# The Advanced Photon Source

## "Watching" Crystal Structure Change in Real Time

The long-standing scientific challenge of watching a material change its crystal structure in real time has been met by Washington State University (WSU) researchers using high-brightness x-ray beams and dynamic compression experiments at the U.S. Department of Energy's (DOE's) Advanced Photon Source (APS).

While exposing a sample of silicon to intense pressure—due to the impact of a nearly 12,000-mph plastic projectile—the researchers documented the transformation from the silicon's common cubic diamond (cd) structure to a simple hexagonal (sh) structure. At one point, they could see both structures as the shock wave traveled through the sample in less than half a millionth of a second.

Their discovery is a dramatic proof of concept for a new way of discerning the makeups of various materials, from impacted meteors to body armor to iron in the center of the Earth.

Until now, researchers have had to rely on computer simulations to follow the atomic-level changes of a structural transformation under pressure. The new method provides a way to actually measure the physical changes and to see if the simulations are valid. The researchers say their findings already suggest that several long-standing assumptions about the pathways of silicon's transformation "need to be reexamined."

The discovery was made possible by a new facility, the Dynamic Compression Sector (DCS) at the APS. Designed and developed by WSU in partnership with the APS, the DCS is sponsored by the DOE National Nuclear Security Administration, whose national security research mission includes fundamental dynamic compression science.

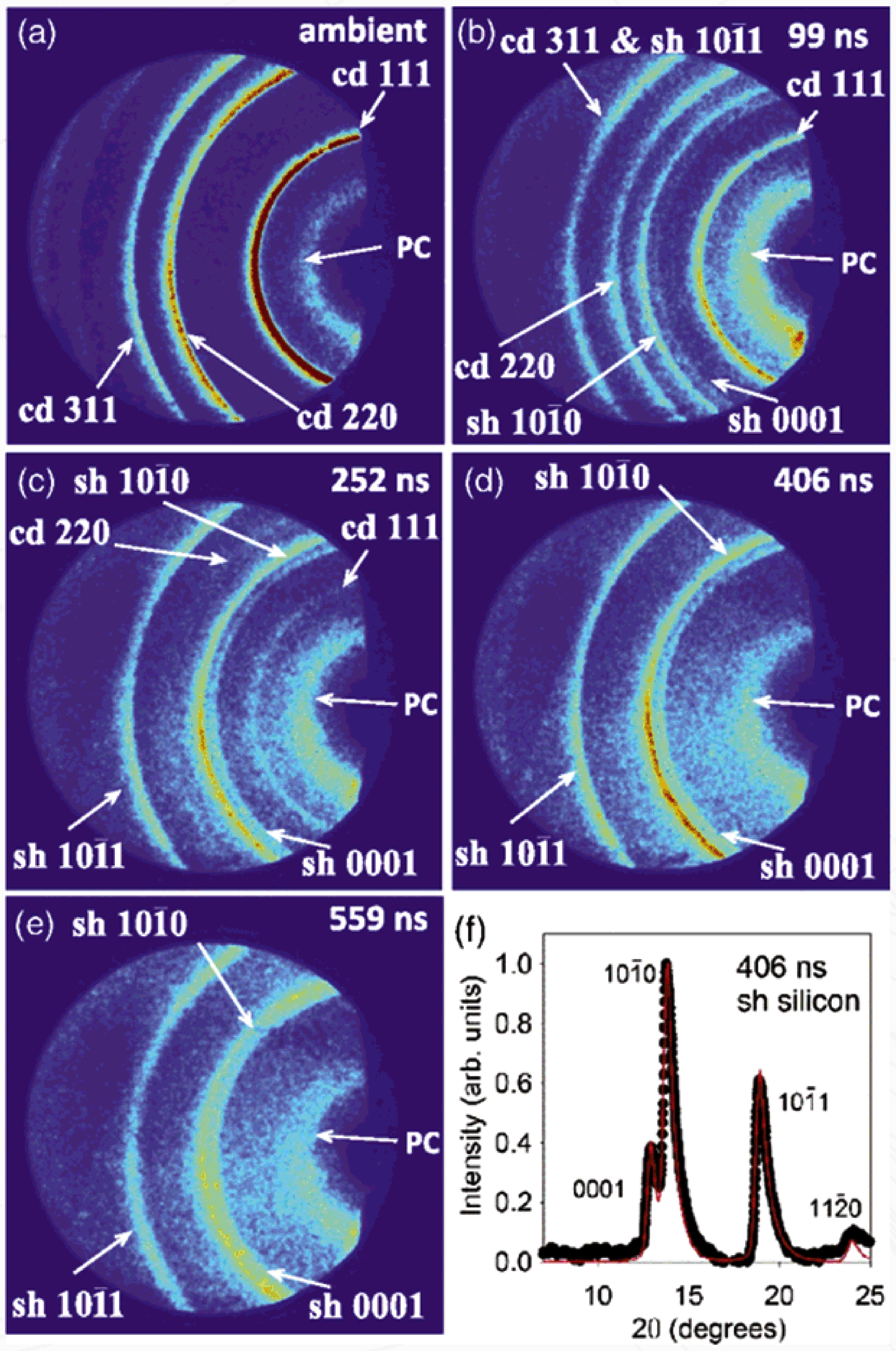
The researchers exposed silicon to 19 GPa, nearly 200,000 times atmospheric pressure, by firing a half-inch plastic projectile into a thin piece of silicon on a Lexan backing. While x-rays hit the sample in pulses, a detector captured images of the diffracted rays every 153.4 nanoseconds—the equivalent of a camera shutter speed less than a millionth of a second.

The results show how the crystal lattice is related to the ending hexagonal structure, showing how the crystal directions evolve.

*See:* S.J. Turneaure*, N. Sinclair, and Y.M. Gupta, "Real-Time Examination of Atomistic Mechanisms during Shock-Induced Structural Transformation in Silicon," Phys. Rev. Lett. **117**, 045502 (2016). DOI: 10.1103/PhysRevLett.117.045502

*Correspondence:* *stefant@wsu.edu

The Dynamic Compression Sector is operated by Washington State University and supported by the U.S. Department of Energy (DOE), National Nuclear Security Administration (NNSA), under Award No. DENA0002442. This publication is also based upon work supported by the DOE NNSA under Award No. DENA0002007. This research used resources of the Advanced Photon Source, a U.S. DOE Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357.




X-ray diffraction results for shocked polycrystalline silicon. (a) Ambient cd phase Si diffraction image. (b)–(e) Time-resolved diffraction images with listed times relative to impact time. The images show the temporal transition from cd phase Si to sh phase Si as the shock wave travels through the material. (f) Measured and simulated (solid line) sh diffraction peaks 406 ns after impact. The broad inner ring labeled PC is from the polycarbonate window and projectile. From S.J. Turneaure et al., Phys. Rev. Lett. **117**, 045502 (2016). © 2016 American Physical Society

## Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.

**General-user proposals for beam time during Run 2017-1 are due by Friday, October 28, 2016.**

Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

Argonne National Laboratory is a U.S. Department of Energy (DOE) laboratory managed by UChicago Argonne, LLC
The Advanced Photon Source is a U.S. DOE Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357



Advanced Photon Source
Bldg. 401/Rm A4115
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439 USA
www.aps.anl.gov
apsinfo@aps.anl.gov