Diamond Detectors Ltd

Fabrication and Packaging Capabilities

Kevin Oliver

Presentation Contents

- Brief Background.
- DDL road map to expand our capabilities further
- Diamond detector application examples.
- Closing comments

Brief History

- **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

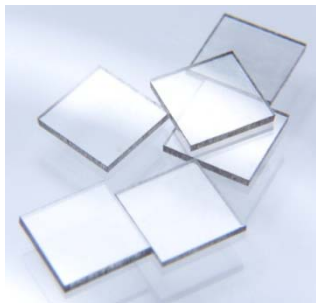
- Certificate of Incorporation February 2007
  (6097934, VAT 904 1112 82)

- 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.

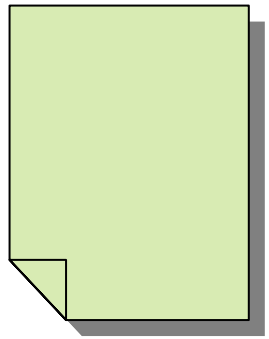
Reason for Spinning Out To Provide Detectors

Diamond Synthesis E6



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

Market Driven Requirements or Specification



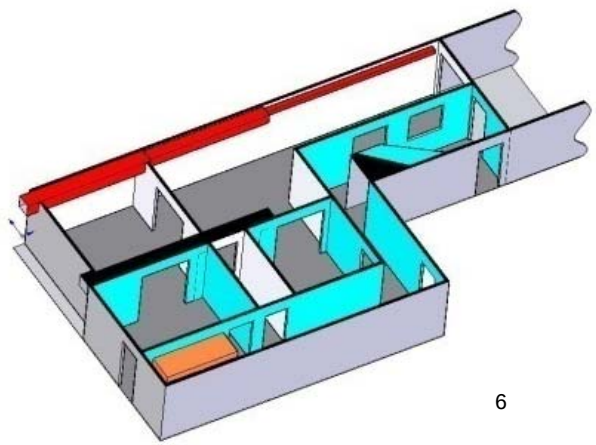
Packaged Solutions to Customers in R&D and Industry

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.

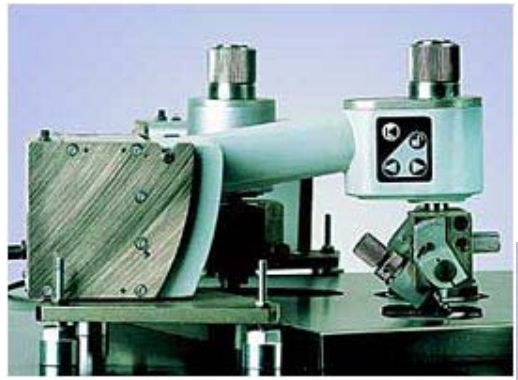


DDL-Build-2007

- 2 Newly built clean rooms class 1000 and 10000 (~100m^2)

DDL-Equipment & Capabilities

- Lapping, Polishing and Semi-automatic scaife

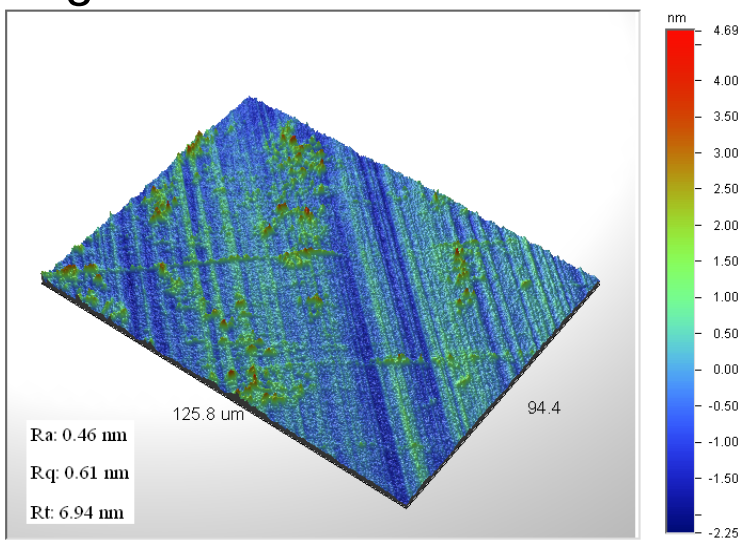


- Optical Profiler NT9100

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

Typical process specifications :-

Polycrystalline standard polish Ra < 30nm.
Polycrystalline detector polish Ra < 12nm.
Polycrystalline Super polish Ra < 5nm.
Single crystal detector polish Ra < 5nm.



DDL-Equipment

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

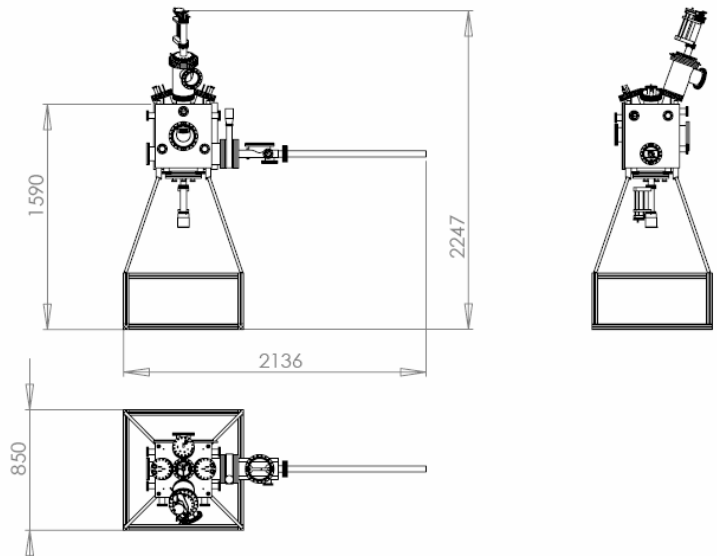
- Wire bond pull strength is monitored using Dage 4000 system.
- Encapsulation (UV EFOS Novacure)
- Asymtek Century Fluid/Adhesive Dispense

- 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

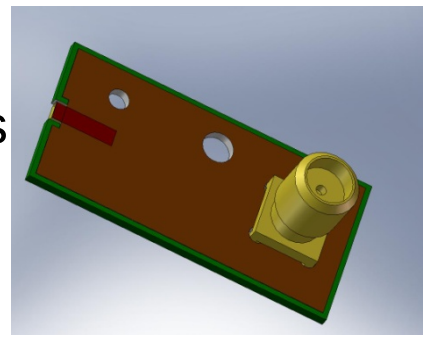


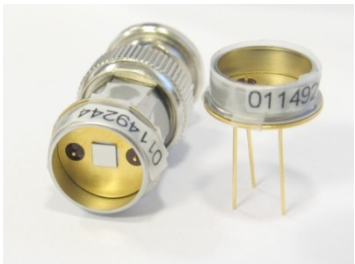
Diamond Detector Applications

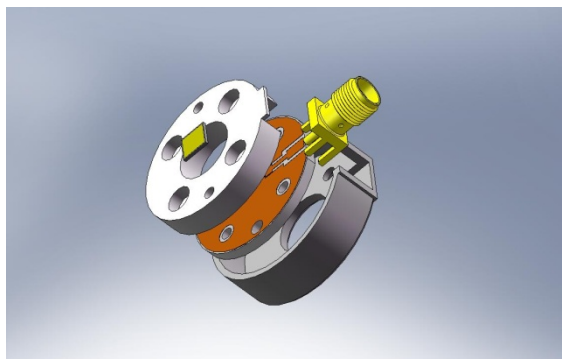
DIAMOND DETECTORS LIMITED

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

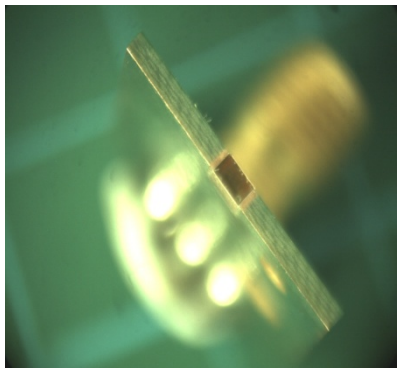
- Particle physics: beam condition monitors, trackers, beam abort systems
- Dosimetry: radiation therapy, equipment calibration, active exposure monitoring
- Nuclear applications: homeland security, nuclear reactors and fusion experiments
- Synchrotrons: white beam monitoring
- UV detectors: photolithography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

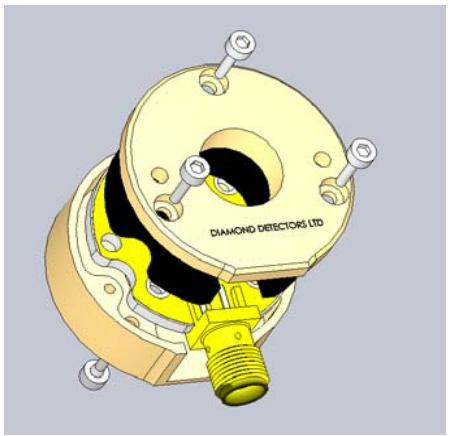


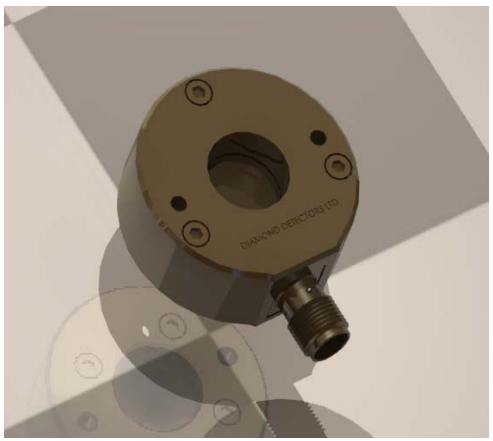


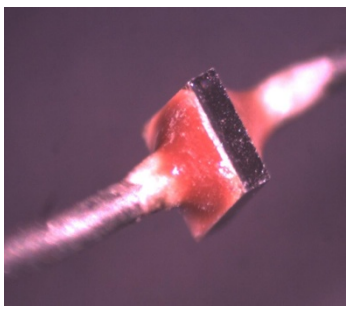


Diamond Detectors Applications



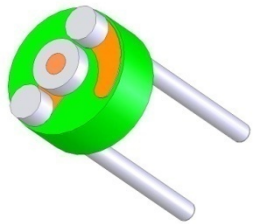






Some examples provided by DDL in 2007/08

X-ray Sensitivity Comparison for Different Dosimeter Types



Higher sensitivity of High Purity SC CVDD

⇨ **Smaller devices**

⇨ **Improved spatial resolution**

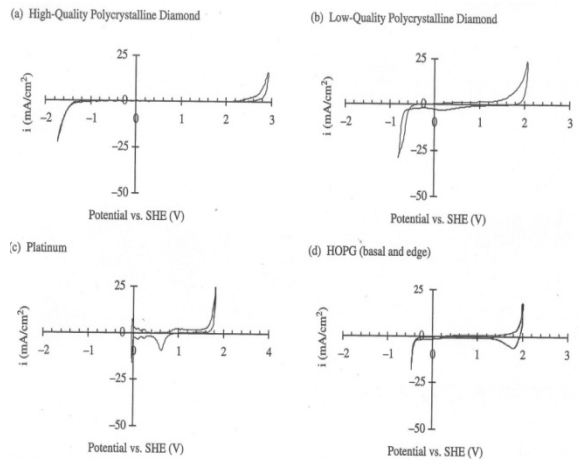
	E6 HP SC CVD diamond	Commercial Silicon dosimeter	Air-filled Ionisation chamber
Sensitivity (nC/Gy)	240	74	7.5
Active Detector Volume (mm^3)	0.3	0.2	120

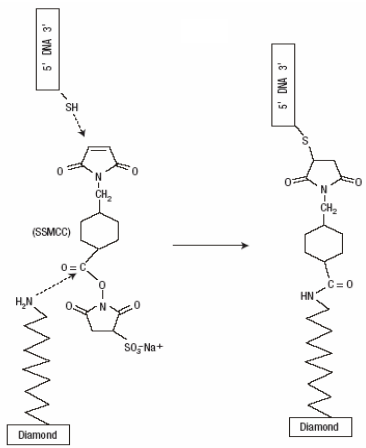
Data for samples irradiated in a 6MV photon beam with a 10cm x 10cm field at a source-to-detector distance of 100cm, courtesy of Scanditronix

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



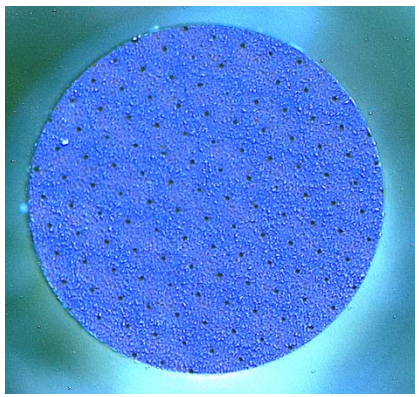


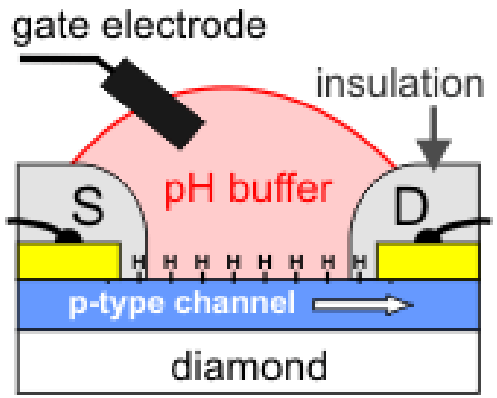
Applications

- **Electro-chemical sensors (RDE,MEA, trace element analysis)**

  (Oil, Mining, Automotive, Medical, Food, Water, Environmental, Emissions , etc)

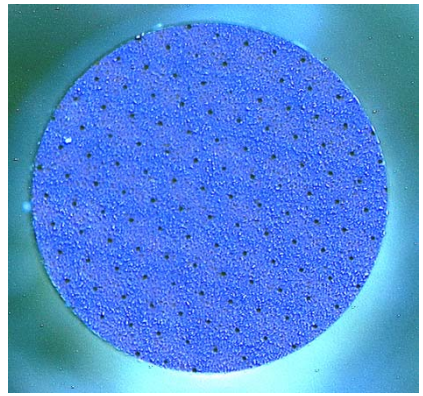
- **PH-Sensors**
- **Temperature-Sensors**
- **Conductivity**





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.**

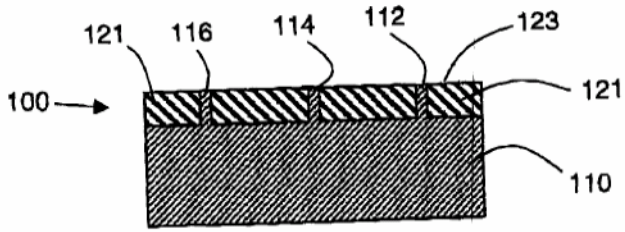
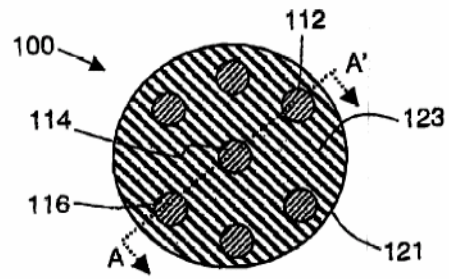


Figure 1a



- **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