SLIDING INDUCED NANOCRYSTALS ON SI

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ABSTRACT

Our previous research has shown that Ga pin sliding again Si induces nanometer length scale crystals. In this research, we continued on with an In pin with one stroke slides on Si substrate. Applied load was varied for sliding Surface characterization was conducted using an atomic force microscope. Results showed that triangular-shaped nanocrystals were formed on Si surfaces. The height and side length of these nanocrystals depend on test conditions. In this paper, we report our findings in crystal structures and boundary properties.

INTRODUCTION

When two materials are in contact, the adhesive bond between them can be much stronger than their cohesive bond within two materials [1]. Transfer of the cohesively weaker material generally occurs due to its subsurface fracture [2]. During slow-speed sliding the asperity to asperity contacts result in high temperatures [3]. The high temperatures at the asperity contacts can lead to tribochemical reactions and phase transformations. It was observed that fretting produced high temperatures resulting in caverns of martensite structure in 1040 steel [4]. It was also reported that 304 stainless steel transformed into α’-martensite as a result of plastic deformation [5].

Our previous experiments have shown that Ga sliding against Si induced nanocrystals[6]. The nucleation and growth mechanism were found to be associated with friction. In this research, we further investigate this new phenomenon with an element of higher melting temperature, In.

EXPERIMENT

A pin-on-disc tribometer was used for this study. The schematic diagram for the test is shown in Figure 2. The pin was made of Indium (In) and the disk was single crystal. The pin travels in a reciprocal motion within a length of 6 mm in one direction (Figure 1). The pin has a diameter of 5 mm. Experiments were conducted at room temperature in dry conditions. Test was conducted at load of 5N, 10N, and 20N.

Analysis through an atomic force microscopy was done for observation of topography and phase change. Image analysis software (Image tool) was used to estimate the projected area and height of the nanocrystals. Both contact mode and non contact mode of image was used. Lateral displacement signal and demodulation imaging were used for phase identification. An AFM (Pacific Nanotechnology) with a silicon probe were used for surface imaging and analysis.

RESULTS

At 5 N load, very few crystals were formed. The phase images clearly showed bright spots which were not visible on the topography images. At a load of 10 N, more number of crystals were observed and the phase images indicated more nucleating sites being formed (Fig. 1.). At a load of 20 N, AFM scans showed more number of crystals and the phase images indicated more nucleating sites being formed. It was observed that the nanocrystals showed an inclination to have the shape of a triangle.

Figure 1. Height (left) and demodulation (right) image at a load of 10N.

An image analysis software was used to calculate the average projected area and average height of the nanocrystals. It was observed that initially as load increased from 5N to 10 N the area and height increased (Fig. 2.). Upon further increase in load to 20 N, not much increase was noticed in average area as well as height. In our earlier research we had used gallium (Ga) pin on silicon (Si) substrate, the average projected area (min 0.479µm²) and average height (min 0.273µm) were much higher than what was observed in this experiment. This can be attributed to several reasons. Firstly, the ductility of Ga is much higher that In, which would lead to better adhesion of Ga on Silicon than In on Silicon. Secondly, the load applied for the Si-
Ga system was only 200 mN. Thirdly for subsurface fracture to occur the adhesive bond has to be stronger than the cohesive strength of the material. As Indium has higher strength than Ga, in Si-In system there may be more adhesive bond breakage than subsurface fracture than in the case of Si-Ga system.

CONCLUSION
Using a dry pin-on-disk sliding apparatus, friction induced nanocrystals on Si by In were found. It was found that the dimension of these nanocrystals is related to the applied load. This is most likely related to the energy dispersion during sliding.

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