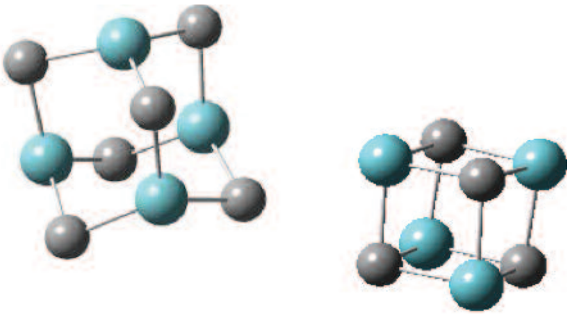
Nanoscience Shapes the Future

The intriguing properties of diamond films and metal–carbon nanoparticles are being explored for possible use in industrial applications.



Simple structures, complex properties: the intriguing properties of nanoparticles could lead to major technological advances.
Image: Greg Metha, University of Adelaide

Thanks to Marilyn Monroe, it's common knowledge that diamonds are a girl's best friend. Less glamorous than Marilyn's assets but even more valuable on an industrial scale are diamonds so small that thousands could fit across the width of a human hair.

Researchers are developing films containing millions of tiny diamond crystals to harness the exceptional hardness and heat conductivity of diamonds for new industrial purposes. More versatile than large single crystals, these films can be deposited on silicon, steel or other surfaces.

Synchrotron X-rays are providing the analytical tools and production methods to realise the potential of new diamond applications such as protective films for knife edges, electron emission devices, heat sinks for solid state lasers and thermo-electric energy converters to generate power from waste heat. Nano-diamonds can also generate photons for quantum communication and cryptographic devices being developed for secure telecommunications.

Professor Alon Hoffman from Technion, the Israel Institute of Technology, visited Melbourne recently to collaborate with the University of Melbourne's Professor Steven Prawer on the production and properties of nano-diamonds. Alon and his collaborators are seeking to control and pattern the local electronic properties of diamond surfaces by removing or bonding atoms such as hydrogen, oxygen and nitrogen. Oxidised diamond surfaces are electrically insulating but hydrogenated diamond surfaces conduct electricity. Finely focused synchrotron X-ray beams can be used to selectively promote the removal of hydrogen atoms and make a diamond surface receptive to the adsorption of oxygen atoms, thereby altering its electrical conductivity.

During his stay in Melbourne, Alon used the soft X-ray beamline at the Australian Synchrotron to investigate the thermal stability and surface properties of nano-diamond particles. His results proved that a synchrotron technique called "near edge X-ray adsorption fine structure" can accurately detect the bonding of hydrogen to diamond surfaces.

Precious Little Metals

Many modern industrial processes rely on catalysts that make chemical reactions happen or run faster. Platinum-group metals are the workhorses of industrial catalysis, but their high cost and limited efficiency has prompted a search for alternatives.

Metal–carbide nanoparticles made from carbon bonded to metals such as titanium, niobium or chromium have chemically similar surface properties to platinum-group metals – and potentially superior selectivity and efficiency. They are also cheaper to produce, but their small size makes them difficult to study.

At the University of Adelaide, a team led by Associate Professor Greg Metha has developed a laser-based method for preparing titanium carbide and other metal–carbide nano-particles in aqueous solutions. The particles are small (5–10 nm) and uniform in size, but their chemical structure is unknown. After laboratory techniques failed to identify the chemical bonds present in the nanoparticles, Greg turned to the Australian Synchrotron.

Using the Synchrotron's far-infrared and high-resolution beamline, Greg and German exchange student Birte Riechers collected data showing the presence of metal–carbon bonds, as expected. A more surprising finding was carbon–hydrogen bonds, suggesting that the nanoparticles may be able to catalyse the decomposition of water.

Greg's next step will be to test metal–carbide nanoparticles prepared in deuterated water to find out whether the carbon–hydrogen bonds are formed during the production of the nanoparticles or from subsequent reactions with the air.

Scientists Narrow Their Focus

A new era in scanning microscopy has arrived at the Australian Synchrotron with the successful installation of the nanoprobe on the X-ray microspectroscopy beamline. Being able to focus the X-ray beam to 150 nm significantly extends the capabilities of this versatile instrument.

Researchers from the University of Melbourne's Department of Pathology and Mental Health Research Institute were the first to use the nanoprobe, investigating metal homeostasis in amyloid precursor protein family knockout cells as part of ongoing efforts to understand key aspects of Alzheimer's disease. Subcellular elemental mapping and imaging will be one of the nanoprobe's major functions.

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