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Approach to XANAM imaging by Quartz tuning fork cantilever

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Scanning Probe microscopy (SPM) is a promising tool to for substrate surface analysis to reveal surface morphology. Recent rapid progress in SPM technology can also provide physical and chemical properties of substrate surfaces. Especially, scanning tunnelling microscopy (STM) and noncontact atomic force microscopy (NC-AFM) provide such information at the atomic level. However, elemental analysis by SPM is still a difficult issue compared to the other challenges. Previously, we have proposed the X-ray aided noncontact atomic force microscopy (XANAM), a new SPM technique for chemical analysis in combination with Synchrotron X-ray. Previously, we found interaction between X-rays and the attractive force in NC-AFM measurements on Au [1-3] as two characteristic features; one is a peak occurred near the absorption edge energy of sample's element, and another is a gradual change across the absorption edge energy. We expect that the former is useful for nano-chemical analysis and imaging as our final goal of this project. However, our original AFM cantilever of a Piezo-thin film type was not easy to apply more precise XANAM measurement and imaging. Hence, we adopted quartz tuning fork (QTF) cantilever as a new force detection system to improve signal to noise ratio and stability of measurements, for detecting the former force component preferentially.

The QTF is normally used as a high quality factor resonator for use as a stable frequency reference for a wrist watch. Previously, Giessibl reported first that the QTF could be applied to NC-AFM measurement as a cantilever with attaching a tiny sharpened metal wire tip like a STM tip, which provided a highly resolved NC-AFM image of Si(111)-(7x7) at the atomic level[4]. The QTF cantilever has three merits compared to the so-called Si cantilever fabricated by semiconductor process for XANAM. First, a substance of the tip can be selected from any solid materials having a sharpened edge. For the XANAM measurement, this feature is advantageous to avoid the influence of X-ray absorption into the tip. It requires X-ray absorption edge energy of the tip material should be distinctively different from the one of target atoms on sample surfaces. Second, the QTF cantilever is the self-sensing and self-actuating probe. It means additional resonators and optics to measure tip deflection are not required to detect the interaction force. Thus, the instruments can be simplified and downsized to be a compact design. The second feature is also advantageous to ensure keeping the X-ray beam position between the tip and the sample surface for a prolonged experimental time. Here, we fabricated a prototype of the QTF cantilever for our apparatus, and examined its performance for the XANAM measurement.

In order to fabricate the QTF cantilever, we used a QTF device which is normally used for a wrist watch with resonance frequency of ~32.7 kHz. The size of QTF is 2 mm x φ1 mm without a wiring part. A small tiny metal wire was attached with electrically-conducting adhesive of EPO-TEK E415G (Epoxy Technology Inc.) onto a prong of the QTF by micromanipulator (Suruga Seiki Co., Ltd.). An exclusive cantilever holder was fabricated to set the QTF cantilever on the AFM stage. We used Au/Ni islands (1000 x 1000 x 10 nm^3) on a Si wafer as a sample to evaluate the performance of QTF cantilever for the XANAM measurement.

Figure 1 shows an image taken by QTF cantilever at the beam line under X-ray irradiation with the energy of 11889 eV. An Au/Ni island fabricated by electron beam lithography was clearly observed on a Si surface with oxidized cover layers. In order to examine the influence of X-ray energy, we changed the X-ray energy into the absorption edge of Au L_3 with irradiating the X-ray on the sample surface during the AFM measurement. However, the stability of the QTF cantilever were not sufficient to scan for a prolonged scan time such as ~46 min/frame, resulting in tip crash to provide irreversible damage of a tip apex. Thus, further improvement of the QTF cantilever is required to establish the XANAM imaging.

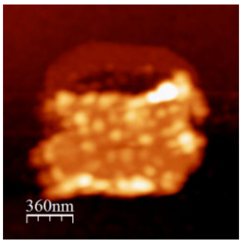

Fig.1 AFM image of Au/Ni islands on a Si surface

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