Successful Inversion of the Coherent X-ray Diffraction Pattern of a Single Nanocrystal

I. Robinson, I. Vartaniants, G. Williams, M. Pfeifer, J. Pitney

Frederick Seitz Materials Research Laboratory, University of Illinois, Urbana, IL, U.S.A.

Coherent x-ray diffraction (CXD) experiments at the UNI-CAT 33-ID beamline have recorded the diffraction pattern shown in Fig. 1 from a 1-μm-sized gold crystal. Flares in the pattern arise from facets on the crystal's shape; these are modulated into fringes because the crystal is smaller than the coherence length of the x-ray beam used.

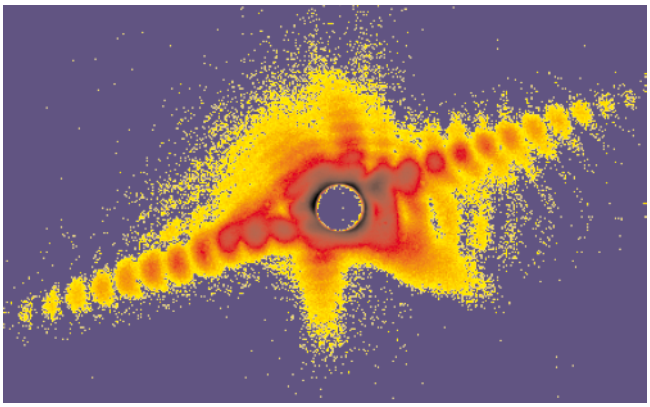

FIG. 1. Coherent x-ray diffraction pattern of a single gold nanocrystal measured with at beamline 33-ID of the Advanced Photon Source. A beam stop is blocking the intense central part of the pattern.

We have inverted diffraction patterns like these to produce images of the crystal under investigation. The computer algorithm we have developed can solve the inherent "phase problem" because the diffraction pattern is oversampled relative to the Nyquist frequency. In a sense, the computer acts as the objective lens of an x-ray microscope. The result is a two-dimensional projection of the shape of the crystal, shown in Fig. 2, which compares favorably with electron microscope images, also shown.

The method should be generally applicable to nanocrystalline materials. The future prospect is to be able to take apart granular materials grain by grain to understand the interactions between these. The 34-ID beamline at APS, which we have just finished building, will be dedicated to this kind of experiment. We expect to make progress in the pursuit of structural fluctuations in materials using the method of photon correlation spectroscopy. We are especially optimistic about being able to image the locations of strain fields within crystalline grains in a general way.

Acknowledgments

This research was supported by the Division of Materials Research of the National Science Foundation under contract DMR97-24294 and by the Frederick Seitz Materials Research Laboratory of the University of Illinois under contract DEFG02-96ER45439. The UNI-CAT facility at the Advanced Photon Source (APS) is supported by the University of Illinois at Urbana-Champaign, Materials Research Laboratory (U.S. DOE, the State of Illinois-IBHE-HECA, and the NSF), the Oak Ridge National Laboratory (U.S. DOE under contract with UT-Battelle LLC), the National Institute of Standards and Technology (U.S. Department of Commerce), and UOP LLC. Use of the APS was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

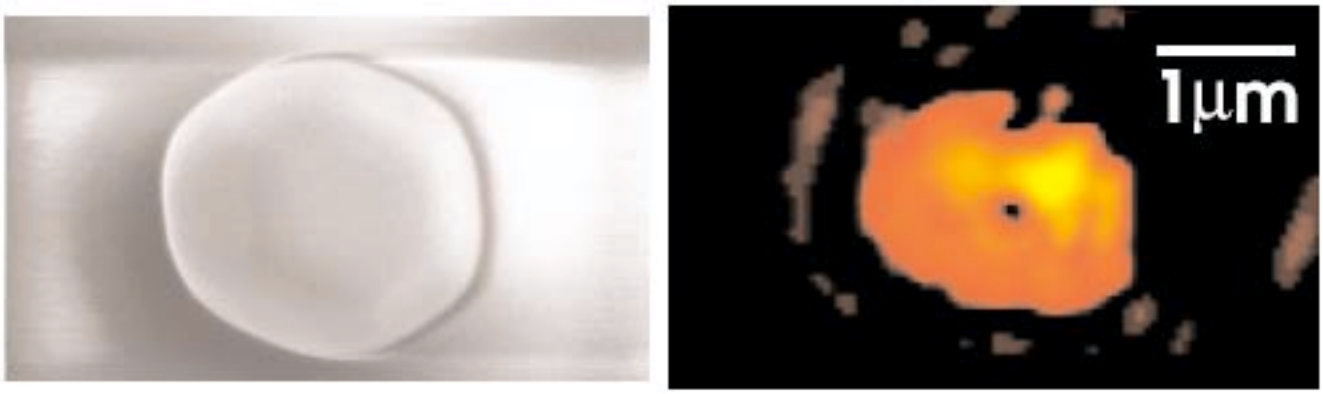

FIG. 2. Reconstructed image of one of the gold nanocrystals (left) and a scanning electron microscope image from the same preparation, displayed on the same scale for comparison (right).