Quantum confined two-dimensional metals for heterogeneous catalysis

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Abstract:

The creation of a green economy demands fresh approaches in energy-related technologies. Two dimensional (2D) materials have been touted as a compelling platform in several key green-energy related areas such as energy storage as battery components, and energy conversion as a catalyst; however, a lack of scalable synthesis methods for producing high quality and chemically stable 2D materials has limited interest outside of the electronics community. Confinement heteroepitaxy (CHet) is a recently developed breakthrough technique for synthesizing large-area, air stable 2D metals. CHet produces 2D metals with a protective capping layer of graphene so it can be deployed with elements across the periodic table including transition metals. Quantum confinement, strain from forced lattice matching with the silicon carbide (SiC) substrate, and a non-centro symmetric bonding gradient over a ~1 nm distance (i.e., covalent to metallic to van der Waals) severely modifies the electronic structure of 2D metals versus bulk; thus, quantum confined 2D metals could offer an entirely new class of catalysts.

This work explores 2D metals for heterogeneous catalysis grown on wafers and microparticles. Specifically, we demonstrate, for the first time, the growth of 2D metals on particles, motivated by the need for large surface-to-volume ratio for industrial catalysis. Confirmation of successful growth of 2D metals on particles by Raman spectroscopy will be presented. In addition to particles, wafers of 2D metals are studied as a model system to investigate the fundamental catalytic properties. To achieve this, a custom, 3D-printed ceramic microreactor was designed. CO combustion was chosen to screen the catalytic performance because it's highly exothermic nature could be a strong match for the excellent thermal conductivity of the SiC/2D metal/graphene material system. This work aims to unlock the potential of 2D metals as a next generation industrial catalyst to contribute towards the green energy revolution.