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Environmental TEM in Energy Research

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The wealth created in the World over the last century is based on easy access to inexpensive fossil fuels. This era is coming to an end. The resources are limited and the demands from everywhere in the world is growing rapidly. At the same time, it is becoming increasingly clear that the emission of CO_2 that follows the use of fossil fuels is threatening the climate of the Earth. Arguably, this makes the development of sustainable energy solutions the most important scientific and technical challenge of our time.

Electron microscopy has played a large role in energy research over the last decades. The increasing use of particularly environmental transmission electron microscopy (ETEM) in materials science provides exciting new possibilities for investigating chemical reactions. Careful experimentation can provide input for the development of new generations of catalysts and photocatalysts for e.g. energy production. In order to design experiments with the highest chance of a successful outcome, a detailed understanding of both the interaction of fast electrons with gas molecules (Figure 1, left), the effect of the presence of gas on high-resolution imaging and the behavior in this environment is necessary. If data is to be interpreted quantitatively, interaction of the primary electrons with gas molecules must be taken into account. Whereas conventional TEM samples are usually thin (below 10-20 nm), the dilute gas in the environmental cell fills the entire gap between the pole pieces and is thus not spatially localized. Imaging samples with a simple geometry, such as gold particles on a flat graphene substrate and analyzing the variations in contrast (Figure 1, right), provides a means for understanding the issues involved with imaging in the presence of a gas.

In this work, we have explored the capabilities, possibilities and challenges of using ETEM in catalysis and energy related research exemplified by nanoparticle dynamics, photocatalysis and alcohol synthesis.

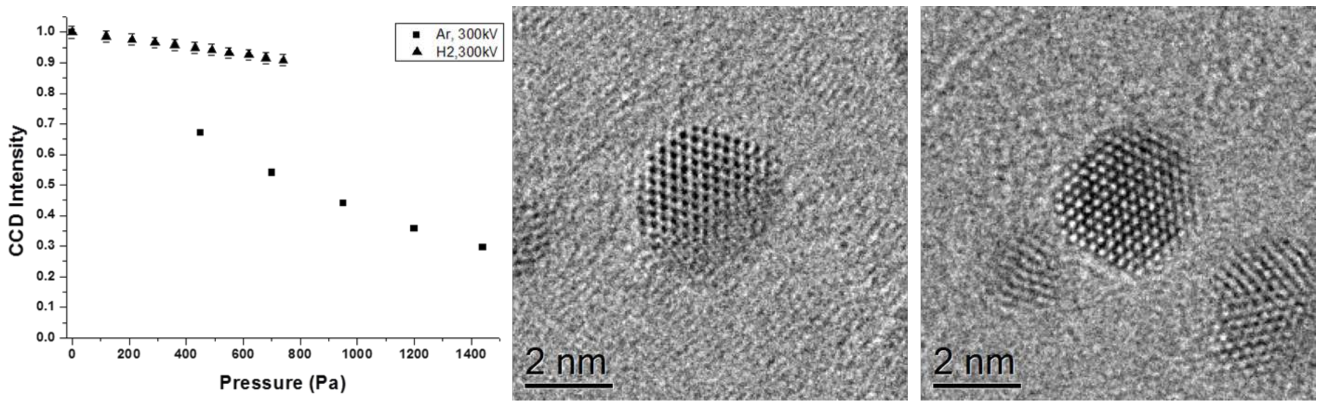

Figure 1: Left: Variation in intensity measured on the CCD as a function of gas pressure in the sample region; middle: graphene-supported Au nanoparticle imaged in vacuum; right: Au nanoparticle imaged in hydrogen at 200Pa.