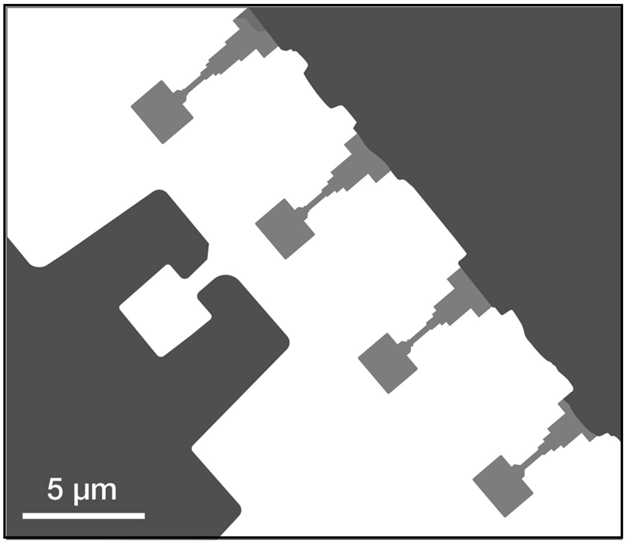
Large uniform tensile elasticity achieved in microfabricated diamond

When thinking of hard materials, descriptors like firmness, solidness, and rigidness come to mind. Researchers have now given a twist to these concepts by microfabricating single-crystal diamond bridge structures (~1 μm × ~100 nm), which sustain a certain degree of elastic strain. Diamond has an ultrawide bandgap (5.47 eV), good carrier mobilities, dielectric breakdown strength, and thermal conductivity. By straining the material, these properties can be translated to functional applications. Researchers at the City University of Hong Kong were able to adjust the bandgap of microfabricated diamond by means of elastic strain engineering, reducing it by approximately 2 eV. Their work was reported in a recent issue of *Science* (https://doi.org/10.1126/science.abc4174).



Side-view transmission electron microscope image showing microfabricated single-crystalline diamond bridge samples and corresponding diamond tensile gripper. Credit: *Science*.

Using bulk diamond grown from microwave plasma-assisted chemical vapor deposition as a starting material, they sculpted diamond samples with micrometer dimensions and performed *in situ* tensile loading–unloading experiments. These used a homemade tensile diamond gripper in which the sculpted structures were positioned and could undergo stretching. Also, fiducial markers were made by electron-beam-induced carbon deposition as a way of tracking strain change while being stretched inside electron microscopes. The experiments were performed at room temperature and the tensile stretching was tested over three directions, [100], [101], and [111]. Density functional theory (DFT) was used to approximate the electronic bandgap changes with tensile loading.

Loading–unloading experiments showed that full elastic recovery was possible. Diamond recovered to its original length after being subjected to uniform strain values of ~4.8%, 6.8%, and 7.5% for different cycles. To test the potential of exploiting this behavior in applications, the researchers fabricated a similar structure but with several bridges. As before, the new diamond array showed elastic strain, this time with a ~5.8% elastic strain value. From stress–strain graphs, a ~865 GPa Young's modulus was determined for sculpted diamond, as compared with ~1100 GPa for [101] bulk diamond, opening the door to future applications. The research team attributes this difference to a surface amorphous carbon layer and growth imperfections (versus single-crystal quality where the lattice is uninterrupted overall).

The team reported a maximum tensile strain of ~9.7% through an optimized sample geometry, which is close to the ideal elastic limit. Moreover, their DFT studies showed that the highest bandgap reduction was 3.09 eV at ~9% strain, for the [101] direction. In addition to directly exploiting these mechanical properties in the target material, the applied strain allows for a bandgap reduction that has potential in photonics, electronics, and quantum information technologies. Also, the microfabricated material's dimensions (μm × nm) suit scales for microelectromechanical systems and ever larger-scale integrations.

Alejandro Burgos-Suazo

Thank you for attending the
2021 Virtual MRS Spring Meeting & Exhibit

Don't miss these upcoming MRS Meetings!

FALL MEETINGS
November 28–December 3, 2021 Boston
November 27–December 2, 2022 Boston
November 26–December 1, 2023 Boston
December 1–6, 2024 Boston

SPRING MEETINGS
May 8–13, 2022 Hawai'i
April 10–14, 2023 San Francisco
April 21–26, 2024 Seattle
April 6–11, 2025 Seattle

mrs.org/meetings-events

© The Author(s), under exclusive license to the Materials Research Society 2021