Gwent Electronic Materials Ltd

Polymers in Advanced Electronic and Biotechnology Applications
Company History

- Formed in 1988
- Manufacture of passive electronic materials
- Contract Research
- Toll Manufacture
- Biosensor materials developed 1994
- AET acquired in 2001
The Gwent Group Explained

- GEM materials and material services
- AET protein stabilisation and prototype biosensor development
- LRH holding company and consultancy
- GSL manufacture of biosensors for agri-food and environmental market sectors
- NDA’s are group wide and not limited to individual companies
Products and Services

- Experience in the development and production of electroceramic materials for the electronics industry

- Supply biosensors for medical, environmental and agri-food market sectors

- Contract research on ink formulations
Major Application Methods

- Screen Printing
- Ink Jet
- Syringe
- Spraying
- Dipping
- Brushing
Major Active Systems

- Particulate
- Organo-Metallic
- Precious Metal
- Base Metal
- Ceramic
- Carbon
- Polymer
- Dielectrics
Markets

- Electroceramics
- Passive components
- Medical diagnostic sensors
- Electroluminescent displays
- Electrochemical sensors
- Biosensors for environmental and food testing
Contract Research Services

• Short 20 day feasibility studies
• One to three month intermediate development
• Long term rolling contract research
Location

- Situated in South Wales
- Half hour from Severn Bridge
- Within easy access of major motorways and airports
- 12000 sq meters of factory space
Quality Standards
Outline of Presentation

• Polymers in our materials - what role do they play
• Application techniques – screen printing
• Sensor construction techniques
• Electroluminescent Display Materials
• Materials used in biosensor transducers
Polymers and their role in our Materials

- Polymers form an integral part of our carrying systems.
- Polymers do not add active functions to our Materials.
- In High Temperature materials they form a temporary application function and are then removed.
- In Lower Temperature Materials they form the Matrix or ‘glue’ for the active materials.
## Constituents of Typical Product

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Weight (%)</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional phase</td>
<td>63</td>
<td>20</td>
</tr>
<tr>
<td>Inorganic binder</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Organic vehicle</td>
<td>21</td>
<td>72</td>
</tr>
</tbody>
</table>

*Shrinkage of film*

- *wet film*
- Dried of cured film

- Fired film
Major Constituents of Carrying Systems

- Functional phase: 38 to 85 parts by weight
- Polymer carrying system: 4 to 9 parts by weight
- Solvents usually: 3 different evaporation rates 11 to 58
GEM Materials and Application Techniques

- Mask Techniques-Screen Printing
- Maskless-Ink Jet Printing
Why is Screen-Printing Popular

• Cheap for small volumes - less than 1 billion sensors per year

• Film thickness can be high (>40µm)

• Other printing techniques give lower weights of deposit
What About Other Methods?

- Flexographic and Gravure printing lower weight of deposit
- Web based printing for volumes over 1 billion and expensive set-up costs
- Maskless technology such as direct write too slow
- Liquid dispensing needed for enzymes other than glucose oxidase
- Dot on demand ink jet pico litre drop sizes and production cycle time issues will be used for smaller structures
The Basic Screen-Printing Process

Fig 1 The basic screen print process
The Print Cycle

- The screen is located over and just above the article to be printed so that it is accurately registered to deposit the print in the desired position. Most people when seeing the process operated for the first time think that the screen is brought into contact with the article. This is not so. If it were allowed to happen the screen would pull away in an uncontrolled manner after printing and spoil the print.
Dek1202 High Definition
Dek260 with Optical Alignment
Electrode Polymer Curing Unit
High Temperature 6 Zone Belt Furnace
Screen-Printing Capability

- Research and Development Scale Dek1202
- Scale –up Dek245
- Class 100 print room
- Prototype Production Dek248
- Optical Alignment system Dek260
- Capability of up to 5 million electrodes per year
Main Application areas

- Simple conductive circuitry
- Flexible heaters
- Electroluminescent Display Materials
- Bio-Sensors
Substrates Used in Base Transducers

- Polyester
- PVC
- Polycarbonate
- Polystyrene
- Alumina
Flexible sensor
Flexible heaters
Flexible needle sensor
Flexible circuits

- Single-sided circuits
- Double-sided circuits
- Multi-layer circuits
- Multi-layer Rigid flexible
- Hybrid circuit / laminated cable
EL Lamps

• The EL lamp is a capacitor structure with an active phosphor material sandwiched between the electrodes. Application of an AC voltage generates a changing field within the active layer that causes the phosphor to emit light.

• The EL lamp is constructed from various layers of screen printed Polymer Thick Film ink compositions.
STANDARD BUILD

Encapsulant
Rear Conductor (C, Ag)
Dielectric
Phosphor
Bus Bar (Ag)
ITO Polyester Film

LIGHT

AC
EL REVERSE BUILD

Clear Encapsulant

Translucent Conductor (ITO)
Phosphor
Dielectric
Rear Conductor/Bus bars (C, Ag)
PWB Substrate

LIGHT

AC
Industrial Example

Biosensors

- There are many forms of biosensors, the biosensor that has made a worldwide impact is the Blood Glucose Biosensor used in the home monitoring of Diabetics.
- The technology is based on an enzyme that interacts with an electrochemical transducer.
- The end result is detected by measuring a generated electrical current.
What's So Special about Materials for Electrochemical Transducers

- Electrochemistry is a surface technique - for electrochemical reactions to occur the surface of electrode materials must be clean and have active materials available for reactions to occur.
- All material systems must have active material at the surface i.e. not coated with polymers
- Inks are formulated to allow this to happen but screen printing and other physical properties are sacrificed to achieve this
- Polymer film strength and other desirable characteristics are sacrificed to achieve the desired electrochemical surface
Transducer

- Definition – power transforming device for which the input and output are of different kinds
- In an electrochemical biosensor chemical energy is transformed into electrical energy
- In my talk I will be concentrating on the non-biological materials-base transducers
Schematic of Electrocatalytic Activity at the Ammonium Sensor Surface
Screen – Printed Materials Commonly Used in Disposable Biosensors

- Carbon – graphite mixes
- Silver conductors
- Silver/silver chloride reference electrode materials
- Insulators / Dielectrics
- Adhesives
Materials Available for Special Applications

- Cross–linked systems used for work with membranes (polar or strong solvents) FIA applications
- High Temperature systems available for ceramic substrates (alumina)
- Gold, Platinum, Palladium, Rhodium in both polymeric and high temperature systems
- Other metals such as Nickel and Copper if needed
Construction of Biosensors

• Well formation – there are many ways to form wells to hold the test solution. Screen or stencil printed, laminated plastic film or micro machined slots. The key parameter is the accuracy needed for the sample volume. In some techniques such as coulombetry the volume of the sample is not important while in others it can add significant error.

• The hydrophilicity of the working electrode is of prime importance to the measurement
Application Methods for Biomaterials

• The only enzyme system commonly printed is Glucose Oxidase
• Many enzyme systems can not be applied with ink jet systems
• The more sensitive systems are applied using liquid dispensing methods
Conclusions

• Screen-printing is the most commonly used application method used for base transducers
• Screen-printing can be used with enzymes
• A variety of application techniques can be used with bio-systems
• The limit for small structures in the future will be 50 microns lines and spaces
Limitations of Mask Technology: Specific Examples

- Volume screen printing
  - 70µm lines and spaces
- Aerospace small volumes
  - 40µm lines and spaces
- Electronics / Biotech Industry pushing for smaller structures
- Thin film uses high vacuum technology which is expensive
Screen Printing Materials
Limitations

• Size of screen mesh
  – Mesh hole for 400 mesh s/s screen is 40μm

• Material agglomeration
  – Three particle agglomerate limits maximum particle size of powder to ~12μm
Sub-Micron Particles

- As particle size decreases, surface area increases.
- This limits the volume fraction of powder that can be used within materials formulation.
Materials for Ink Jet Printing

- Nano powders
- Colloidal or solution-like materials
- Advanced Polymer Systems
Ink Development Issues

- Nanoparticles or soluble precursors
- Post-deposition heat treatment?
- How to get dielectric properties without heat treatment
- Key property is viscosity
- Surface tension and fluid density are also important
- Resolution requires understanding of substrate interactions
Examples of Organometallic and Nano Powder Ink Jet Printing Materials

Printing Metallic Tracks

- Use organometallic Ag precursors
- Suspensions of nanocrystalline Ag powders
Mixed Technology Examples
The role of Polymers in Enzyme stabilization

The addition of polyelectrolytes to solutions of proteins promotes the formation of soluble protein/polyelectrolyte complexes by electrostatic interaction. Polyhydroxyl compounds are then able to penetrate the structure more effectively leading to stabilization.
Enzyme Active sites and Charged Polymers

![Dry Stability of AChE B03](image)

Acetyl choline esterase stability determined by microtitre plate assay
Iso Electronic Focusing and Complex size and Charge

1= Markers
2=L-GLDH
3=L-GLDH+ 0.5% Polymer 1
4=L-GLDH+ 0.5% Polymer 2
5=L-GLDH
6=Markers
7=L-GLDH+ 0.5%Polymer 3
8=L-GLDH+ 0.5%Polymer 4
9=L-GLDH
10=L-GLDH + 0.5%polymer 5
11=L-GLDH
12=Markers
Conclusions

• Direct writing has a vital role to play today in mixed technology solutions

• There have to be a number of key materials solutions to allow direct writing to be used in power devices

• Smart card technology could be a large market for direct writing
The Gwent Group

- GEM can provide a unique range of materials and services for all electronic materials
- Together with AET we provide a one stop shop for all types of biosensor development
- GEM produce materials and base electrochemical transducers
- AET provide Bio stabilisation services and Biosensor fabrication service
Gwent Electronic Materials Ltd
Monmouth House
Mamhilad Park
Pontypool
Torfaen
NP4 0HZ
United Kingdom

Tel: 00 44 (0) 1495 750505
Fax: 00 44 (0) 1495 752121
Email: sales@gwent.org
Website http://www.gwent.org