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In-situ visualization and analysis of single atom dynamics in nanoparticle catalysts on ceramic supports using novel environmental (scanning) transmission electron microscopy

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Many heterogeneous catalytic processes employ metal nanoparticles on ceramic oxide supports to produce environmentally sustainable energy, healthcare products and to control emissions. These catalytic chemical reactions take place at the atomic level. Understanding and controlling complex catalytic reactions at the atom level are therefore crucial for the development of improved processes and materials. To visualize and analyse gas-ceramic supported catalyst reactions, we have designed and constructed the first atomic resolution environmental transmission electron microscope (ETEM) (1), which has been exploited for commercial production and used globally. We have now developed it further to support full ES(scanning) TEM functionality with aberration correction (AC), (AC ESTEM). Single atom resolved high angle annular dark field (HAADF) imaging (image) and full analytical functionalities, including electron diffraction and EDX, are enabled for the first time under controlled chemical reaction conditions of high temperatures in a continuously flowing gas atmosphere around supported nanoparticle catalysts while retaining single atom sensitivity for atom-by-atom analysis of critical catalytic processes [3-5]. The AC ESTEM instrument in our laboratory has been used to obtain new insights into processes of metal nanoparticle catalyst activation and deactivation on ceramic supports which has both economic and societal importance. Gas pressures used are fully adequate to flood the surface with gas molecules and to drive the chemistry which also aim to avoid electron beam effects. The AC ESTEM supports quantitative atom-by-atom analysis of the underlying mechanisms of sintering and metal-ceramic support interacttons in nanoparticle systems supported on several ceramic supports (ceria, alumina and silica) have been been studied with new levels of single atom precision using the novel capabilities in our laboratory and leading to a better informed understanding of their effect on the catalyst function and enabling developments needed going forward

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