different metal nanoclusters. The analysis enabled the researchers to rank 14 different metals both in order to their bonding with carbon (3) and their catalytic activity, showing significant variation across the Periodic Table of Elements. The complex atomic dynamics revealed directly by imaging in real time sheds light on atomistic workings of nanocatalysts, with key features mirroring heterogeneous catalysis, as shown by the Sabatier principle (4) – the cornerstone of heterogeneous catalysis that we can now demonstrate at the atomic-scale.

Ute Kaiser, Professor in Experimental Physics and Leader of the Group of Electron Microscopy for Materials Science at Ulm University, who conducted the studies in the frame of the SALVE project (www.salve-project.de) says “Aberration-corrected transmission electron microscopy in combination with carbon nanotubes as test reactors now allowed us for the first time to study systematically the changes in the atomic structure of metal nanoclusters caused by their catalytic activity and their defect formation rate. Our extensive systematic study enabled fundamental conclusions for the understanding of catalysis at the level of the single atoms. We found that also the metal catalysts are changing during their reaction with carbon and proposed a new classification of the transition metals with respect to their catalytic activity.” Professor Kaiser has recently been appointed a Honorary Professor at the University of Ulm.

Figure 1: Illustration of nanosized clusters of transition metals.

The Private Life of Nanoclusters

A team of researchers finds a new table of elements for the catalytic activity of transition metals

September 4th, 2018 - The atomic-scale dynamics of metal nanoclusters determine their functional and chemical properties, such as catalytic activity. Indeed, many key industrial processes currently rely on nanocatalysts: the Fischer-Tropsch process on Fe, the water-gas shift reaction or methanol synthesis on Cu, and oxygen reduction in fuel cells on Pt/Co, just to name a few. With latest estimates indicating that catalytic chemical reactions contribute 30–40% of the global gross domestic product (GDP), revealing nanocluster’s catalytic behaviours at the level of the single atoms an urgent task. However, the complex challenges are nanocatalyst’s non-uniform structures coexisting within the same sample and their highly dynamic nature during catalysis. (And this made elucidation of the exact atomistic catalytic mechanisms virtually impossible until the German-British team, most of them are also author of the current Nature Communication paper) discovered that the electron beam in the atomic-resolution low-voltage transmission electron microscopy experiment acts simultaneously as the probe to image and the source of energy to drive the reaction; in fact they succeeded in filming reactions of molecules (1). (doi: 10.1021/acsnano.6b08228)

In their latest work the team applied their strategy on the comparison of atomic scale dynamics for the middle and late transition metal nanocatalysts, published in Nature Communications (2). (DOI: 10.1038/s41467-018-05831-z) Their analysis of the dynamical behaviour in atomically resolved time-series of TEM images revealed chemical transformations promoted by the different metal nanoclusters. The analysis enabled the researchers to rank 14 different metals both in order to their bonding with carbon (3) and their catalytic activity, showing significant variation across the Periodic Table of Elements. The complex atomic dynamics revealed directly by imaging in real time sheds light on atomistic workings of nanocatalysts, with key features mirroring heterogeneous catalysis, as shown by the Sabatier principle (4) – the cornerstone of heterogeneous catalysis that we can now demonstrate at the atomic-scale.

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of the future."

Unravel the intimate lives of the tiniest building blocks of metals, this study demonstrated that metal nanoclusters entrapped in carbon nano test tubes provide a universal platform for studying organometallic chemistry and enable direct comparison of the bonding and reactivity of different transition metals as well as elucidation of the structure-performance relationship for nanocatalysts – vital for the discovery of new reaction mechanisms and more efficient catalysts of the future.

References:

Figure 2: Time-series images of nanocrystals during continuous irradiation. First line: A Ni nanocluster abstracts carbon atoms from a point of contact with the host NT and promotes the formation of a new carbon structure. Second line: A Pt nanocluster abstracts carbon atoms from the host NT, restructures them into a carbon shell, incorporates them into the host NT and forms a new carbon shell inside the NT.