment
  - Communication (internal & external)
  - Community and network building



5 Year Plan

- Phase 1
  - Infrastructure acquisition and commissioning
- Phase 2
  - Establish project portfolio
  - Demonstrate technical feasibility
- Phase 3
  - Develop project portfolio
  - Pre-prototype demonstrators
  - Exploitation focus
  - Develop a sustainable operations model for CIKC

Currently here

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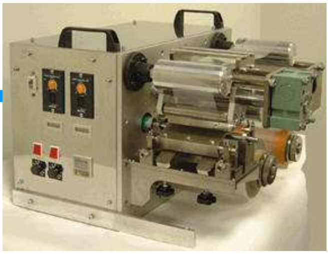
Phase 1 - Infrastructure

Infrastructure acquired for

- printing organic electronic devices,
- LCOS prototype fabrication
- low temperature deposition of transparent conducting oxides
- LC displays on plastic substrates

Litrex 120L high resolution ink jet printer for oTFT fabrication



Yasui Seiki Microgravure Coater for printing polymer films for PV

Hot melt coaters and laminators for LC on plastic

Kadett SemiAutomatic Device Bonder

Plasma Quest HiTUS sputter deposition of TCO at low temperature

Pegasus S200 Semi-Automatic Prober to test FET arrays

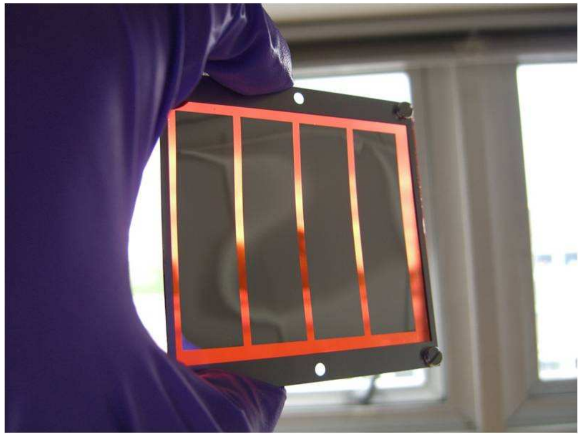
Wyko NT1100 3D optical profiling system

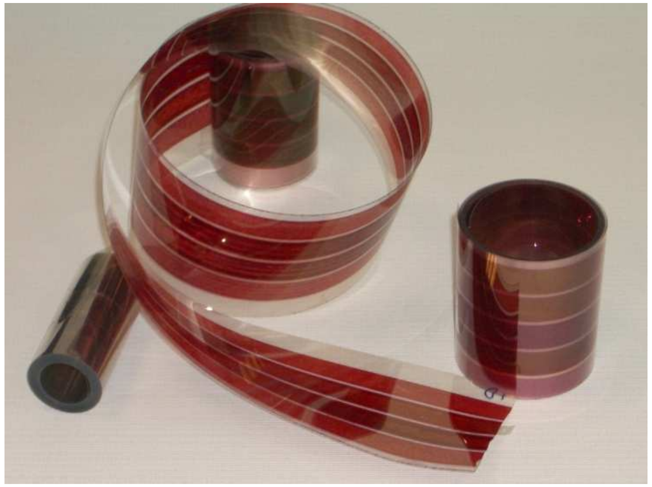
Phase 2 – Establish Project Portfolio

Project	Topic	Partners	Objective
3PV	**OPV**	Carbon Trust, TTP	Development of process tehcnology for the manufacture of organic photovoltaic (OPV) devices by printing onto flexible substrates
PRIME	**OTFT**	Plastic Logic, Merck, Dupont Teijin Films	Development of scalable printing-based manufacturing processes for polymer transistor circuits
ROOT	**OTFT**	Hitachi	Understanding the causes of operational degradation in organic TFTs (OTFT)
HiPZOT	**iTFT / TCO**	CAPE Partners, Plasmaquest	Low temperature deposition of transparent conductors (TCO) and inorganic TFTs (iTFT) on flexible substrates
PASSBACK	**LCoS Display & Optical Switching**	ALPS Electric	Liquid crystal on silicon (LCoS) devices for phase-only holography for applications in video projection and telecommunications
PLACORD	**Reflective Display**	Advex, Dow Corning	Large area colour displays using Smectic A liquid crystal on plastic substrates
PIES	**Optical data transmission**	Dow Corning, Avago, Tyco	Environmentally stable low-cost polymer interconnects for optical data transmission on PC boards

Printed Polymer Photovoltaics (3PV)

- Target: Low-cost organic solar cells for consumer, building-integrated and solar farm applications
- Background: Extensive work on polymer materials and device development at Cavendish Laboratory
- Aim: To develop roll-to-roll printing processes for organic photovoltaic devices
- Progress: Team in place; roll-to-roll coating established; demonstrated 5% efficient cells on glass; first printed modules being tested.



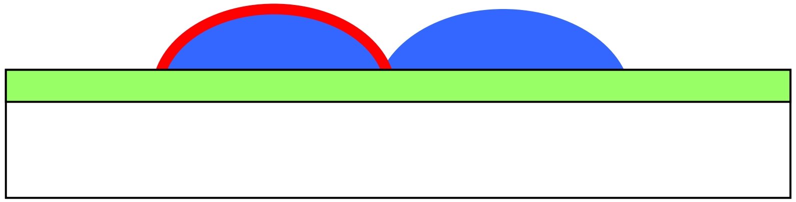


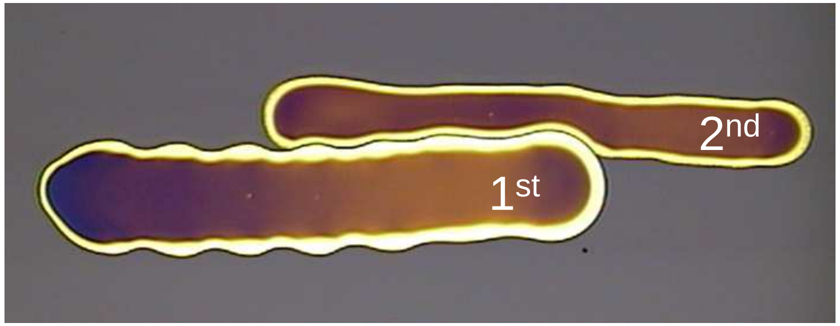
3PV Context and Commercialisation Plans

Advanced Photovoltaics Research Accelerator

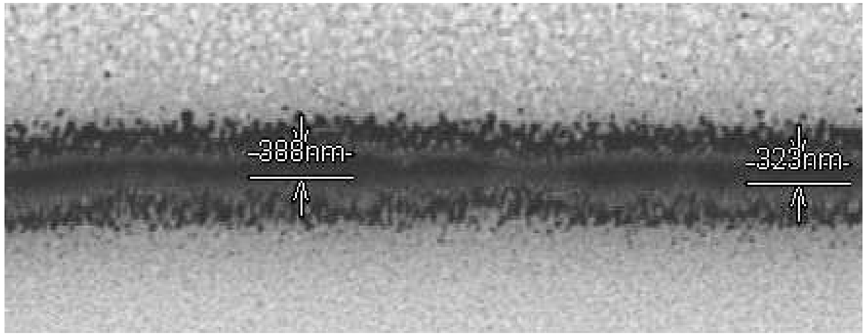
- Up to £5m Carbon Trust Funding over 3 years
- Initial £1m development phase inside the University, alongside 3PV funding
- Current total team of 4 scientists/engineers, with significant industrial experience
- Aim to spin-out commercial company Q1 2010
- Commercial aims: to manufacture efficient, stable organic PV modules
- Accelerate transition of University materials and device developments into manufacturing

Self-aligned printing



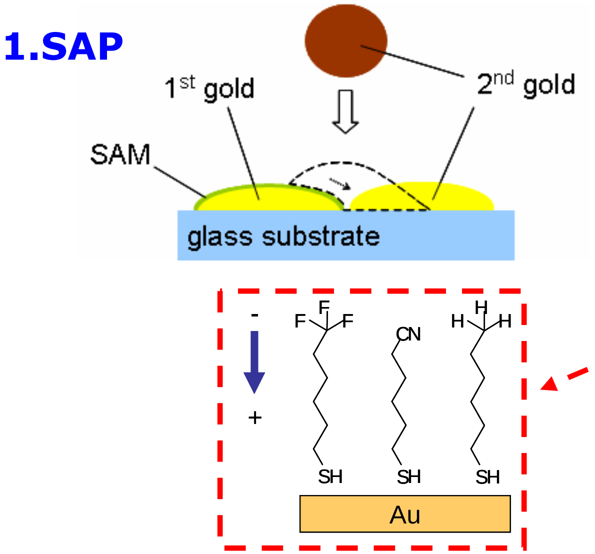


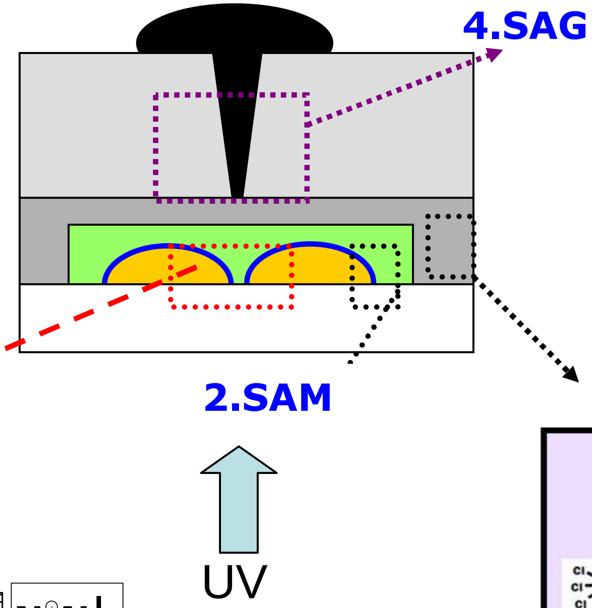
C. W. Sele, et al., Adv. Mat. 17, 997 (2005)

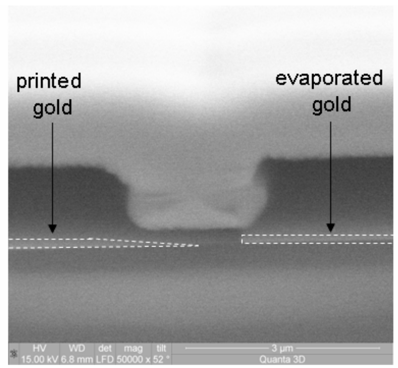


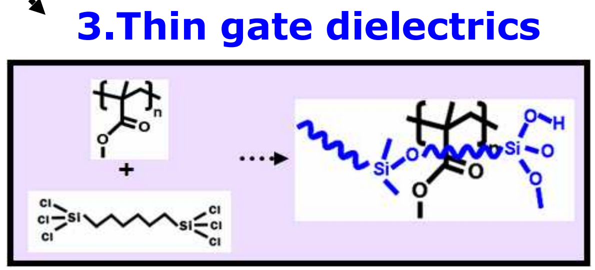
- No lithographic step required, no need for substrate prepatterning
- Feature size 50 – 400 nm
- Can be used to define source-drain electrode of FET
- Demonstrated with conducting polymer (conductivity 1S/cm) and gold nanoparticle ink (10000 S/cm)

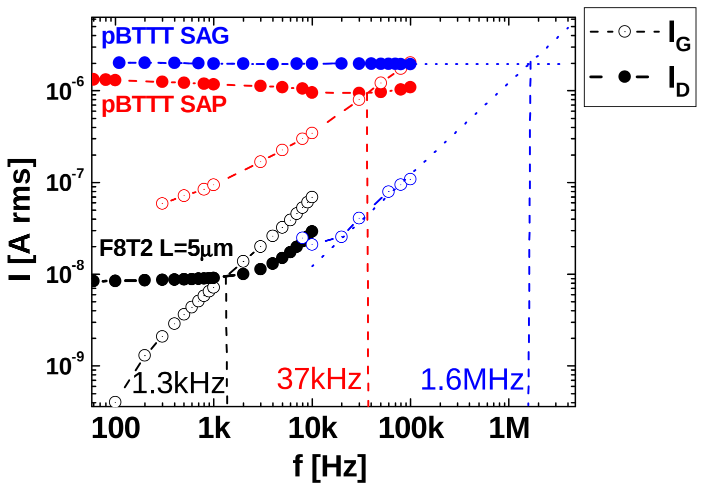
Performance enhancement by downscaling











- Channel length L =200-400 nm; Self-aligned gate with parasitic capacitance 0.3-0.6 pF/mm
- Operation below 5V
- Transition frequency > 1MHz

Noh, et al., Nature Nanotechnology 2 (2007) 784

HiPZOT - High Performance Zinc Oxide TFTs

- ZnO TFT mobility > 10 $cm^2 V^{-1}$ s-1
- Transparent
- RF magnetron sputter deposition:

✓ Very easy growth technique

✓ Easy to optimise

✓ Low cost, established technology

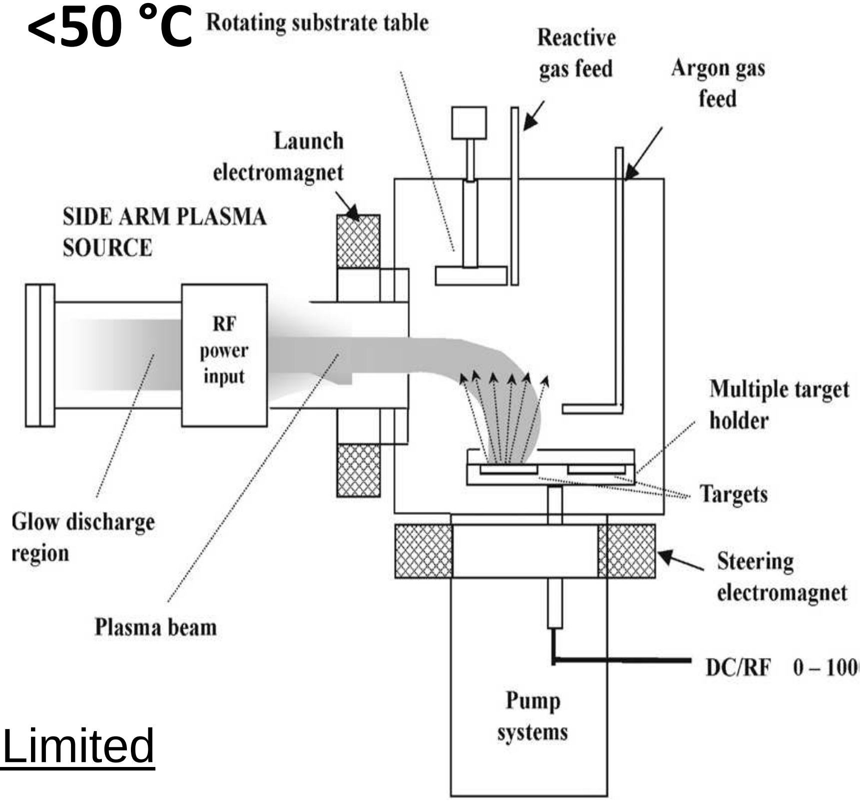
× Ion energy is dependent on RF power

  → low deposition rate

× Samples are also exposed to the ion bombardment plasma

  → processing temperature ~200 ℃

- **HiTUS remote plasma sputtering allows deposition of high quality, low stress materials at <50 °C**

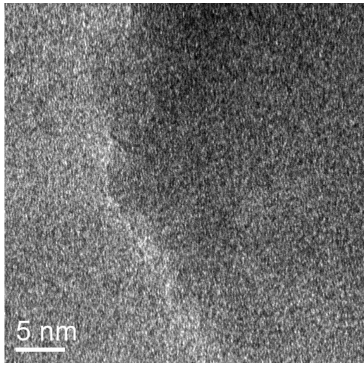


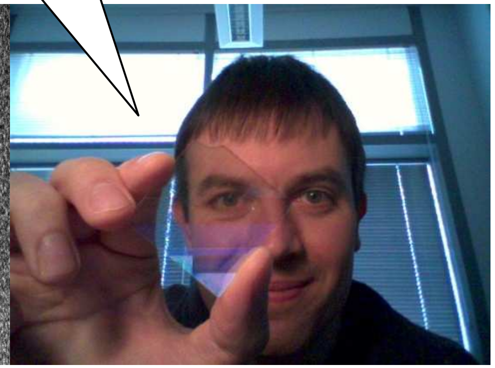
PlasmaQuest Limited

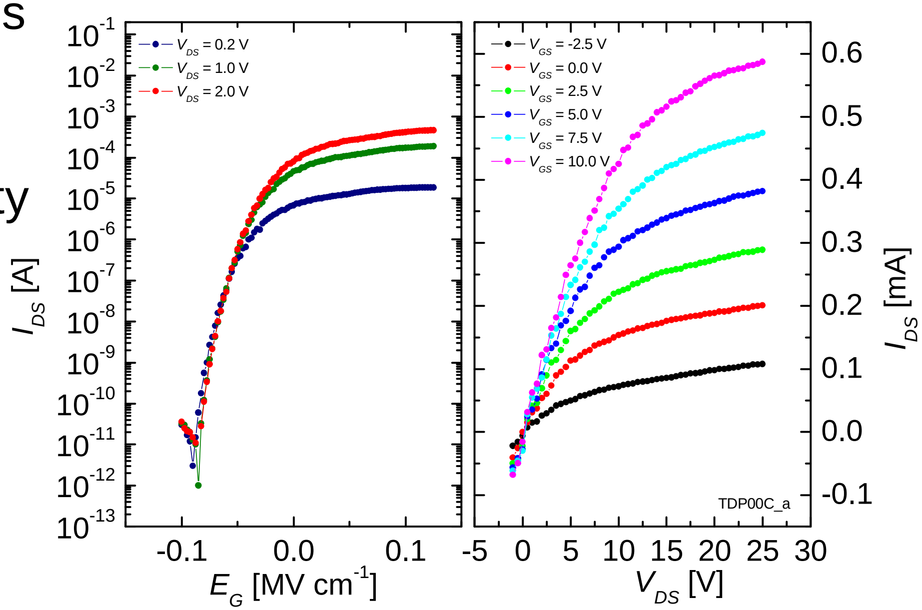
HiPZOT: Results

- Deposition of a range of metal oxide materials demonstrated without intentional substrate heating
  - Indium zinc oxide n-type semiconductor with mobility >10 $cm^2\ V^{-1}\ s^{-1}$
  - Hafnium oxide dielectric with amorphous structure, resistivity > $10^{14}\ \Omega$ cm and $\varepsilon_r = 30$
  - Aluminium oxide dielectric with resistivity > $10^{14}\ \Omega$ cm
- High performance TFTs with high mobility and optical transparency
- A TSB funded project spun off
- Two more project grant applications awaiting responses

Note the transparency!

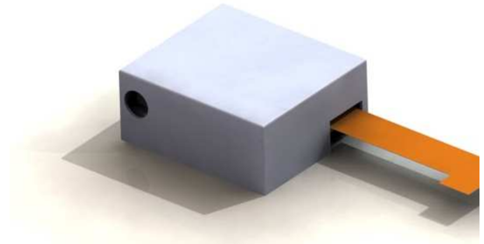






Liquid Crystal on Silicon (LCOS) - *PASSBACK*

- Target: prototype LCOS devices for
  - *holographic projection systems*
  - *add-drop multiplexers*
  - *lab-on-chip devices able to manipulate biological entities.*
- Aim:
  - To develop in-house LCOS prototype device fabrication processes for high-spec LCOS devices
  - To build prototype devices for various applications
- Progress so far:
  - Successfully commissioned a 20 step semi-automatic LCOS prototyping process
  - Phase-only holographic projection engine prototype built and tested in collaboration with commercial partner, ALPS



- 32 phase levels
- Field sequential colour
- 60Hz frame rate
- 720x720 pixel hologram
- 1920x1080 pixels displayed

ALPS

ALPS ELECTRIC CO., LTD.

PLACORD (Plastic Large Area Colour Reflective Displays)

Reflective displays based on Smectic A liquid crystal

- Bistable
- Greyscale response.
- Bright white state > 50%.
- Reflective contrast > 7:1
- Clear state – so stackable
- Very large arrays of pixels can be multiplexed with no pixel circuitry.

A: At room ambient condition B: Under high power lamp luminance

Figure 3-58: Pictures of monochromatic demo at different luminance conditions

Target Application:

large area reflective colour LC displays on plastic substrates

Project Aims:

•Set up a state-of-the-art laboratory for making plastic encapsulated devices.

•To develop and test liquid crystal guest-host materials for e-posters.

•To make a composite tile involving three stacked layers of single colour sub-tiles.

ADVEX

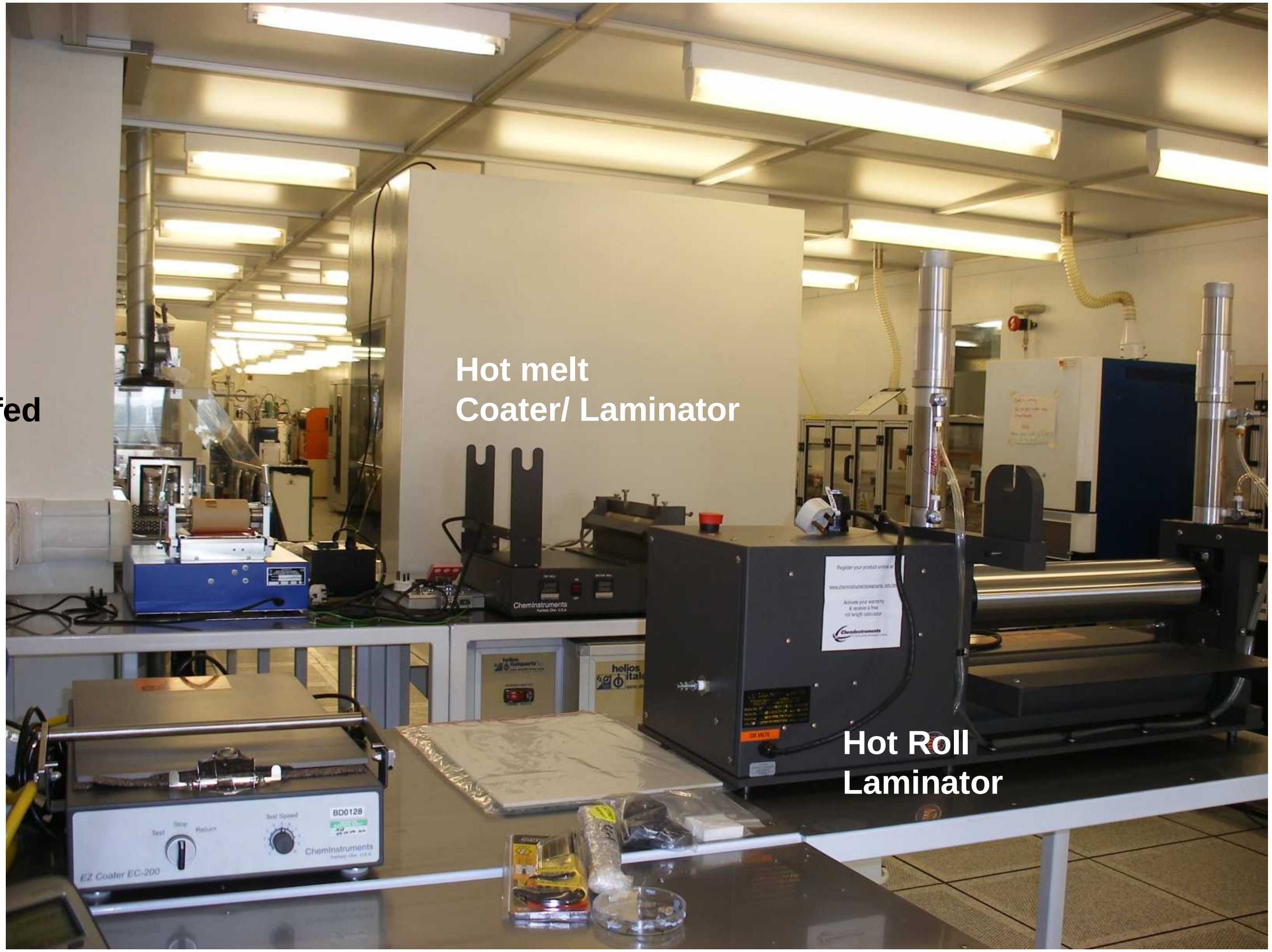
DISTEC BASIC

Out-of-Home Media Products · Digital Media · Scrollers · Street Furniture & More

DOW CORNING

Laminated Electro-active Foil Laboratory

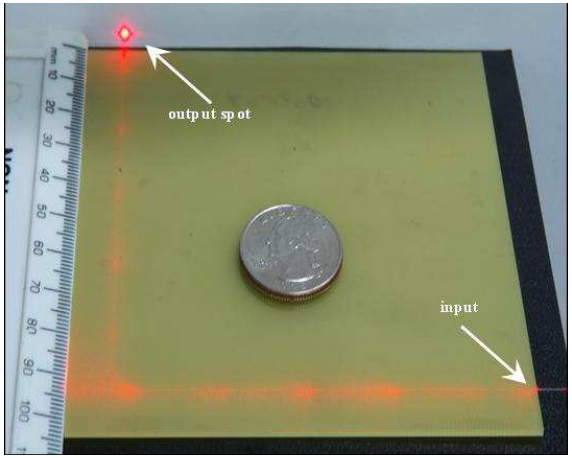
RK Sheet fed Laminator



EZ sheet coater

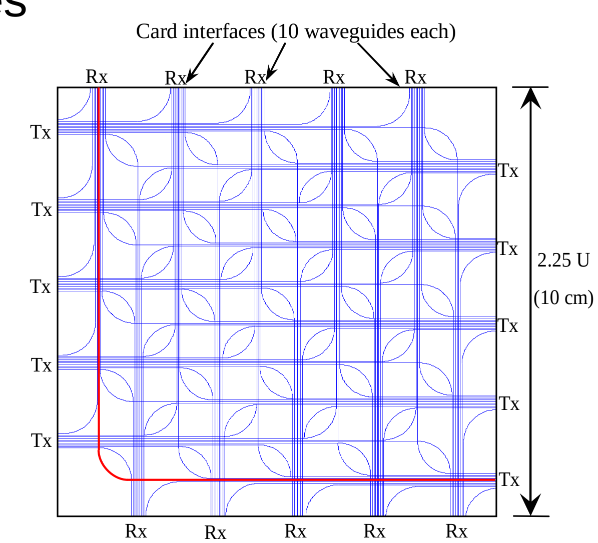
Polymer Waveguides for On-board Optical Interconnects (PIES)

- Superfast interchip communication
- Integrated manufacturing approach
- Issues
  - Insertion/Crossover losses
  - Crosstalk
  - Environmental stability
  - Mechanical attachment of VCSEL/Photodiodes
  - Active optical switching



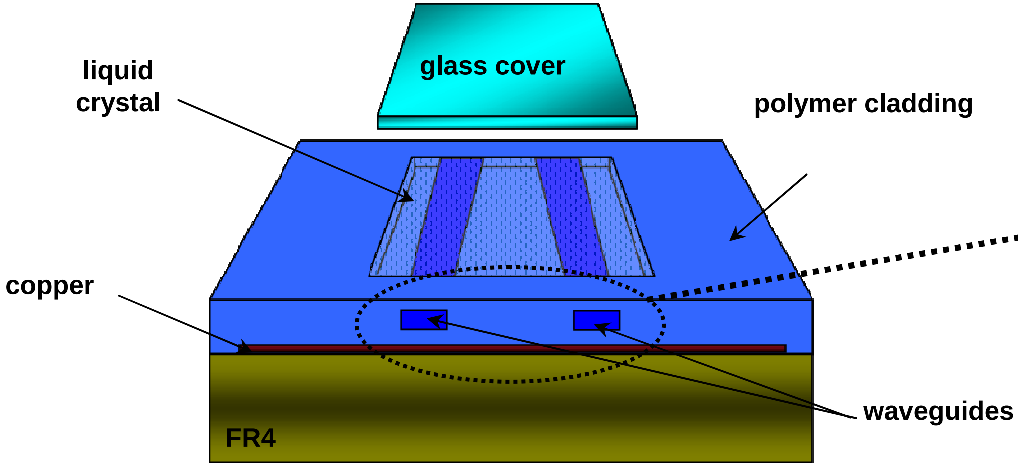
Terabit backplane demonstrator
100 10Gb/s waveguides
single 90° bend per waveguide
90 crossings or less per waveguide

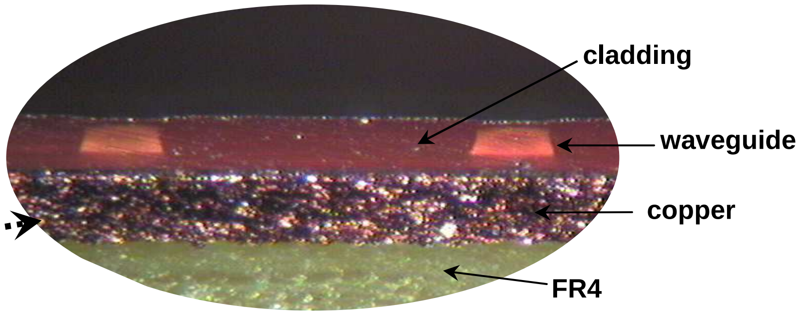
Input Type	Insertion Loss	Worst-case Crosstalk
50 μm MMF	2 to 8 dB	< -35 dB
SMF	1 to 4 dB	< -45 dB

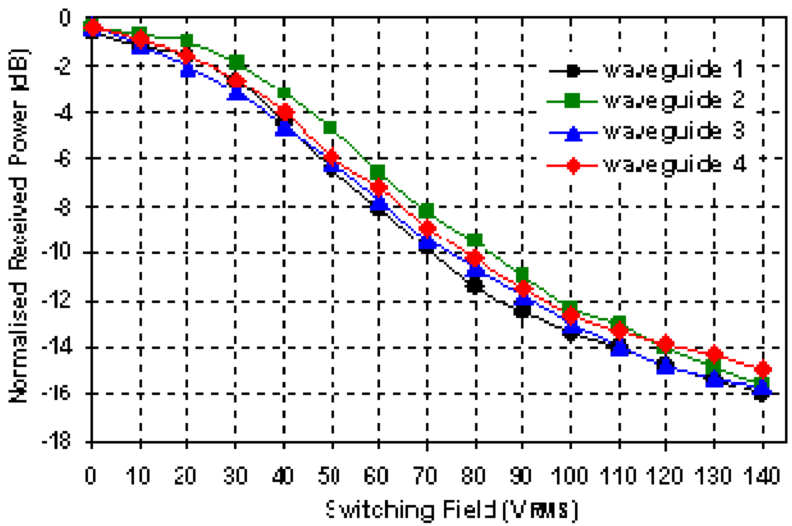


Schematic of 10-card backplane layout

Integrated LC/Polymer Switch on FR4 PCB



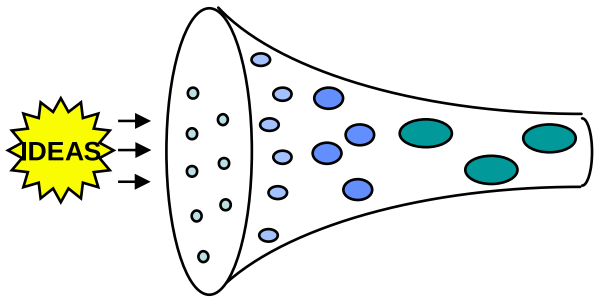




- 850nm operating λ(though easily varied)
- 0.5dB excess loss and 15 dB switching
- Excellent repeatability ~0.5dB across 4 waveguides

Beals et al., submitted to CLEO'09

Populating the research pipeline



- Small Grants Scheme
  - Small scale (£20k) short projects
  - Feasibility Studies - seed funding to allow radical ideas to be explored.
  - Collaborative projects (academic or industrial), e.g. use of CIKC infrastructure, facilities or services
- Examples of small grant topics
  - Direct laser writing of polymer waveguides using fs lasers
  - Characterisation of novel light activated colour switch materials
  - Process development for PDLC on plastic
  - Nanoscale switches in IZO
  - Novel patterning process for TCO microstructures
  - Graphene spintronics
  - Carbon nanowire TFTs
  - R2R transparent electrode process for anodes for OPV
  - Best practice for accelerating business development of CIKC projects
- Further funding for small grants during next 2 years

CIKC as a National Centre

- Part of UK's National Infrastructure for Plastic and Printable Electronics
- Memorandum of Understanding recently signed between 4 centres

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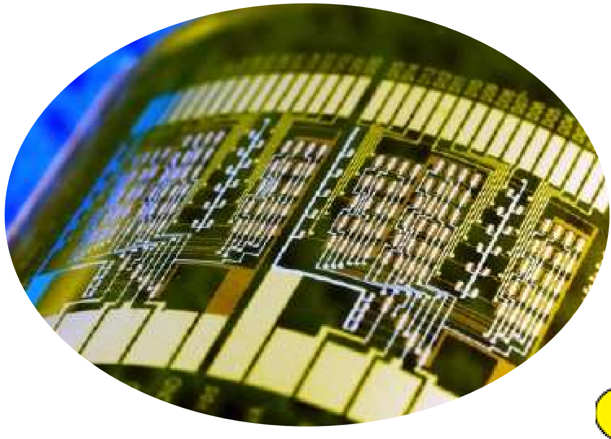
Advanced Manufacturing Technologies for Photonics and Electronics –
Exploiting Molecular and Macromolecular Materials

omic Organic Materials Innovation Centre

ORGANIC MATERIALS INNOVATION CENTRE



petec ...the future inspired

PRINTED ELECTRONICS TECHNOLOGY CENTRE

Welsh Centre for Printing and Coating
WCPC
Canolfan Argraffu a Chaenu Cymru

WELSH CENTRE for PRINTING and COATING

CIKC Successes

- New infrastructure for device prototyping commissioned
- Primary project portfolio established
  – 7 projects
  – Many large market opportunities being addressed
- Strong partnership with industry
  – Met 5 year target for matching funding after 2.5 years
  – 15 companies actively participating in projects
- Exploring multiple exploitation paths
  – PV start-up is in the advanced planning stage
  – Another start-up is in the early discussion stage
- Commercialisation support for technology teams
  – JBS (Judge Business School)
  – CBR (Centre for Business Research)
  – IfM (Institute for Manufacturing)
- Small grants scheme
  – 13 projects approved

CAMBRIDGE Judge Business School

IfM

CBR

Ways to work with CIKC

- Participation in "Phase 3 Projects"
- Participation in a Small Grants Project
  - Small scale (£20k) short projects
  - Feasibility Studies - seed funding to allow radical ideas to be explored.
  - Small Scale Collaborative Projects with external partners (academic or industrial), e.g. use of CIKC infrastructure, facilities or services
- Participation in commercialisation research projects
- Student projects (MBA, Engineering, M Phil projects in tech mgmt)
- Use of CIKC equipment under Open Access arrangements
- Training opportunities
- CIKC Events – open day, roadmapping workshops, etc

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