ture. Aiming for a structure of the Na_xSi_{136} type, this team has used a combination of successive vacuum "degassing" of Na from ionic Zintl phase sodium silicide, followed by density separation and centrifugation. As reported in the September 15 issue of *Physical Review B*, Na_xSi_{136} samples with low sodium concentrations (<4%) were washed in concentrated hydrochloric acid, dried and degassed at 430°C under a vacuum of 10^{-5} torr over a period of several days in order to lower the amount of sodium fractions. This process of washing and degassing was cycled several times, and ended with a final centrifuging in a dibromomethane-methanol solution for isolating the fraction with sodium content lower than 600 ppm.

X-ray diffraction analysis of this "open framework" form has revealed a volume per silicon atom of 23.01 Å^3, 16% greater than that of normal silicon (19.9 Å^3). The semiconducting nature is confirmed by electrical resistance measurements on cold-pressed discs of the sample. A bandgap of ~1.9–2.0 eV has been determined using reflection spectrometry.

The researchers said that such wide bandgap materials based on silicon could be developed for designing optoelectronics materials compatible with existing silicon technology if a precise control over form and stoichiometry can be developed.

CLAUDIU MUNTELE

Color Centers in Diamond Yield Potential Single Photon Source for Quantum Cryptography

A reliable single photon emission source can tremendously advance the field of quantum cryptography. The idea behind quantum encryption is that it is impossible to decipher the complete quantum state of a single particle. This method of coding will provide impenetrable security. So far, single photon emission sources for this purpose have been unreliable because of the low (liquid He) temperature requirement, the random triggering of emissions, and low collection efficiency (< 0.1%).

A group of researchers at the Optic Institute, the Charles Fabry Laboratory of the National Center of Scientific Research in France have pioneered a reliable, laser pulse-triggered, single photon emission source with a relatively simple setup. As reported on the September 1 issue of *Optics Letters*, the experiment is conducted with bulk diamond at room temperature. A 514-nm argon ion laser (10 mW) provided this trigger. The photon source is a piece of bulk diamond ($0.1 \times 1.5 \times 1.5$ mm^3) with nitrogen-vacancy defect centers.

The color center in the diamond is fabricated by the purchase of bulk diamond with nitrogen as an impurity. A 2-MeV electron beam with 3×10^{12} electrons/cm^2 was used to create the color center defects. Each defect consists of a substitutional nitrogen and a vacancy left by the nitrogen. The diamond sample is then vacuum annealed at 850°C for 2 h. The zero phonon wavelength is 637 nm, and excited state lifetime is 11.6 ns.

Data of the raw count rate were collected along with the image of the individual color centers. From the raw count rate, the correlation function of the defect center can be calculated. In this experiment, the correlation function equals zero only at $t = 0$,

https://doi.org/10.1557/mrs2000.188 Published online by Cambridge University Press

which corresponds to the time of the fluorescent event. This suggests that the defect center fluorescence is a unique, nonrandom event compared with the background signal. Zero correlation in this case also implies that only a single defect center is responsible for the event.

The overall collection efficiency in this experiment is still very poor (0.0014). The researchers suggest that one improvement is to "couple an emitting dipole to a microcavity so it will emit light in a single mode." They also said that better collection optics and samples will also improve efficiency. The researchers hold that despite low collection efficiency with the current setup, the relative simplicity of this experiment provides a good platform for future development.

JUNE LAU

Quantum Mechanical Bond Breaking Characteristics Explain Fracture Anisotropy of Silicon

In the June 5 issue of *Physical Review Letters*, scientists from the Max Planck Institut für Metallforschung in Stuttgart and the Universidad Autonoma de Madrid have reported quantum mechanical simulations of the bond breaking process at the tip of a crack in silicon which explain the well-documented cleavage anisotropy of this material.

Cracks in silicon propagate on two types of cleavage planes and clearly prefer one particular direction on both of these planes. This experimental finding cannot be explained with arguments based on the Griffith criterion, which relates fracture resistance to the surface energy of the fracture surfaces. A more thorough theoretical analysis is difficult because cracks form on the atomic scale but extend to macroscopic dimensions. However, the enormous increase in computing power recently has now opened new opportunities for such studies.

In the present case, the atoms around the crack tip were first loaded with the stress field of a macroscopic crack. The energy and all the forces on the atoms were then calculated *ab initio* using density functional theory. Upon increasing the externally applied load, the bond breaking process and the relaxations of the surrounding atoms were then monitored. Scientists Rubén Pérez and Peter Gumbsch said that the surprising result of the simulations was that the bond breaking at the crack tip proceeds differently for the different crack orientations. While the crack tip bonds smoothly lengthened for the easy propagation direction, the bond length remained almost unchanged for the difficult orientation until the external load reached a critical value at which the bond abruptly broke like a snapping elastic spring.

The discontinuous bond breaking is preceded by a significant load sharing between several bonds at the crack tip, which effectively shields the crack tip bond from the applied load. This leads to a so-called trapping of the crack, which stabilizes it up to loads far above the Griffith value. Consequently, the macroscopically observed fracture anisotropy can be directly viewed as a result of the difference in the way the atomic bonds break.

2D Photonic Bandgap Structure Significantly Improves Performance of Laser Emission from a Conjugated Polymer System

Having recently demonstrated the feasibility of surface-emitting conjugated polymer lasers using a one-dimensional feedback mechanism, researchers in Germany now report the development of a mechanically flexible polymer laser utilizing two-dimensional distributed feedback (2D-DFB) due to a two-dimensional photonic bandgap structure. Investigators from the Ludwig-Maximilians University

https://doi.org/10.1557/mrs2000.188 Published online by Cambridge University Press