Materials and Manufacturing Methods for Biosensors

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 plus contract base transducer (biosensor) manufacture
- 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
- Supplier of base sensors and materials for medical, environmental and agri-food market sectors
- Contract research on ink formulations

Major Application Methods

- Screen Printing
- Ink Jet
- Syringe
- Spraying
- Dipping
- Brushing

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Major 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

- >20 day feasibility studies
- One to three month intermediate development
- Long term rolling contract research

Location

- Situated in South Wales
- Within easy access of major motorways and airports
- 12000 sq meters of factory space

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Quality Standards

SYSTEM CERTIFICATION ISO 13485 SGS

SYSTEM CERTIFICATION ISO TS 16949 SGS

SYSTEM CERTIFICATION ISO 9001:2000 SGS

UKAS QUALITY MANAGEMENT
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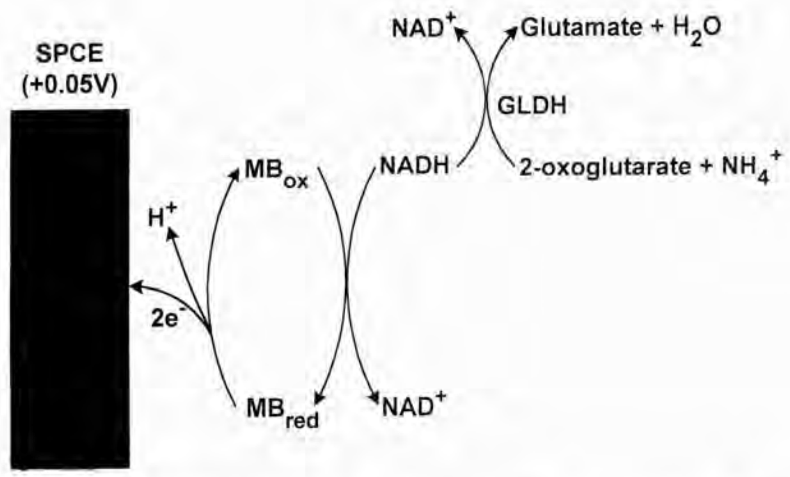
Outline of Presentation

- Transducers - what role do they play
- Materials used in biosensor transducers
- Application techniques – screen printing
- Sensor construction techniques

Transducer

- Definition – transforming device for which the inputs and outputs are of different energy types
- In an electrochemical biosensor chemical energy is transduced into electrical energy
- In my talk I will be concentrating on the non biological materials used in the tranducer

Printed Electrode with Mediator: Processes at Sensor Surface



Schematic diagram showing the various reactions taking place during the operation of the NH_4^+ biosensor

Substrates Used in Base Transducers

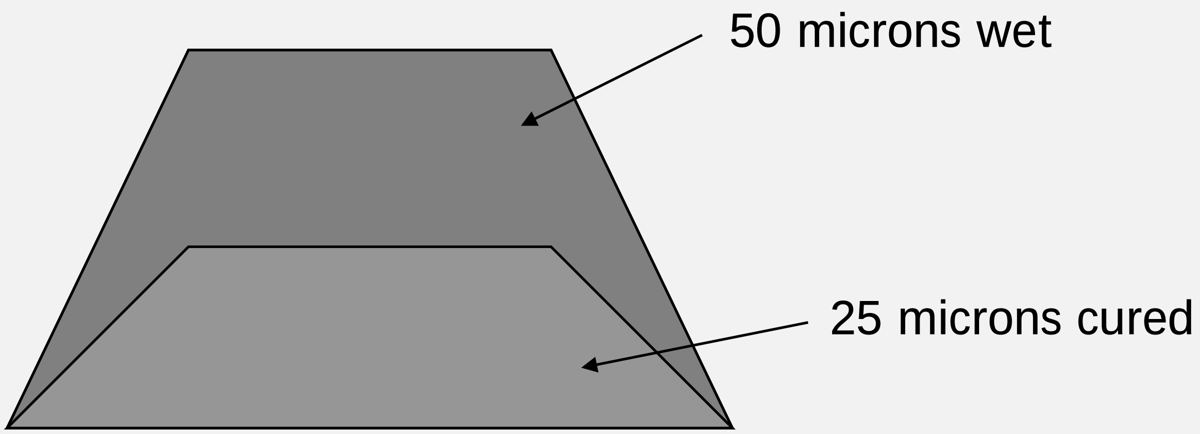
- Polyester
- PVC
- Polycarbonate
- Polystyrene
- Alumina

Screen –Printed Materials Commonly Used in Disposable Biosensors

- Carbon – graphite mixes
- Silver conductors
- Silver/silver chloride reference electrode materials
- Insulators / Dielectrics
- Adhesives

Major Constituents of Inks

- Functional phase: 38 to 85 parts by weight
- Polymer carrying system: 4 to 9 parts by weight
- Solvents: usually 3 different types 11 to 58 parts by weight



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

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

What's So Special about Materials for Electrochemical Transducers

- All material systems must have active material at the surface i.e. not coated with polymers

- Inks are formulated to allow this is happen but screen printing and other physical properties are sacrificed to achieve this

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?

- Flexigraphic 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

What About Other Methods?

- 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

Sensor Design and Application Techniques

- The absolute limit of screen printing is 70 micron lines and spaces
- Due to the physical limitations of electrochemical materials 100-150 micron lines and spaces is accepted as the practical limit of this technique
- A new screen is needed to lay down a different material
- Art work needs to be generated for each screen

The Print Cycle

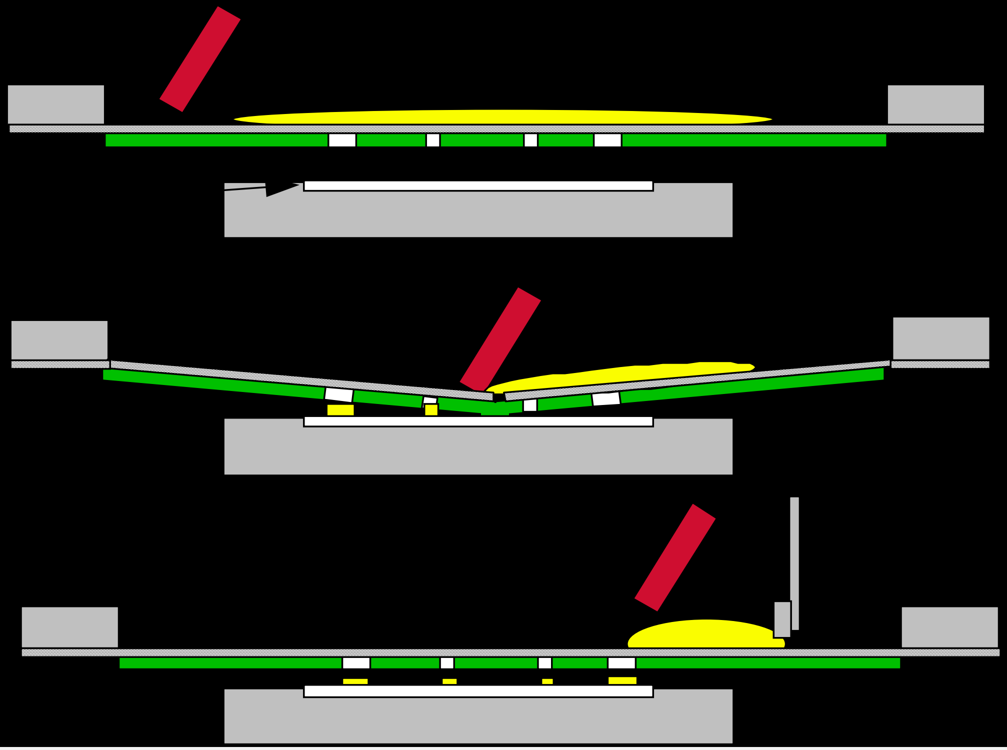
- The screen is located over and just above the article to be printed so that it is accurately registered to deposit the print in the desired position.
- Most people when seeing the process operated for the first time think that the screen is brought into contact with the article. This is not so.
- If it were allowed to happen the screen would pull away in an uncontrolled manner after printing and spoil the print.

Print Cycle continued

- The mesh of the screen is brought into line contact with the article by the squeegee as it is moved across the screen.
- Ink is pushed into the open area forming the pattern and the surplus is removed by the edge of the squeegee.
- The mesh should peel away from the surface immediately behind the squeegee, leaving all the ink that was in the mesh deposited on the printing surface.
- The screen can then be lifted clear without fear of the print being spoiled.

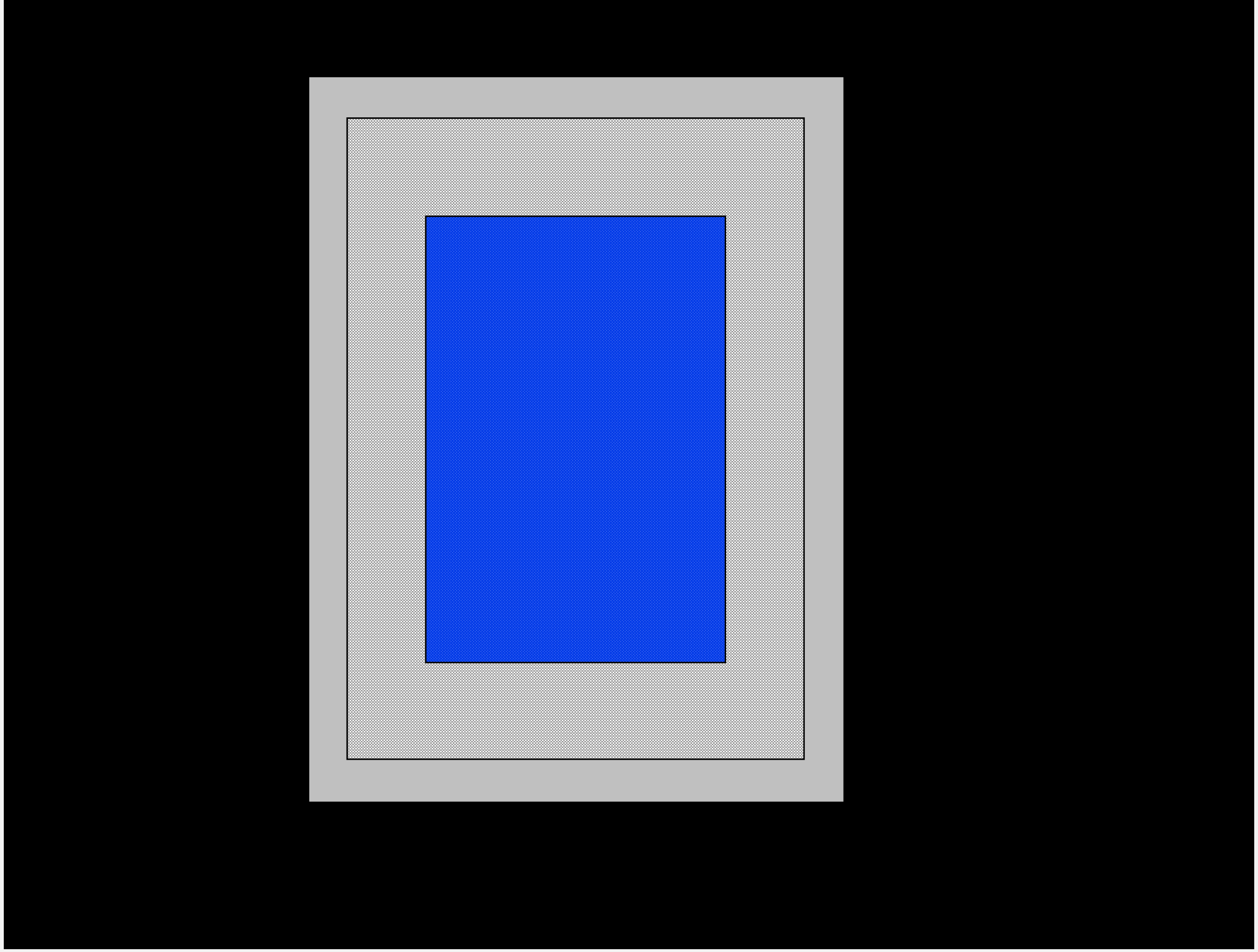
The Basic Screen-Printing Process

Fig 1 The basic screen print process



Screen Frame Size Relative to Working Area

Fig 2 Screen / image size



The Screen Mesh: Practical Rules

- The number of threads per centimetre and per inch, thread diameter, mesh opening, open area or open surface and cloth thickness are reasonably self explanatory but one or two comments may be in order.
- The first rule is that the mesh opening should be at least three times the particle size of the print medium being printed.

The Screen Mesh: Practical Rules

- The open area of the mesh has a great effect on the passage of print medium through the screen. For ease of passage, the greatest percentage open area screens should be selected. Open area is calculated as:

$$\frac{(\text{mesh opening})^2}{(\text{wire diameter} + \text{mesh opening})^2} \times 100\%$$

Types of Mesh

- Two types of material are in general use today: Polyester and Stainless Steel. One type will not satisfy the requirement for all types of work and sizes of screen

- Both types of mesh are available in a large quantity of weaves as they are multi-purpose materials

Rules of Thumb

- The minimum line width which can be printed with a given mesh is 3 times the mesh thread diameter. Narrow lines cannot be printed with large thread diameter mesh.
- Practically it is unwise to use mesh with wire diameters less than 24 microns,
- The mesh opening should be at least three times the particle size of the printing ink. Normally, the ink particles will be < 5-10 μ diameter, so the finest meshes can be used. However, Silver chloride particles are typically 6-35 μ diameter, which limits the choice of mesh available

Typical Screen Meshes

classification	Typical mesh	polyester	Stainless steel
Very heavy deposit, quality of outline not important	Under 40/cm 100/in	21/cm 54/in	31/cm 80/in
Heavy deposit, good definition	40-80/cm 100-200/in	77/cm 195/in	77/cm 200/in
All lettering & illustrations	80-125/cm 200-325/in	120/cm 305/in	125/cm 325/in
Thin deposit, extra fine detail	125-154/cm 320-400/in	150/cm 380/in	154/cm 400/in

Curing of Printed Electrodes

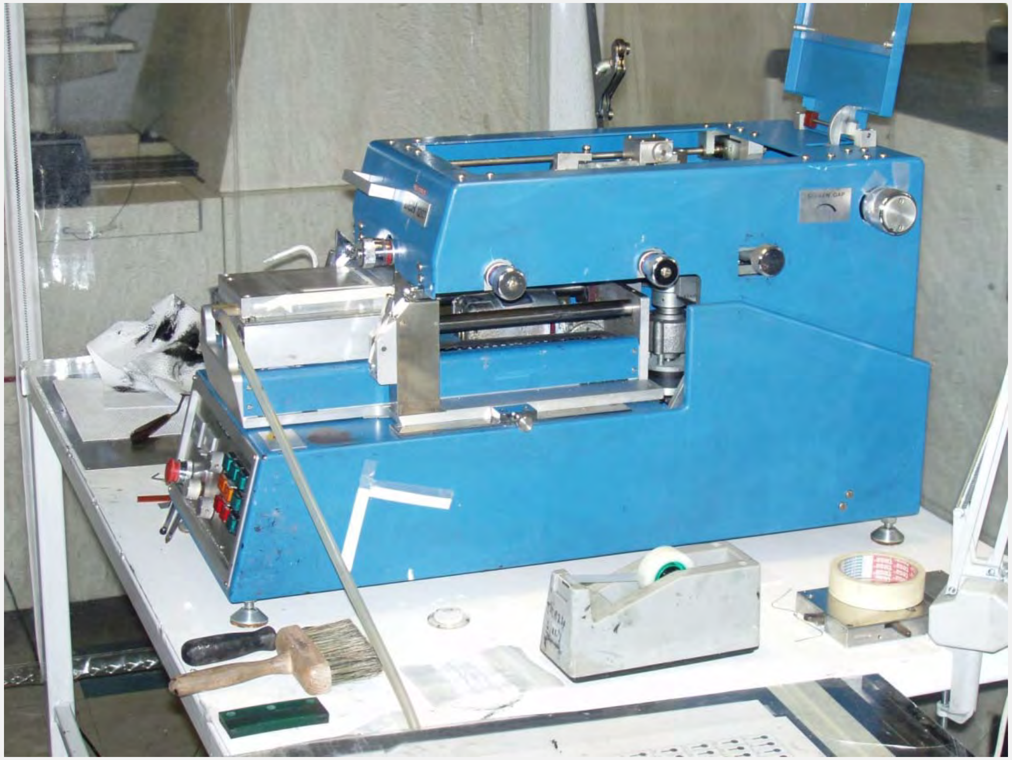
- For a few prototypes simple oven curing is acceptable. For most grades of polyester, 60-110 deg C is suitable
- For production quantities a IR belt furnace is often used
- Some manufactures use rotary wicket driers in an attempt to save production space

Electrode Polymer Curing Unit

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

Dek1202 High Definition



Dek248 Production Printer

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Dek260 with Optical Alignment

High Temperature 6 Zone Belt Furnace

Outline of Construction Techniques

- Printing and curing of the base transducer
- Visual/Electrochemical QC
- Biological application/well lamination
- Final device QC
- Packaging

Construction of Biosensors

- The key parameter is the accuracy needed for the sample volume. In some techniques such as coulometry the volume of the sample is not important while in other electrochemical techniques it can add the major 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 cannot be applied with ink jet systems
- The more sensitive systems are applied using liquid dispensing methods

Conclusions

- Screen-printing is the most commonly used fabrication method for base transducers
- Screen-printing can be used with robust enzymes
- A variety of other application techniques can be used with more sensitive biosystems
- The limit for screen printed structures in the future will be 50 μ lines and spaces

The Gwent Group

- Can provide a unique range of materials and services for all biosensor systems

- GEM produce materials and base electrochemical transducers

- AET provide biostabilisation services and biosensor fabrication

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