Diamond Detectors Ltd

Fabrication and Packaging Capabilities

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Diamond Detectors Ltd is currently 100% owned by Element Six Technologies and was spun out in 2007.

Why DDL was created?

• The focus of Element Six Ltd is on material development and bulk material synthesis.

• The detector/sensor market requires a diverse range of engineered products and skills. Including development, manufacture and sales.

• DDL has been formed to provide market focus and develop a range of packaged devices. To provide research and industry with a partner capable of providing the added processes needed to take diamond from material to characterised device.
Brief History
Diamond Detectors Ltd

• Certificate of Incorporation February 2007
  (6097934, VAT 904 1112 82)

• Press release Thursday 3rd May 2007
  “Element Six Spins Out New Company to Develop Diamond
  Detectors……..

• Moved into our own
  premises June 2007.
  Location  Poole, Dorset.
Reason for Spinning Out
To Provide Detectors

Diamond Synthesis E6

DDL
• Material Processing
• Die Fabrication and Test
• Die/Wire Bonding.
• Packaging
• Characterisation.

Packaged Solutions to Customers in R&D and Industry

Market Driven Requirements or Specification

June 20, 2008
DDL – Roadmap

• Phase-I (2007 - Q3)
  Technology Transfer from E6 to DDL.
  Build Start (access to premises from 2nd June 2007)
  - Lapping & Polishing Processes
  - Chemistry Lab.
  - Laser Lab.
  - Lithography and Assembly Clean rooms. (class 1000 & 10000)

• Phase-II (2007 - Q4)
  - Fabrication and packaging of simple devices
  - Build Completion.

• Phase-III (2008/09) Purchase of additional manufacturing tools including:-
  - Metallization (Delivery July 2008)
  - Laser Dicing (Delivery July 2008)
  - Lithography (Direct write tools)
  - Development of more complex detectors/sensors including electronics.
DDL-Build-2007

- 2 Newly built clean rooms class 1000 and 10000 (~100m²)
**DDL-Equipment & Capabilities**

- Lapping, Polishing and Semi-automatic scaife

- Optical Profiler NT9100

- Diamond Thinning and Polishing Processes including
  - Lapping
  - Resin wheel polishing
  - Scaife polishing

**Typical process specifications :-**
- Polycrystalline standard polish  $Ra < 30\text{nm}$.
- Polycrystalline detector polish  $Ra < 12\text{nm}$.
- Polycrystalline Super polish  $Ra < 5\text{nm}$.
- Single crystal detector polish  $Ra < 5\text{nm}$.
**DDL-Equipment**

- Die bonding including universal wedge bonder (K&S 4523) and ball bonding (K&S 4124)

- Wire bond pull strength is monitored using Dage 4000 system.

- Encapsulation (UV EFOS Novacure)

- Asymtek Century Fluid/Adhesive Dispense

- High Voltage Electrical Isolation Test (Keithley 6517A, 487 and 236).
DDL-Equipment

- Laser Dicing System
  - Shaping Software
  - Dicing up to 5mm thickness

- Sputtering System
  - 3 Targets (1 nano-cluster)
  - 4” Substrate Holder
  - Ion-Beam-Polishing
  - 850C Substrate temperature.
  - 25kev Substrate bias.
  - RF plasma clean/etch
Diamond Detector Applications

A wide range of detector applications and detector types make diverse demands on the material

• Particle physics: beam condition monitors, trackers, beam abort systems
• Dosimetry: radiation therapy, equipment calibration, active exposure monitoring
• Nuclear applications: homeland security, nuclear reactors and fusion experiments
• Synchrotrons: white beam monitoring
• UV detectors: photolithography, flame detection and solar physics
• Alpha/Beta: air-Flow and survey meters, waste incineration
Diamond Detectors Applications

Some examples provided by DDL in 2007/08
# X-ray Sensitivity Comparison for Different Dosimeter Types

Higher sensitivity of High Purity SC CVDD

- Smaller devices
- Improved spatial resolution

<table>
<thead>
<tr>
<th></th>
<th>E6 HP SC CVD diamond</th>
<th>Commercial Silicon dosimeter</th>
<th>Air-filled Ionisation chamber</th>
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</thead>
<tbody>
<tr>
<td>Sensitivity (nC/Gy)</td>
<td>240</td>
<td>74</td>
<td>7.5</td>
</tr>
<tr>
<td>Active Detector Volume (mm³)</td>
<td>0.3</td>
<td>0.2</td>
<td>120</td>
</tr>
</tbody>
</table>

Data for samples irradiated in a 6MV photon beam with a 10cm x 10cm field at a source-to-detector distance of 100cm, courtesy of Scanditronix
Diamond Sensor Applications
Why Diamond

- Wide electrochemical window
- Extremely low background current.
- Bio-Compatible (non-fouling)
- Very stable surface (Chemically inert)
- Varied surface terminations possible
- Mechanically robust
Applications

- Electro-chemical sensors (RDE, MEA, trace element analysis)
  (Oil, Mining, Automotive, Medical, Food, Water, Environmental, Emissions, etc)
- PH-Sensors
- Temperature-Sensors
- Conductivity
Diamond Sensor Devices

- **Microelectrode Array (MEA)**
  - Structured array of many small (2 - 25µm) BDD electrodes surrounded by non-conducting intrinsic diamond
  - Housed inside sensor with membrane to select analyte
  - Requires analyte-specific solutions in contact with surface

- **Applications**
  - Petroleum industry (well logging)
  - Academic research (biology, electrochemistry)
  - Environmental (trace element analysis)
  - Process monitoring (food / beverage, chemical, pharmaceutical)
  - Medical.

- **Development status**
  - Prototypes available (2nd generation in design)
Diamond Sensor Devices

- **Rotating Disc Electrode**
  - Small BDD disc (3 – 10 mm) attached to a shaft and protected by a PEEK coating
  - Used in conjunction with a potentiostat

- **Applications**
  - Trace metal analysis (stripping voltammetry)
  - Pharmaceuticals (new drug analysis)
  - Electrochemical investigations in aqueous electrolyte and organic solvents

- **Development status**
  - Small volume production
Closing Comments
Closing comments

• From early experiments using naturals, diamond detector applications have grown into diverse applications with a growing interest from commercial and research markets where high performance detectors/sensors are required.

• Outstanding technical challenges remain including surface quality, metallization and material size for high purity single crystal.

• DDL continue to support single crystal development with E6 R&D The goal of this development is predominantly to improve yield and size.

• CVD diamond high purity single crystal and polycrystalline materials are now readily available. DDL stock material to avoid long lead time on standard product.

• DDL have a number of parties interested in thin materials in both single crystal and poly. This work has been more difficult than expected but process is being made.
Closing comments

• New markets are being opened up by improved material quality, larger available sizes, and an increased understanding of diamond performance

• New diamond detector applications are being driven by technological advances in other fields e.g. radiation therapy

• A new detector company, Diamond Devices Ltd, has been set up to service these markets.
The End

Thank you