Low-temperature catalytic activity of CO oxidation and NO reduction driven by uni-sized Pt clusters bound to Si substrate

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As exhaust gas from fuel-efficient engines is cooler than that from conventional ones due to high thermal efficiency, lower-temperature catalytic converters are required for sustainable society still for decades. We are tackling this crucial issue with new materials, i.e. Pt cluster disks chemically bound to a Si substrate, Pt_N/Si (N=5–60) [1]. We have found that CO oxidation on the Pt_{30}/Si disks starts at 130 K by atomically-adsorbed O [2], which is lower by 200 K than that on the Pt(111) single-crystal surface [3] (see Figure 1). Furthermore, NO reduction proceeds at lower temperature by 100 K than supported Pt nano-particles. In this talk, the prominent low-temperature catalytic activity is unveiled on a basis of surface-chemistry measurements.

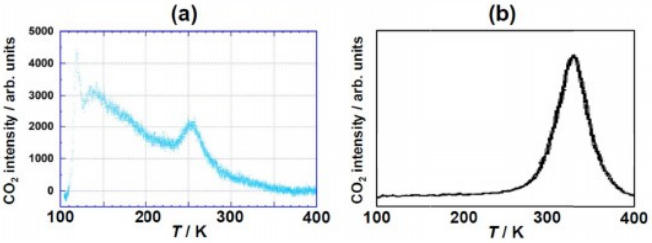

Figure 1. Temperature-programed reaction/desorption spectra of CO oxidation by atomically-adsorbed O on (a) Pt_{30}/Si disks and (b) a Pt(111) single-crystal surface.

This particularity was observed also in turnover rates (TOR) under a more practical condition of continuous supply of CO and O_2 [4]. Figure 2 shows quasi-stead-state TOR of the CO oxidation on the Pt_{30}/Si disks. Hysteresis is discernible in the heating and subsequent cooling periods due to the bistability switching between O- and CO-rich regimes of Pt_{30}/Si, while no hysteresis for Pd nanoparticles on an MgO substrate [5]. Furthermore, the CO oxidation proceeds at as cool as 330 K in the cooling period.

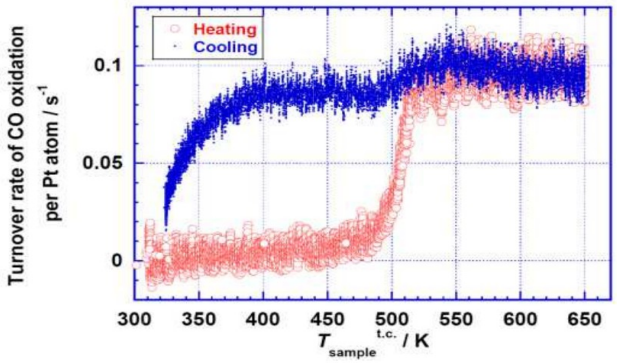

Figure 2. CO-oxidation TOR on Pt_{30}/Si disks at O_2 and CO pressures of 1.3×10^{-4} and 2×10^{-5} Pa, respectively.

Considering a report that a small reaction rate compared to the adsorption rates damps the hysteresis of nano-reactors [6], the atomic O species produced by Pt_N/Si are highly reactive to maintain the hysteresis. This is also true in the NO reduction, in which reactive atomic N species recombine into N_2 at lower temperatures. It is probable that the low-temperature and highly-efficient catalytic activities of Pt_N/Si derive from electron accumulation at the sub-nano interface between the Pt cluster and the Si surface [1].

References

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