CMP TRIBOLOGICAL STUDY OF CARRIER RING PLASTIC MATERIALS

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Abstract:

Understanding the tribological properties of the plastic material used in the retaining or carrier ring is important because the plastic is also polished along with the wafer film in contact mode configurations. The tribological plastic properties are related directly to the carrier ring lifetime as well as influencing certain types of defects. In this study, several types of plastic materials were polished in different chemical mechanical polishing (CMP) environments. Different types of plastic discs of 1" diameter were polished on a bench top CMP polisher. Silica based oxide and tungsten slurries as well as alumina based copper slurry were used as the basis for simulating different CMP process environments. Relative plastic wear rates, coefficients of friction and acoustic emission signals were measured and analyzed for each CMP process environment studied. Surface studies of the plastic disks were performed through the use of optical microscopy and atomic force microscopy (AFM). Results of this study indicate that the tribological characteristics of a particular plastic are dependent upon the CMP process environment.

Introduction:

Wear is defined as "the progressive loss of substance from the operating surface of a body occurring as a result of the relative motion of that surface" [1]. Phenomena that are associated with wear include: adhesion and transfer, abrasion, plastic deformation, fatigue, surface fracture, tearing, chemical degradation, and melting [2]. The use of new carrier technologies involves the pressurized insertion of the retaining ring directly on the pad surface [3]. The result of this insertion is that the plastic contact surface of the retaining ring is also polished along with the desired film on the semiconductor wafer.

Typical industrial plastic selection criteria have focused on pin-on-disk tests involving plastic sliding over steel and sand slurry abrasion tests. The problem with using these tests to select the optimum plastic for CMP retaining rings is that the CMP environment is very different from these typical industrial tests. In CMP, the retaining ring plastic is subjected to a plastic-to-plastic adhesive force component involving the polyurethane pad, chemical attack from the chemicals in the slurry as well as an abrasive component associated with slurry particles.

Each of these components: surface roughness, material of the opposite surface, chemistry, particle characteristics, pressures, speeds, temperatures, etc. can vary for different CMP processes polishing tungsten, oxide, low-k dielectrics, copper, polysilicon, aluminum or other electronic films. The purpose of this study was to perform initial tests to look at plastic tribology in conditions simulating typical CMP environments. Plastic wear, Coefficient of Friction (COF), and Acoustic Emission (AE) characteristics were compiled from a tribometer used in this study. Several different types of plastics as well as various types of commercially available slurries were used in this study. The impact of this study suggests that the selection of the plastic used in the retaining ring can have a significant economic impact on the CMP process in terms of ring lifetime and in terms of defects which may be associated with ring wear, ring vibration, or ring surface roughness.

Experimental:

Experiments were performed with a bench top CMP tribometer. Details of the instrument have been discussed elsewhere [4]. A schematic of the CMP process adopted in these experiments is shown in Fig. 1. Details of the samples that were tested are given in Table 1.

The operating parameters of the tribometer for each commercial CMP slurry were chosen to mimic typical CMP process conditions wherever possible. Operating pressures ranged from 4-6 PSI while the pad speed varied from 1-1.2 m/s. The slurries were recycled and the slurry flow rates were 100-125 ml/min. Conditioning was done with a diamond tipped apparatus. The pad used was an IC1000/SubaIV stack. Different plastic discs of 1" diameter were used in each polishing environment.

Throughout the experiment, AE signal, which is related to the intensity of polishing and COF, which is the measure of interaction of plastic surface with pad and slurry, were monitored and recorded. A typical graph showing the variation of COF and AE signal is shown in Fig. 2. Surfaces of the plastic disks were investigated using optical microscope and atomic force microscopy (AFM) to compare the surfaces before and after polishing.

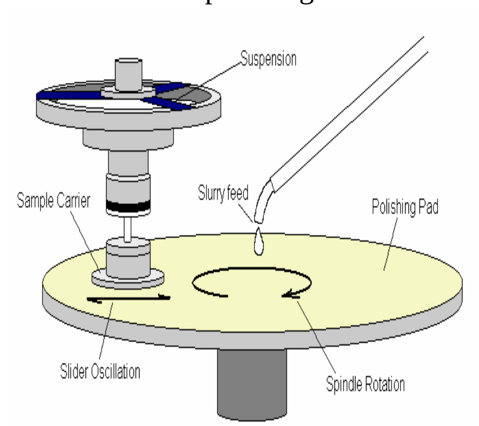


Fig. 1. Schematic of CMP process

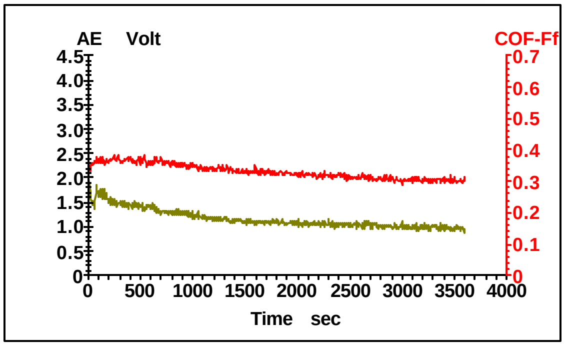


Fig. 2 Change of coefficient of friction and AE signal with time.

Results and Discussion:

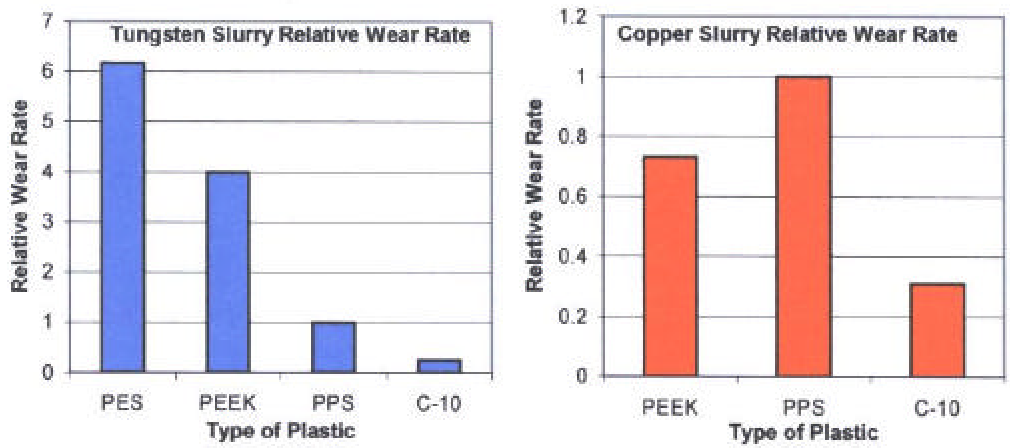
The relative wear rate in the final column of Table 1 compares all of the plastics to PPS which is used as a standard, since PPS is currently an industry standard material for direct contact polishing retaining rings. Polycarbonate could not be polished successfully due to excessive vibration. As can be

Table 1. Properties of plastics with wear data for oxide CMP environment.

Plastic*	Specific Gravity	Tensile Str. (PSI)	Tensile mod. of elas. (PSI)	Shear Str. (PSI)	Hard Shore D	COF	Relative Wear Rate
PC	1.20	10,500	320,000	13,000	----80	------	------
PET	1.41	12,400	460,000	8,000	87	0.20	1.2
PES	1.37	12,200	385,000	9,000	80	-----	3.3
PEEK	1.31	16,000	500,000	8,000	85	0.40	1.52
PPS	1.35	13,500	500,000	9,000	85	0.40	1.0
C-10™	1.42	10,500	420,000	9,000	87	0.21	0.35

*The plastics described in Table 1 include the following: PC (Polycarbonate), PET (Polyethyleneterephalate), PES (Polyethersulfone), PEEK (Polyetheretherketone), PPS (Polyphenelynesulfide) and C-10™ (Trademark of Semplastics).

seen, the physical properties of the plastics give little clue as to their wear rate performance in an oxide CMP environment. The C-10™ plastic shows great promise with respect to direct contact polishing. Figure 3(a) details the relative wear rates of several plastics with respect to PPS in a tungsten CMP environment while Figure 3(b) compares several plastics in a copper CMP environment. It could be noted that there are significant differences in relative plastic wear rates between oxide, tungsten and copper CMP environments. For instance, the relative wear rate of PEEK in comparison to PPS is 1.52 for the oxide CMP environment studied, 4.0 for the tungsten CMP environment, and 0.72 for the copper CMP environment.



(a) (b)

Fig. 3. (a) Relative wear rate of different plastic disks while polishing with tungsten slurry and (b) Relative wear rate of different plastic disks while polishing with copper slurry.

Figure 4 compares the effect of conditioning upon the wear rates of two plastics-PPS and C-10™ using an oxide CMP slurry. Please note the significant impact that conditioning has on the PPS removal rate. The conditioning operation increases the PPS wear rate by a factor of 1.7X while the C-10™ plastic shows a modest increase in wear rate due to the conditioned pad surface.

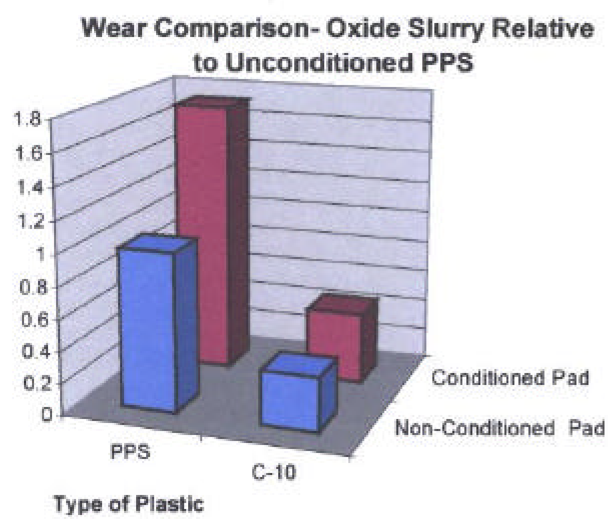
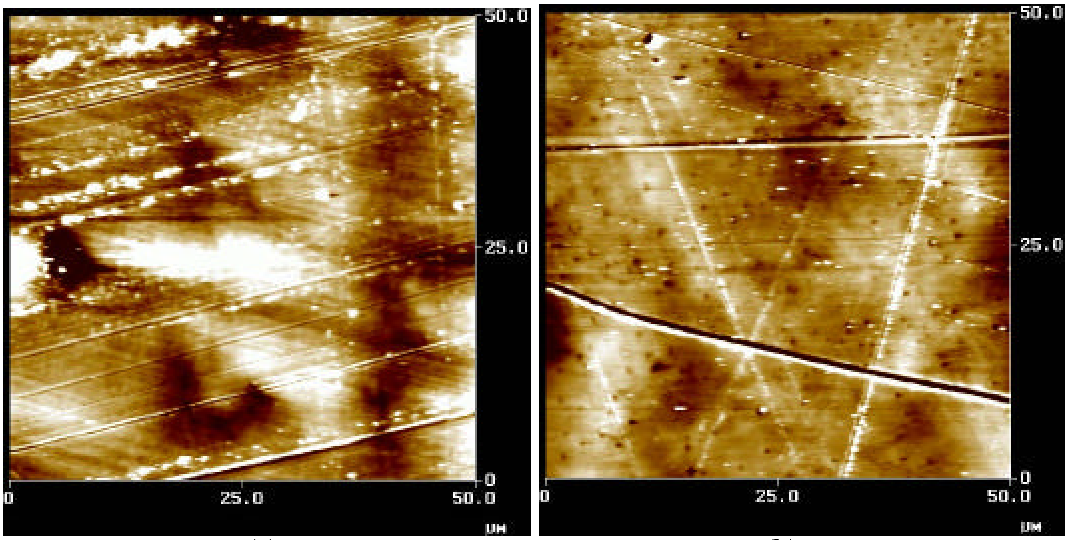


Fig. 4. Relative wear behavior of two types of plastic disk with different pad surface treatments.

As seen previously in Figure 4, conditioning of the pad increases the relative wear rates of the two plastics-PPS and C-10™ for the oxide CMP environment studied. Figure 5(a) is an AFM top view of the polished surface of the PPS disk after pad conditioning. The average roughness (R_a) of this surface is 13.8 nm and the maximum height is 703.6 nm. Figure 5(b) is an AFM top view of the polished surface of the

C-10™ disk after pad conditioning. The R_a of the C-10™ surface is 9.2 nm and the maximum height is 305.7 nm.



(a) (b)

Fig. 5. AFM top view of plastic disk polishing after conditioning the pad with DI water: (a) plastic PPS and (b) plastic C-10

Conclusions:

This study looked at the tribological characteristics of many plastics in different CMP environments. The relative wear rates of different plastics polished changed depending upon the CMP processing conditions and the slurry characteristics. The conclusion of this study is that it is of utmost importance to know the tribological behavior of plastics in actual CMP environments in order to choose optimized materials for carrier ring technology.

References:

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