Nano-microscopy reveals collective transport of gold atoms in real-time

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Researchers at Delft University of Technology used a High Resolution Electron Microscope to observe in real-time the collective transportation of gold atoms in a thin layer. This research illustrates the rapid progress that is currently being made by real-time nano-microscopy. Within 5 years this research area should be able to take the step from the laboratory to realistic conditions, and this will open up a wealth of possibilities for industry and the medical world.

In this research project, which was conducted by Delft University of Technology's Kavli Institute of Nanoscience, a small group of gold atoms were placed on a gold surface. The Delft researchers then used a High Resolution Electron Microscope (HREM) to show in real-time how this group of atoms collectively sank into the underlying layer of atoms (see the short film at http://virtuallab.nano.tudelft.nl/movies/audis/) and then became arranged in the shape of a surface dislocation (which is an extra row of atoms that is 'squeezed' between the other rows of atoms).

At a later stage, the dislocation disappears, as if a string of beads has been pulled away lengthwise. According to Professor Henny Zandbergen, this is the first time that such a phenomenon has been observed in real-time. This was possible due to the progress that has been made in recent years in image-forming techniques and the processing of the data.

Atomic calculations validated and certified the observation mechanism: for this, Delft University of Technology worked in close cooperation with Princeton University (USA). The research results were published in *Physical Review Letters*. According to Professor Zandbergen, the observable manner in which the atoms arranged themselves in the underlying layer and the movement of the dislocation (see film) is, in principle, an attractive way of transporting materials from the upper layer to the underlying layer and also within the underlying layer. Normally - and as comprehensively detailed in scientific literature - before an atom can 'hop' from one layer to the underlying layer, certain energy barriers exist. But such barriers do not exist with this manner of transport. The findings of this TU Delft research project clearly indicate that when people are modelling the (industrial) production of thin layers, they must also consider this type of collective processes.

Zandbergen's research is a typical example of the rapid progress currently being made by nano-microscopy, or nano-imaging. Nano-microscopy – the observation of individual atoms or molecules - is becoming increasingly more accurate and faster. It is now possible to observe the movements of atoms in real-time, and this allows the position of the atoms to be determined with great precision (approximately 0.01 nm). So far, this has primarily been observed under laboratory conditions. But soon live nano-imaging will take the next step to realistic and industrial conditions: real-life, real-time nano-imaging.

This will open up a wealth of possibilities for all kinds of medical and industrial applications, especially for those that involve a combination of various nano-imaging technologies and conventional optical microscopy. This will allow information about the different length scales to be combined. It will then be possible to follow the biological processes very realistically, and this will also provide many excellent opportunities for industry. One example is catalysis research. Real-life, real-time nano-imaging allows for closer observation of the catalysis processes, with the logical consequences of this being better catalysts and more efficient chemical processes. In the Netherlands, Delft University of Technology, Leiden University and the microscope manufacturing company FEI, are conducting joint research in nano-microscopy.

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