METALS TECHNOLOGY AND THE ADVANCED PHOTON SOURCE

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Metals are essential materials for many of our most economically important industries and technologies, as well as for our security. Extreme-brightness x-ray beams from the Argonne Advanced Photon Source (APS) help scientists and engineers analyze the properties of many materials—including metals—at the molecular level, where important physical changes occur that can impact the way a material performs, or that can lead to new materials.

Understanding why and how metals deform will improve their structural properties and help to eliminate the eventual failure of components made of metal. Researchers from Risø National Laboratory and Argonne used APS x-ray beams to capture a series of "snapshots" of the evolution of defect patterns in copper during deformation, providing revolutionary insights into how a particular metal responds to a load.

Metallic glasses combine the outstanding mechanical properties of metals with the processing flexibility of glasses or polymers. They may be useful for many applications, including military hardware and sporting equipment, such as golf club heads. Learning more about the performance of this material will extend its use even further. Argonne and Johns Hopkins University researchers, using the APS, have obtained accurate measurements of the elasticity of metallic glass on the atomic scale as the material is deformed. At right is an x-ray scattering image of metallic glass superimposed on metallic-glass golf clubs.

Two or more elements (at least one of which is a metal) mixed together result in an alloy that is often superior to its constituents in terms of engineering potential. Alloys are ubiquitous in manufacturing and technology, so the more we know about alloys, the better off we are. Scientists from Argonne, other U.S. Department of Energy national laboratories, and several universities using APS x-ray beams are:

- **Investigating how to improve shape-memory alloys that have a unique, almost magical ability to "remember" their original shape, making them tremendously useful for military, medical, safety, and robotics applications.**
- **Studying how changes to the molecular structure of a titanium alloy that features prominently in products from turbine blades to airframes, from hip joint replacements to pacemakers, will affect its mechanical properties after welding and heat treatment.**
- **Learning how to control heat-related disruptions in the structure of high-performance superalloys that are ideal for industrial applications including the aerospace and marine industries.**

The Advanced Photon Source at the U.S. Department of Energy's Argonne National Laboratory provides this hemisphere's brightest x-ray beams for research. Scientists and engineers using the APS help assure a bright future for our nation by carrying out research that promises to have far-reaching impact on our technological and economic competitiveness, our health, and our fundamental knowledge of the materials that make up our world.

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Researchers from Risø National Laboratory and Argonne employed a novel experimental technique at X-ray Operations and Research (XOR) beamline 1-ID at the Argonne Advanced Photon Source (APS) to demonstrate that the formation of dislocation structure in a macroscopic sample can be observed during deformation. This work provides revolutionary microscopic insight into the collective behavior of defects under load. Such data provide decisive tests of advanced models of the strength of materials.

See: Bo Jakobsen[1], Henning F. Poulsen[1], Ulrich Lienert[2], Jonathan Almer[2], Sarvjit D. Shastri[2], Henning O. Sørensen[1], Carsten Gundlach[1], and Wolfgang Pantleon[1], "Formation and Subdivision of Deformation Structures During plastic Deformation," Science **312**(5775), 889 (12 May 2006). DOI: 10.1126/ science.1124141

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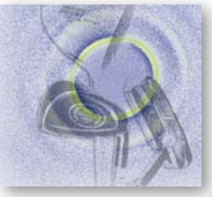

Researchers from Johns Hopkins University, Ames Laboratory, and Argonne used the XOR 1-ID beamline at the APS to measure elastic strain on a bulk amorphous metallic alloy. This study shows that elastic strain in metallic glass can be measured accurately with high-energy x-ray scattering.

See: T.C. Hufnagel[1], R.T. Ott[1,2], and J. Almer[3], "Structural aspects of elastic deformation of a metallic glass," Phys. Rev. B **73**, 064204 (2006). DOI: 10.1103/PhysRevB.73.064204

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With help from the XOR 2-BM beamline at the APS, researchers from the University of Maryland, the GE Global Research Center, Argonne, Hirosaki University, the University of Minnesota, the Caesar Research Center, Ruhr-Universitat Bochum, and the University of Maryland discovered a promising area from which better shape memory alloys for medical, electronic, optical, and other applications may spring.

See: Jun Cui[1,2], Yong S. Chu[3], Olugbenga O. Famodu[1], Alfred Ludwig[6,7], Sigurd Thienhaus[6,7], Manfred Wuttig[1], Zhiyong Zhang[5], and Ichiro Takeuchi[1,8], "Combinatorial search of thermoelastic shape-memory alloys with extremely small hysteresis width," Nat. Mater. **5**, 286 (1 April 2006). DOI: 10.1038/nmat1593

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See also: *APS Science 2006, the annual report of the Advanced Photon Source*, "Exploring Shape Memory Alloys," ANL-06/23, p. 39, and on the Web at http://www.aps.anl.gov/News/Annual_Report/APS_Science_2006.pdf.

Researchers from the Lawrence Livermore and Oak Ridge national laboratories using XOR/UNI beamline 33-BM-C at the APS imaged details of a crucial microstructural transformation that occurs in a workhorse titanium alloy during heating.

See: See: J.W. Elmer[1], T.A. Palmer[1], S.S. Babu[2], and E.D. Specht[2], "Low Temperature Relaxation of Residual Stress in Ti–6Al–4V," Scripta Mater. **52**, 1051 (2005).

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See also: *APS Science 2005, the annual report of the Advanced Photon Source*, "Stress Relaxation in a Titanium Alloy," ANL-05/29, p. 48, and on the Web at ANL-05/29; http://www.aps.anl. gov/News/Annual_Report/.

Researchers from Oak Ridge National Laboratory used XOR/UNI beamline 34-ID at the APS to study the structural changes that occur in the welds of Ni-based, single-crystal alloys. Their study shows that it is possible to retain the quasi-single-crystalline structure of Ni-based, single-crystal superalloys under certain welding conditions.

See: Oleg M. Barabash, Rozaliya I. Barabash, Stan A. David, and Gene E. Ice, "Residual Stresses, Thermomechanical Behavior and Interfaces in the Weld Joint of Ni-based Superalloys," Adv. Eng. Mat. **8**(3) (2006). DOI: 10.1002/adem.200500239

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See also: *APS Science 2006, the annual report of the Advanced Photon Source*, "When Superalloys are Joined Together," ANL-06/23, p. 38, and on the Web at http://www.aps.anl.gov/News/Annual_Report/APS_Science_2006.pdf.