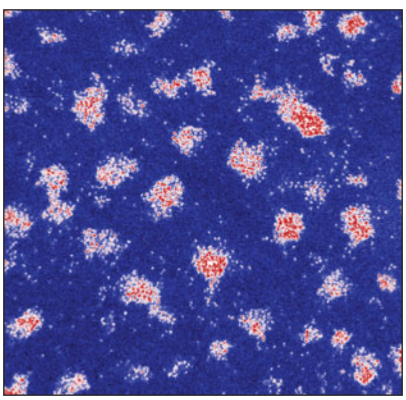
Single atoms imaged *in situ* with environmental STEM

Atomic-scale, real-time characterization of solid-state catalysts under gas-phase reaction conditions can provide unique information about reaction mechanisms. However, atomic-scale resolution is extremely difficult to achieve without the use of cryogenic temperatures and ultrahigh vacuum. Just a few months after receiving the L'Oreal-UNESCO Women in Science Award for developing the environmental transmission electron microscope (E-TEM), Pratibha Gai, the JEOL Professor and Yorkshire Forward Chair of Electron Microscopy from the University of York, UK, with Edward Boyes, who is co-director of the York JEOL Nanocentre, has designed a new environmental scanning TEM.



Environmental scanning transmission electron microscope (E-STEM) image reveals single Pt atoms dispersed on a carbon support under dynamic conditions. Image credit: Pratibha Gai, Edward Boyes, Leonardo Lari, and Michael Ward.

The E-STEM technology, published in the June issue of *Annalen der Physik* (DOI 10.1002/andp.201300068; p. 423), enables characterization of single atoms, small clusters, and nanoparticles in dynamic experiments. The instrument enhances the atomic-scale resolution of the E-TEM, and now incorporates full scanning functionality, aberration correction, diffraction analysis, and high-angle annular dark-field imaging. For *in situ* studies, the microscope can operate at >500°C in pressures of >0.1 mbar at the sample. Gai, who co-directs the York JEOL Nanocentre, said that the E-STEM "opens up exciting new opportunities for observing and studying reacting atoms."

To demonstrate the capabilities of the new microscope, Gai's research team examined Pt deposited on an amorphous carbon support. At temperatures of up to 400°C in 0.02 mbar hydrogen, the instrument was able to resolve both single Pt atoms and larger Pt nanoparticles. The persistence of isolated atoms can have ramifications for reactivity and particle growth, and Gai said that the work "reveals the importance of dynamic single atoms in catalysis in the reaction conditions." Additionally, the temperature dependence of the nanoparticle structures was observed, as the clusters evolved from disordered 1–2 layer discs to more cube-like configurations when heated for 30 minutes at 500°C under hydrogen. At this temperature, single atoms were not observed to the same extent due to either their incorporation into the larger particles or their increased mobility at the elevated temperature.

Mingwei Chen of Tohoku University, who was not involved with the work, asserts that the new E-STEM "is a promising technique to help us to solve many important catalysis-related questions." However, despite the vast improvement in operating pressure that the new E-STEM allows, both Chen and Gai agree that a further increase would be valuable. The pressures currently available to the instrument are enough to saturate the surface of the sample, but higher pressures would provide access to more catalytic reactions. Gai said that the research team is "going in stages" to improve the pressure range by orders of magnitude in the coming months.

Emily Lewis

Crystalline reflectors enable ultralow-thermal-noise optical cavities

Atomic clocks and gravitational-wave detectors involve some of the highest precision experimental measurements in the world. However, both have become limited by thermally induced noise in high-reflectivity mirrors used in optical interferometric cavities. This noise originates from the mechanical damping characteristics of tantala-based high-reflectivity coatings, and has been difficult to reduce. Now, G.D. Cole, W. Zhang, and colleagues at the University of Vienna; Crystalline Mirror Solutions; and JILA, the joint institute of the National Institute of Standards and Technology and the University of Colorado, Boulder, have demonstrated high-reflectivity compound-semiconductor-based crystalline mirrors with a factor-of-ten reduction in thermally induced noise. They report their findings in the July 21 online edition of *Nature Photonics* (DOI: 10.1038/NPHOTON.2013.174).

Current ultrahigh-precision optical interferometers use mirrors based on alternating dielectric layers of silica (SiO_2) and tantala (Ta_2O_5) deposited on transparent substrates using ion-beam sputtering. These exhibit optical absorptions as low as a few parts per million. The noise limit for optical cavities formed from these mirrors is dominated by "coating thermal noise," which is a consequence of the Brownian motion of the surface. This is driven by inherent thermal fluctuations and is controlled by the excess mechanical damping of the tantala layers. For gravitational wave detectors, this means that multi-kilometer-long optical cavities have noise characteristics dominated by optical coatings only a few microns thick. Previous efforts to minimize this noise have involved adding TiO_2 to the tantala layer to reduce the mechanical damping, but have only improved the noise floor by a factor of two.

https://doi.org/10.1557/mrs.2013.216 Published online by Cambridge University Press