High-resolution Kelvin Probe Force Microscopy Study of Pt Clusters on TiO_2(110) in a N_2 Gas Environment with an Atmospheric Pressure

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1. Introduction

Platinum is a highly efficient cocatalyst for photocatalytic reactions on a titanium dioxide (TiO_2) substrate. Improved catalytic performance is attributed to electron trapping by nanometer-sized Pt clusters as well as to their catalytic activity. Kelvin probe force microscopy (KFM) utilizing frequency modulation atomic force microscopy (FM-AFM) allows us to map local surface potentials (SPs). However, high-resolution KFM imaging has been limited in vacuum environments where the Q-factor of the cantilever resonance usually exceeds 10,000. It is heavily reduced in an environment with an atmospheric pressure and hence the effective force sensitivity is decreased. We have developed a high-resolution KFM working in such an environment based on a commercially available AFM (Shimadzu: SPM-9600).

2. Experimental

The TiO_2(110) surface was cleaned by repetition of argon ion sputtering at room temperature and vacuum annealing at 900 K in an ultrahigh vacuum chamber. Pt was evaporated from a heated Pt wire out gassed beforehand. After taking out the sample from the chamber, we introduced it into the environment controlled chamber and atmosphere is substituted for dry nitrogen. We have developed a low noise cantilever deflection sensor by optimizing the optical design of the sensor and by modulating the laser power with a radio frequency signal, which was strikingly effective in the reduction of the optical feedback noise and the interference noise. The noise level of the optical beam deflection sensor was reduced to 7 fm/$\sqrt{\text{Hz}}$ in air.

3. Results and discussion

Fig.1 shows high-resolution KFM images of Pt clusters on TiO_2(110) substrate in N_2 gas with an atmospheric pressure. The bright particles marked by circles in the topographic image (a) are Pt clusters. The surface potentials of the Pt clusters marked with circles are higher in the SP image (b) than those on the surrounding TiO_2. In contrast, the surface potentials of some other Pt clusters indicated by arrows are lower. These results demonstrate that our KFM is capable of mapping surface potentials with a few nanometer resolution even in an atmospheric pressure environment to simulate catalysts in their working states.

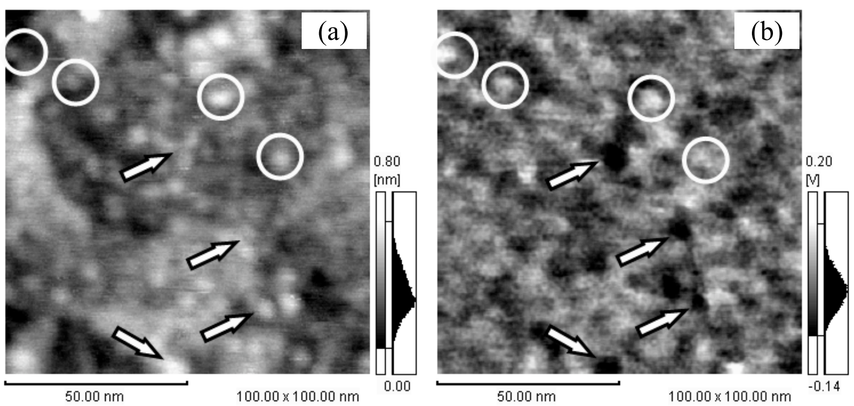

Fig.1 KFM images of vacuum-deposited Pt clusters on a TiO_2 substrate in an atmospheric pressure N_2 gas environment. (100nm□, Δf=-80Hz, A=5.2 nm, Q=436) (a) Topographic image and (b) surface potential image.