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Surface dynamics of catalytic nanoparticles in non-vacuum conditions

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In situ electron microscopy is a unique method for imaging materials in their operating state or for monitoring growth phenomena at the atomic scale [1]. Data collected under operating conditions tells a lot more about a material than that acquired under high vacuum conditions. However, the electron beam can have a significant influence on the structure of materials, particularly under non-vacuum conditions. *In situ* electron microscopy investigations have been performed through modification to the microscope column by inserting pressure-limiting apertures. Over the last decade, the use of electron transparent membranes has been more mainstream. Whereas the former requires microscope modifications, it sets no restrictions on the sample holders. The latter makes use of a dedicated holder that can be moved between different microscope installations.

With recent development of camera technology, the use of *in situ* imaging has become even more interesting. The latest generation of cameras provide high sensitivity and high frame rates making it possible to detect dynamic phenomena such as particle migration and mobility of atomic columns with a higher temporal resolution than previously while keeping the electron dose rate at a minimum. Even at low electron dose rates, we can detect individual atomic columns and track them in time.

The recent developments facilitate the analysis of nanoscale dynamics of materials. Particularly in catalysis, the surface structure and how the surface configuration changes with changing surroundings have attracted tremendous attention and has been the topic of several investigations using a plethora of experimental approaches [2, 3]. We have studied mainly the surfaces of gold nanoparticles supported on cerium dioxide under condition relevant for CO oxidation.

Using environmental transmission electron microscopy, gold nanoparticles were subjected to hydrogen, oxygen and carbon monoxide containing atmospheres at elevated temperatures. Several types of structural changes were observed and an attempt at categorizing these events was made [4]. In presence of a hydrogen gas a concerted motion of surface atoms was observed. Entire layers at the {100} facet moves in a concerted fashion to a different location on the nanoparticle and reappears later, as seen on Figure 1. The process is observed continuously during image recording. As the temperature is increased, the process occurs faster. Under similar conditions, the topmost layer of the {111} facet was observed to glide parallel to the surface, still in a concerted fashion, as seen on Figure 2.

In this work, we will show our observation of different changes observed in gold nanoparticle samples and our attempt at understanding the underlying dynamic processes and the effect of the electron beam.

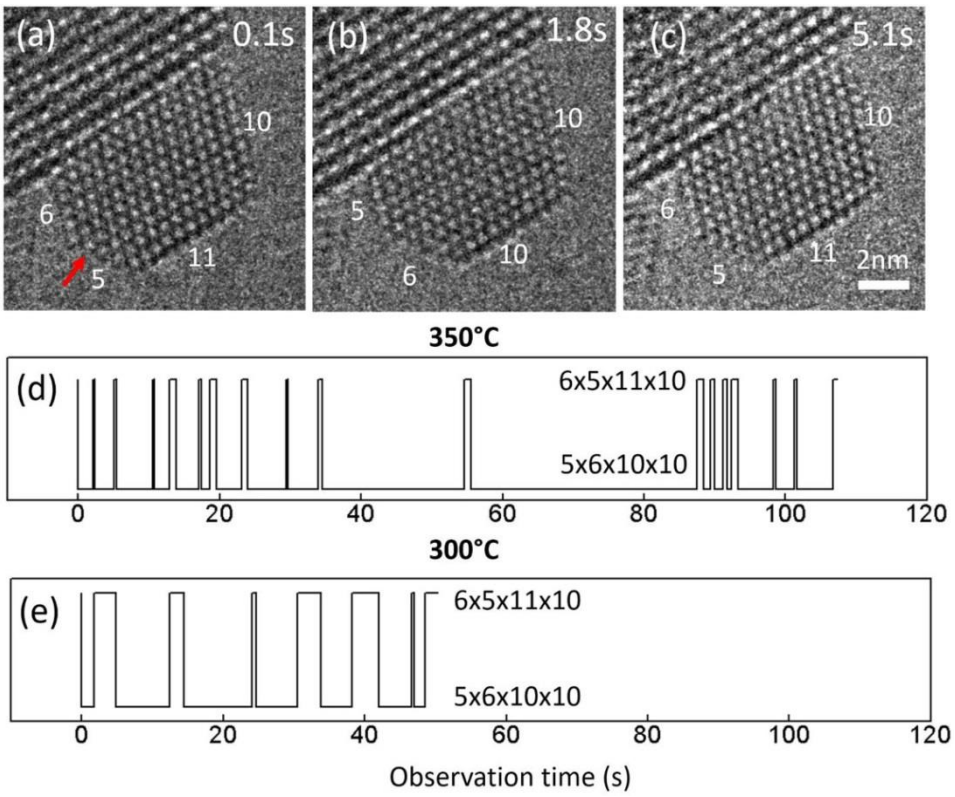

Figure 1. Figure 1: Evolution of the surface configuration of a gold nanoparticle in 4.5 Pa hydrogen gas over time [4].

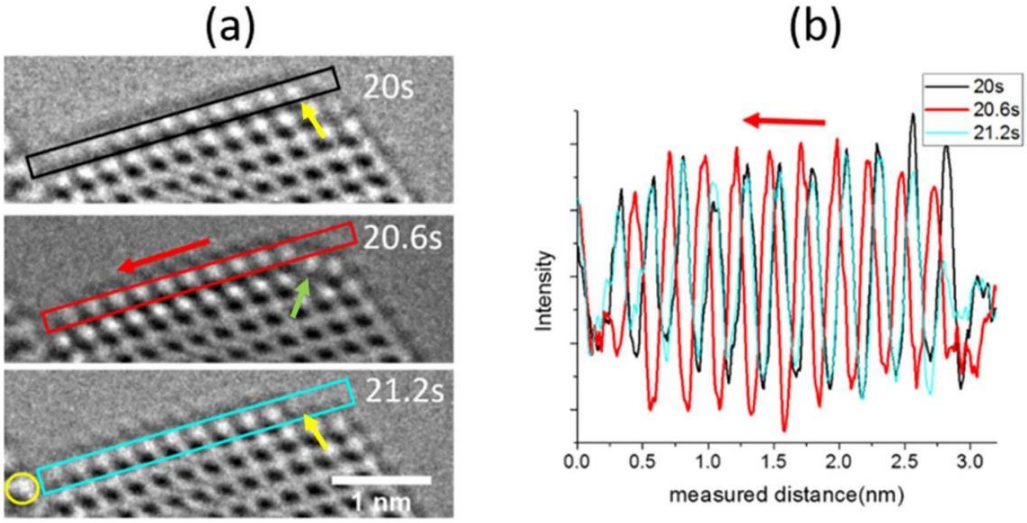

Figure 2. Figure 2: Gliding of the topmost layer on the {111} facet [4].

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