

# Adsorption and in-diffusion of Hydrogen at metal and metal oxide surfaces

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Hydrogen adsorption and absorption at solid surfaces is a prototype surface reaction, where fundamental concepts of gas-surface interaction are embodied. As such, hydrogen interaction with solid surfaces has been extensively studied in the surface science community [1]. To investigate the behavior of hydrogen at surfaces, our group has developed nuclear reaction analysis (NRA), which allows us to quantitatively measure the H depth distribution and H location in materials [2], and resonance-enhanced multiphoton ionization combined with atomic/molecular hydrogen beams, which allows us to detect the internal quantum states of hydrogen including the spin and ro-vibrational motion [3]. With these techniques, we have studied molecular physisorption, dissociative adsorption, and diffusion into the bulk of hydrogen on various metals such as Pd, V, Fe and Ti and metal oxides such as TiO<sub>2</sub>, CeO<sub>2</sub> and perovskite oxides.

Palladium and Vanadium are typical H-absorbing metals. We demonstrate the hydrogen diffusion across the Pd surface can be controlled by molecular cap and surface alloy formation [4]. By applying low-energy hydrogen ions, furthermore, metastable hydride states were formed in the near-surface region of Pd and V films. The resistance of the films was found to change as the films relax from the metastable states to stable states. By measuring the time evolution of the film resistance, the diffusion of H in the films were analyzed, which revealed a crossover from a classical thermal regime to a quantum regime [5]. Even if the substrate does not absorb hydrogen exothermically, hydrogen ions penetrate the surface and migrate into the near-surface region causing heavy H doping. The depth distribution measured by NRA was consistent with SRIM simulations. As observed by photoemission spectroscopy and transport measurements, it is shown that hydrogen acts as an electron donor for most metal oxides including TiO<sub>2</sub> and SrTiO<sub>3</sub> [6]. From the depth profile of H, the diffusion coefficient in TiO<sub>2</sub> is analyzed.

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