A Diamond is R&D's "Synthetic" Best Friend

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Diamonds aren't just a girl's best friend; they're also R&D's best friend—or at least a new acquaintance. Many laboratories and companies are embracing synthetic diamond for its elevated super properties in applications ranging from analytical instruments and biomedical sensors to electronics and lasers to water purification.

A synthetic diamond's molecular structure makes it a versatile super material. With greater hardness than other materials, its strength is ideal for cutters used in oil and gas drilling where it enables longer tool life by minimizing wear. In electro analytical applications, synthetic diamond sensing materials provides stable electrochemical properties that enable high levels of sensitivity.

About 50% of electronic failures occur as a result of heat. And synthetic diamond's high thermal conductivity is four times higher than copper, and is the ideal material for thermal management. Synthetic diamond also has the widest spectral band of any material, extending from ultra violet to far infrared and the millimeter-wave microwave band, making it a suitable material for laser applications.

Lastly, synthetic diamond is chemically and biologically inert and can survive in severe physical, chemical and radioactive environments that destroy other materials.

There are two different forms of synthesis for synthetic diamond materials. One form is high-pressure, high-temperature (HPHT), a technique developed a few decades ago that emulates the environment when diamond is formed. The synthesis is conducted where a material scientist takes a number of precursors and form capsules and places these capsules under tremendous press under high temperatures. The other synthesis method is chemical vapor deposition (CVD), where diamond is grown layer by carbon layer.

Element Six Technologies, a Division of Element Six, a leader in synthetic diamond development, focuses exclusively on the microwave CVD synthesis technique to develop their products and collaborate with universities and laboratories to spread the super powers of this super material.

Optical products:

Polycrystalline diamond is one form that Element Six Technologies specializes in and has a good application fit for optical products due to its broad wavelength capability and transmission wavelength.

The company’s polycrystalline diamond material can be produced up to 135 mm dia and is used as output for lasers. The material is interesting in this application as it has broad transmission, but also because it has very high thermal conductivity. Any absorption that occurs, heat is then rapidly dissipated to the heat sinks.

Another area in optics that is a significant source of revenue for the company is ATR prism manufacture, a single crystal product. The company worked with Univ. of Strathclyde for use of their synthetic crystal diamond to develop a Raman shift technology. Raman shift is used in combination with wavelength splitting to create wavelengths of laser energy at reasonably high powers that wouldn’t normally be produced with a standard laser. The diamond transmits or wavelength shifts.

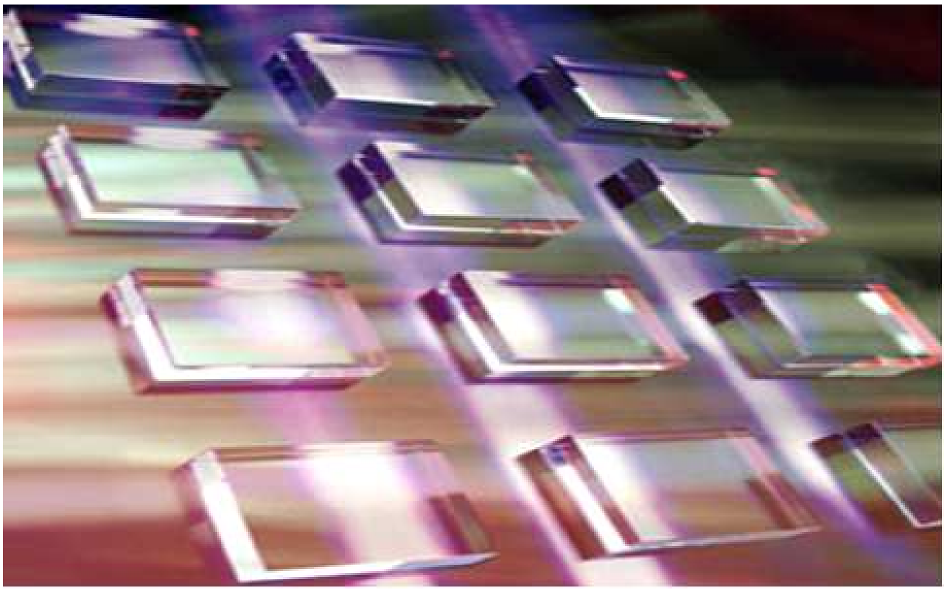
Semiconductors:

Synthetic diamond is also commonly used for heat spreading in semiconductor and electronics applications, moving heat from point a to b for removing hot spots from electronic devices. The goal with a heat spreader is to reduce the operating temperature of the semiconductor. Diamonds allow a solution and can reduce the footprint of the electronic system and increase the amount of power that the system can manage.

The other area of semiconductor in which diamond is important is the provision of a substrate upon which researchers can create electronic devices. Element Six is developing a gallium nitride (GaN)-on-Diamond product, which is in wafer form. This wafer is provided to the military community for the manufacture of radio frequency (RF) devices such as radar and telecommunications. The reason why this GaN-on-Diamond wafer is used for RF is because RF has a demanding need for higher power density, according to Adrian Wilson, Director of Element Six Technologies Group. It’s anticipated that these substrates could well displace gallium nitride on silicon (GaN-on-SiC) for some applications.

“We expect in the next few years that power semiconductors will also start to approach a very high power density and will use our gallium nitride on diamond products,” says Wilson.

Sensing:



Another application area using synthetic diamond technology is sensing. Sensing in terms of particle detection is probably the most publicized field in terms of collaborations, where diamond is provided for neutron detection.

Diamond has interesting properties where it is able to convert incoming neutrons into electrical energy, which can then be measured to determine the density of neutrons. Element Six provided the diamond that was used in the detection of the Higgs boson experiment in collaboration with CERN.

Another area in sensing that diamonds are used in is quantum optics or quantum research in general.

Element Six single-crystal CVD diamond used for optical, sensor and detector applications. Element Six single-crystal CVD diamond used for optical, sensor and detector applications.

"Quantum is really an interesting area of research," says Wilson. "If you roll the clock back about seven or eight years, the number of institutes looking at the use of diamond in quantum applications was maybe three or four. If you look today, there are over 40 institutes worldwide that are researching diamonds for quantum physics."

This field of research can range from magnetometer through to quantum encryption. And the reason why diamond is so interesting for this application area is that it's an extremely stable lattice.

"It's a great lattice to hold the quantum state, or NV center (nitrogen vacancy center)," says Wilson.

The NV center is the absence of a carbon atom and the presence of a nitrogen atom. This creates a quantum state that can be manipulated. Researchers can conduct quantum state movement programming at room temperature through the use of diamond. Whereas with other materials, such as silicon, they must be operated at cryogenic temperatures.

Water purification:

Water is also an application where diamond finds its home.

Diamond electrodes can be used for caustic processing. If a diamond is doped with boron it becomes part of the overall lattice, both bonded and interstitial, and makes the diamond conductive. The resulting material is also inert, but also allows current to pass through. As a result, these boron-doped diamond plates can be placed in water and a current can pass through the plates and create a bi-polar configuration, creating powerful hydroxyl radicals that can break down caustic material.

"There's a lot of research done by large companies looking at this technology as alternative to current methods for processing caustic material," says Wilson.

These boron-doped diamond plates with the introduction of a membrane technology can also create ozone. Researchers can generate ozone in a water solution that can then be used for surface or water purification.

However, not only can these boron-doped diamond plates help aid in the removal of caustic materials or generating ozone for water purification, but they can also aid in sensing and the detection of certain substances in water. If a researcher passes a current through the plates they can attract materials to its surface. Once the materials are attracted, researchers can reverse the polarity and eject the material and measure the amount of current required to eject that material. From there they can derive the concentration of the material in the liquid.

"We are working with Warwick Univ. in this electrochemistry field and looking for the presence of heavy metals in water," says Wilson. "We are able to provide a very robust method of measuring the presence of chemicals because diamond is inert and doesn't interfere with the chemistry of the liquid. As a result, you can get a highly resourceful method of measurement."