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Measuring lattice distortions from HR(S)TEM images

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High-resolution transmission electron microscopy (HRTEM) and high-angle annular dark-field imaging in scanning transmission mode (HAADF-STEM) provide a wealth of information about atomic configurations and lattice distortions at the nanoscale. In principle, these HR(S)TEM images can be analysed using similar quantitative techniques but each have their own specificities. Here, we present analysis using two techniques: geometric phase analysis [1] and model-based analysis of image contrast [2]; and gives results for two types of images: HRTEM and HAADF-STEM.

Geometric phase analysis (GPA) is best suited for the determination of the distortion of the crystalline lattice over large fields of view but at nanometre resolution, rather than atomic. Model-based analysis relies on fitting the contrast of individual atomic columns and is therefore more suitable to measuring displacements at the very highest resolution. Indeed, the displacements of atomics columns within the unit cells can be monitored across defects and interfaces with this technique, something impossible for GPA. In principle, model-based analysis is better adapted to the analysis of HAADF-STEM images than HRTEM whilst GPA is equally applicable to both.

When comparing TEM and STEM modes, TEM still gives the larger field of view, though recent progress in scan control is reducing the difference. Nevertheless, HRSTEM imaging still suffers from scan distortions which hamper the measurement of atomic displacements. HAADF-STEM provides images of thicker crystal which are in general more easily interpretable than HRTEM. Aberration correction has benefited both techniques, producing images with superior signal-to-noise and hence results with higher precision, as the examples will show.

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Structures of catalytically important nano-structured materials revealed by TEM

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As the size of metal particles approach to nanometer range, they have considerable scientific and technological significance in the catalytic field [1]. Despite the wealth of experimental and theoretical data, it remains unclear what kind of structure they have. The most straightforward one is transmission electron microscopy (TEM) to identify the structure of metal nanoparticles [2]. In particular, the spherical aberration (Cs) corrected scanning TEM is extensively used for extracting atomic and chemical information through a quantitative high-angle annular dark-field (HAADF) image which is remarkably senstive to the atomic number (Z) [3] and number of atoms along the electron beam [4]. Here we show some examples for atomic-level characterization of metal nanoparticle.

Three dimensionally connected mesoporous Pt nanonetworks were synthesized within the mesopores of silica with Ia-3d symmetry and their structure was characterized. The Pt nanonetwork was formed with nearly single fcc crystalline nature and there was no specific orientation relationship between the Pt nanonetwork and original silica mesoporous crystal. Interestingly an envelope surface of the Pt nanonetwork showed rhombic dodecahedron.

TEM structural characterisation was also performed for ultrafine Ru and Rh nanoparticles synthesized by a polyol reduction method. We used free-standing graphene sheets as supporting film to obtain a clear image of sub 3 nm nanocrystals. By reducing background signal, we could obtain clear lattice-resolved image of nanoparticles. Using high resolution TEM (HRTEM) and Z-contrast STEM images, we could determine the shape and structure of each metal nanoparticles. Ru nanoparticles had a multiply twinned polyhedral (a face centered cubic structure) and triangular nanoprismatic shape (a hexagonal close packed structure). On the other hand, Rh nanoparticles showed a similar morphology, but only having a face centered cubic structure.

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Imaging a sub-Ångström electron beam after scattering in a crystal

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The ability to generate electron probes in transmission electron microscopes (TEM) with a diameter less than one Ångström has opened the possibility of obtaining information about the position, type and bonding of individual atoms selected within a specimen. However, to extract this information, it is critical to understand how a sub-Ångström electron probe scatters within a crystal. Calculations have shown [1-4] that the electron probe rapidly disperses from its impact point onto and between adjacent atomic columns, so that the spatial origin of the final scattered signal is not easily attributable to specific atoms within the specimen. Here we describe a method for imaging the distribution of a sub-Ångström electron probe in real space after scattering from a crystal, using a double-aberration corrected TEM. We image the scattered electron intensity in real space with sub-Ångström resolution for a sequence of 10 incident probe positions located at 0.3Å intervals within a unit cell of Au [5]. These images reveal the acute sensitivity of the electron distribution to these tiny shifts in the probe position and to the local site symmetry of the incident probe. We also image the intensity distribution after excitation of a plasmon for different incident probe positions within a unit cell of LaB_6, which are again