Variation of surface layer during chemical mechanical polish

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Nanoparticles have been widely used in oils and polish slurry such as chemical mechanical polish (CMP) processes. The movement of nanoparticles in liquid and the interaction between nano-particles and solid surface are very important to obtain an atomic smooth surface in CMP processes. This paper presents both experimental and theoretical studies on the movement of nanoparticles in fluid and the collision between nanoparticles as well as that between the particles and solid surfaces in two phases flowing process.

Keywords: Tribology, Two phases flow, Wear, Chemical mechanical polish

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1 Introduction

What will occur when nanoparticles collide on a solid surface is an important problem in ultra-smooth surface manufacturing industry, e.g., computer hard disk drive and ultra-large scale integration manufacturing. It would also provide precious insights for a general understanding of collision which is critical to control and prevent solid surface damage generated by nanoparticles collision in nano-modification. In recent years, a great deal of the simulations and tests of collision between energetic clusters and surfaces are performed to explore the interactions between energetic clusters and solid surfaces\(^1\)\(^-\)\(^6\). However, researches on nanoparticles collision on solid surface are quite rare.

In order to understand the movement and collision process, an experiment under controlled conditions with the room temperature and the relative humidity of 50-60% were carried out, and the variation of the solid surface are checked by a high resolution transmission electron microscope (HRTEM), energy-dispersion spectrometer (EDS), and an atomic force microscope (AFM). Furthermore, molecular dynamics simulations of collision between nanoparticle and monocrystalline Si surface were analyzed.

2 Experimental Set-up and Results

A schematic diagram of the experimental system is shown in Figure 1. The system consists of an injection pump, a slide with a channel on it, a fluorescence microscope, a CCD camera and an image processing system. Fluorescent nanoparticles (Figure 2) with a diameter between 50 and 60 nm were studied in aqueous solutions with a mass concentration about \(10^7\) to \(10^6\). The fluid with nanoparticles is driven by an injection pump to flow through a channel and observed by a fluorescence microscope. Trajectories of particles are recorded with a CCD camera mounted on top of the microscope and analyzed by an image processing software (Figure 3). Using this system, movement of the particles, collision between two particles, collision between particles and solid surface, and the distribution of particles can be observed, recorded and analyzed (Figs 4-6).
Figure 4 shows the velocity of particles in flows with different flux.

3 MD Simulation of Collision

In chemical mechanical polishing of Si wafer, the collision of SiO$_2$ nanoparticle with Si wafer is one of the actions that lead to material removal. Different from the dynamics behaviour of cluster in implantation and deposition, SiO$_2$ nanoparticle recoils from the wafer after collision. The phenomenon of

Fig. 2—SEM image of nanoparticles

Fig. 3—Trajectories of particles in a flow

Fig. 4—Velocity of particles in flows with different flux

Fig. 5—Process of collision incident angle: 60°, incident energy: 5 eV/atom
collision and recoil has been simulated, and atomic-scale change of the Si wafer, including the energy properties, the elastic and plastic deformation of Si surface have been studied.

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References