

The New Printed Electronics of the 21st Century

A personal view by Neil Kirby
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Agenda

- Historical Origins
- Flares & long hair
- Space 1999 & beyond
- The RFID bubble
- Printed electronics accepts a mission
- Overview & Future
 - The future is not set...

Historical Origins

- First patent circuit consisted of cut metal foil adhesively bonded to paraffin coated paper – Albert Hanson of Berlin in 1903
- Paper painted adhesive with graphite suggest by Edison to his friend Frank Sprague in 1904
- Materials were not robust enough for applications of the time
- However, the principle is not so different from the new Printed Electronics today

Flares & long hair

- Ceramic circuits used in aerospace applications
- Later used in automotive applications
- These process are still used today
- processes used where sintering of inks resulted in removal of the organics by heating to 850C
- These inks were applied using a printing process (stencil printing)
- Used to make gold circuits

Flares & long hair

- Later used to make resistors which could later be trimmed using lasers
- Silver inks were also used
- Then inks used in polymer blends where the solvent was removed but not the polymer
- Polymer held the metal particles in place
- Curing temperatures reduced to 180C
- Carbon used on potentiometers

Flares & long hair

- Silver inks had cure temperatures lowered to 140C allowing use of low temperature substrates such as Polyester (PET).
- Low cost robust lightweight switches with traditional graphical interface
- Sir Clive Sinclair & the ZX80 launched a revolution in home computing/gaming
- Membrane switch industry utilised this technology - & was/is particularly successful in computer keyboards – even in UK in 1998

Space 1999 & beyond...

- Screen printing being used for a range of different products e.g.
- Keyboards for computers & printers
- Mobile phone keypads
- Electroluminescent displays
- Remote control units for TV, Video
- Calculators
- Disposable medical patches & pads
- Then along came RFID ... & we got really excited...

RFID – Radio Frequency IDentification

- Already in use in 125kHz applications:
- Car key immobilizers & remote locking
- Malaysian passport appeared 1995
- Contactless cards for building entry
- Mining industry
- Tagging of fish & other wildlife ... including...
- Presidents of the USA(?)

RFID – Radio Frequency IDentification

- Interest in 13.56MHz applications
- Philips – iCode, for sale to industry
- Texas in house only
- One size to fit all !!! (Claim)
- After a few examples appeared this was soon shown not to be the case
- Nearly every new application had different requirements resulting in a different tag (antenna) design!
- Different chips had different electrical requirements, usually associated with capacitance of the chip (on & off)
- Water, curved surfaces & metals became the challenges of the designers
- What generated the excitement ... airport baggage tags

RFID – Radio Frequency IDentification

- Back to basics & the basics were for the physics of solid metals
- Market predictions were huge
- Always that Airport passenger figure floated out as the big juicy carrot!
- Everyone seemed to be after the same carrot!
- Heathrow: 1 million pieces of luggage a day
- Replacement of the bar-code

RFID – Radio Frequency IDentification

- The 1 penny (cent) tag
- With a 50 pence (cent) chip???!!!
- Reality & Marketing (yes a big gap!)
- Flurry of activity by chip manufacturers
- Conferences
- The numbers of applications is huge & growing ... just think of the barcode ... its everywhere ... this was/is the thought process

RFID – Radio Frequency IDentification

- How do we lower the cost of the tag?
- Printing it like the bar-code seems like a good idea!
- First printed antenna were produced
- Poly-Flex Circuits first printed antenna for iCode in 1999
- Connecting to the RFID chip challenging
- Frequency changes – due to problems with metals & water (& paper)
- 850MHz 915MHz – dipole antenna designs
- More difficult antenna design – more specialist
- 2.45 GHz also used – use allowed in some countries
- Standards start to appear ISO Cards

RFID – Radio Frequency IDentification

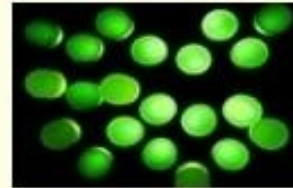
- How do we lower the cost of the tag?
- Dipole antennas easier to print
- 2.45GHz antenna not far from the mobile phone antenna at 3.1GHz
- Printing of antenna
- Printing of chips???
- Printed Electronics now had/has a mission ...

Printed Electronics accepts mission

- Mission impossible? Mission improbable? Or more correctly “Mission not accomplished ... yet!”
- 1 cent tag with chip?
- Printed antenna?
- Printed RFID Chip?
- So the huge volumes being predicted for the RFID industry started people thinking about how to make these in high volume, at low cost & quickly ... printing ... like the bar code!!!
- Other electronic applications began to be investigated ... materials were & are the key factors then & today & for the future
- Once the materials are there then the applications bloom...

Printed Electronic Materials

- Inks
 - Organic & inorganic
 - Dielectrics
 - Semi-conductors
- Substrates
 - Glass, plastics, metals, papers
- Environmental issues
 - Moisture,
 - Humidity & oxygen,
 - mechanical robustness, toxicity
- Manufacturing processes
 - Screen print, gravure, inkjet, others...
- Cost
 - cost, cost ... & cost



Printed Electronics Applications

- Displays
- Lighting & Signs
- RFID, Security & Smart Packaging
- Sensors
- Batteries & Photovoltaics)
- Transistors, LEDs & ICs

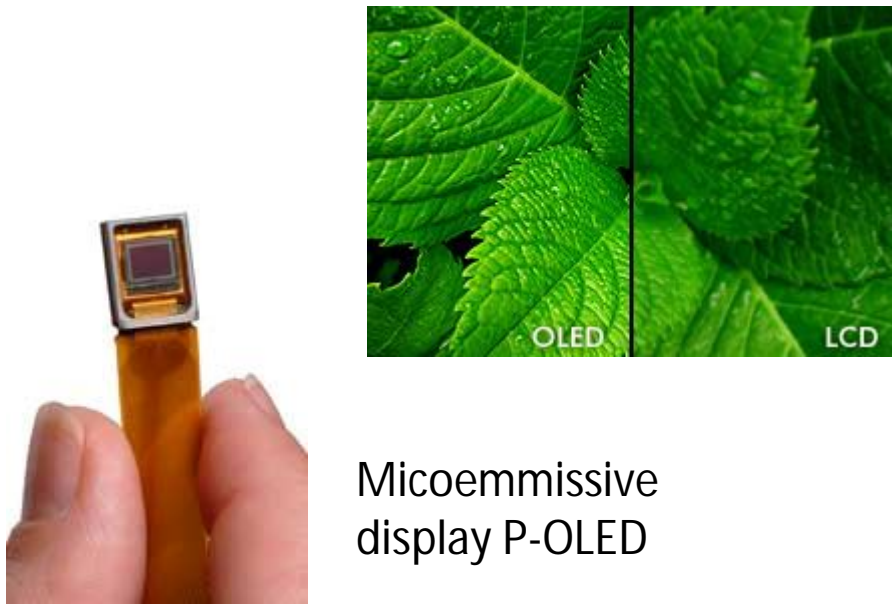
Displays

- Back in 1992 CDT was formed to promote the use of P-OLEDs
- This technology has now been used in mobile phones, MP3 players & now TV screens
- Materials are sensitive to moisture so this has to be kept out & the materials improved
- Other colour display technologies from Epson
- B&W displays from e-ink & others which use capsules or powder - electrophoretic

Displays

- Coloured displays more complicated from materials, design & manufacturing standpoint
- Big displays more expensive cf LCD technology
- Products: mobile phones, & TVs
- Lower power, brighter, better viewing angle
- B&W displays have found applications in store shelving, USB sticks, & now e-books

Display examples



Micoemmissive display P-OLED



40" display produced by inkjet



E-ink display on USB stick



Lighting & Electronic Signs

- Generally using simpler technologies such as electroluminescence
- This is a technology that has been around for many years (first used in avionics)
- Recent interest due to development of lower temperature curing inks & screen printing used for manufacture
- Also appearance of lower cost electronics due to use of EL displays in mobile phone backlighting

Lighting & Signage



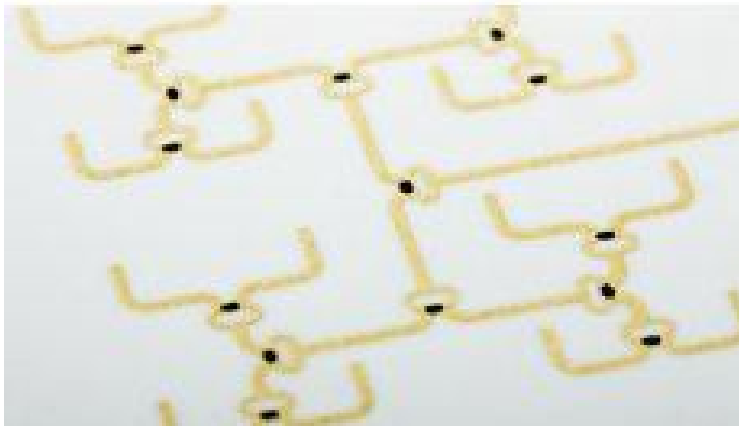
RFID, smart packaging & security

- Printed antenna
- Screen printing, gravure, inkjet, R2R
- Challenges around signal speeds for chips
- Chip connection often using conductive & non-conductive adhesives
- High volume process (3million/day)
- High yield required because of chip cost, minimum around 8 cents in high volume, low complexity chips

RFID & smart packaging & Security

- Packaging for medicines – speaking, timers
- Secure parcel packaging with inbuilt tracking & timing
- Security – passports, & ID badges
- Library cards & membership at Universities
- Genuine & luxury goods, clothing
- Airport luggage tracking
- Theme parks, ski-passes, ticketed events

RFID, smart packaging & security



Sensors

- Traditional cardiac patches
- Nerve damage sensors
- Biosensors & OLED
- Temperature sensors - blood tracking
- Power – detection of battery life
- Sound – speakers
- Actuators

Sensors



Batteries & Photovoltaics

- Printed batteries
 - Thin
 - Flexible
 - Robust
 - Rechargeable?
- Photovoltaics
 - Solar panels & efficiencies
 - Moisture & humidity challenges
 - Plastic substrates
 - Metal substrates
 - R2R processing

Batteries & Photovoltaics



Transistors, LEDs & ICs

- Printed transistors
 - Plastic substrate
 - Inkjet & lithography
- LEDs
 - POLEDs – inkjet & screen printing
 - OLEDs – ink jet
- ICs
 - RFID chips

Transistors, LEDs & ICs



Overview & Future

- Printed electronics is a huge expanding market
- £200bn in 2028!
- Creating new products & not replacements
- No One-Stop Shop that fits all
- A combination of circuit technologies required
- Start up & university spin offs need help ...
- Materials development key to development of products of the future

Overview & Future

- Get involved with Universities in UK & EU
- Need commercial guidance
- Cando vs Cantdo
- Creativity leads to more business
- Network & sharing will increase understanding
- Understanding the technology makes you better informed about future opportunities

Some know how RFID technology works...

