

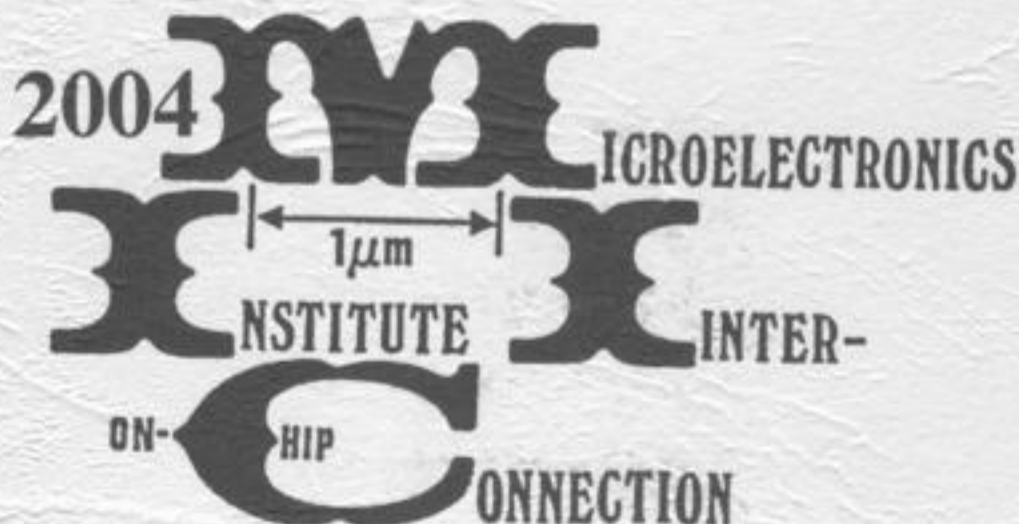
February 24 - 26, 2004

CMP-MIC Catalog No.
04 IMIC - 900P

Marriott Hotel
Marina Del Rey, CA

2004
PROCEEDINGS
NINTH INTERNATIONAL
CHEMICAL-MECHANICAL
PLANARIZATION
FOR
ULSI MULTILEVEL
INTERCONNECTION
CONFERENCE
(CMP-MIC)

A SPECIALTY CONFERENCE OF



Library of Congress No.
89-644090

Advanced Specification and Tests of CMP Retaining Rings

Norm V. Gitis, Jun Xiao, Center for Tribology, Inc., Campbell CA 95008
Ashok Kumar, University of South Florida, Tampa, FL 33620
Arun K. Sikder, University of South Florida and Center for Tribology, Inc.

Abstract

High-quality CMP retaining (guiding) rings are crucial for uniform wafer planarization. Among the numerous functional requirements for ring materials and geometry, the crucial parameters are tested and discussed here, namely: durability of the ring, level of friction between ring materials and polishing pad, and stability of friction between ring and polishing pad. Indeed, ring wear can produce unacceptable debris, contaminating and even scratching the wafer, as well as cause changes in both wafer-over-ring height and pad-under-ring/wafer-edge deformations, leading to non-uniform polishing. The ring-pad friction has to be both low to avoid any pad surface deterioration by the ring and highly stable to dampen the effects of pad grooves on smoothness of the polishing process. Novel test procedures have been developed and used in this work to measure these crucial parameters for rings from various materials and vendors. The results can be used for qualification and incoming inspection of CMP ring materials at the semiconductor fabs, as well as for ring research and development.

Introduction

Distribution of uniform pressure on wafer is essential for controlling the within-wafer non-uniformity in planarization technology. Dominant factors for the uniformity are the carrier type and the means used to control the shaping of local forces. The retaining ring and wafer leveling means are two key design elements of carrier. The primary function of retaining ring is to prevent wafer from slipping out from under the carrier during the process. There are two types of retaining ring design, non-contact retaining ring carrier (NRRC) and contact retaining ring carrier (CRRC) (Fig. 1). In the case of NRRC, there is a 100-200 μm gap between retaining ring (RR) and pad while carrier is at rest. The CRRC design causes the retaining ring to contact the pad. As the RR makes contact with the pad during polishing process in CRRC, it is essential to understand the friction behavior, wear characteristics, chemical resistance of RR with respect to the process parameters in order to develop new RR materials or to apply optimum down-pressure on it.

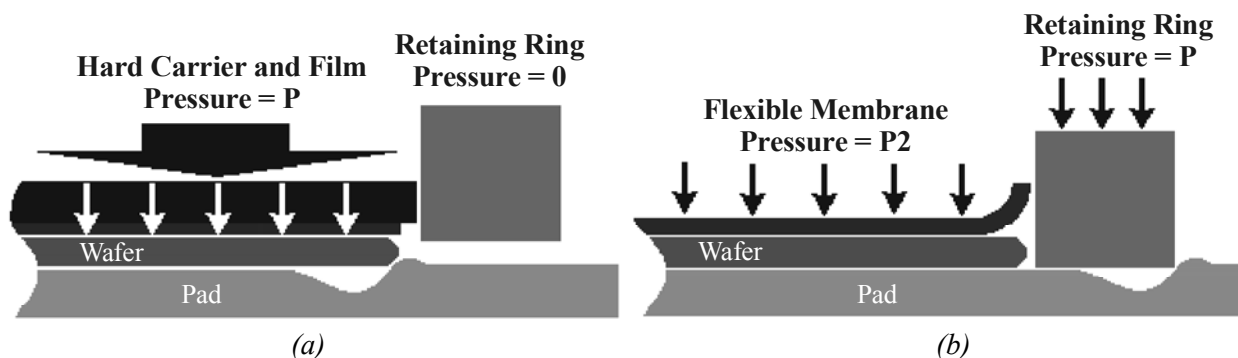


Fig. 1. Schematic of film-backed non-contact retaining ring carrier (a) and of bladder-backed contact retaining ring carrier (b)

Typical industrial plastic selection criteria have focused on pin-on-disk tests (involving plastic sliding over steel) and sand slurry abrasion tests. The CMP environment, however, is very different from these idealized 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.

It is difficult and expensive to study the polishing properties *in-situ* on a large production CMP polisher. A bench-top CMP tester, used in this study, has several sensors (force, acoustic emission, wear and electrical), which are very effective for *in-situ* monitoring and optimizing the CMP process. The accuracy and repeatability of the measurements allows for effective qualification, incoming inspection and ongoing functionality testing of retaining rings, polishing pads, slurries, conditioners, etc. The capability to accommodate small wafers and pads with small amounts of slurry reduces the cost of testing comparing to that on full-scale production CMP machines.

The purpose of this study is to further understand the effects of the polishing of retaining ring materials in a CMP process environment. Several types of plastics, as well as various commercial slurries, were used in this study. 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 either ring wear or ring vibrations.

Experimental

Figures 2 and 3 show the CMP Tester model CP-2 that was used to characterize the retaining ring polymer samples in a series of tests. This bench-top CMP machine provides the user a fully instrumented CMP process on up to 2” wafers (up to 4” on model CP-4), conditioning disks and 6” pads (up to 9” on model CP-4). In performing its test functions, the CMP Tester is capable of providing precision translational, rotational, and reciprocating motions, with speeds ranging from 0.1 $\mu\text{m/s}$ to 10 m/s. A normal load is applied by a closed-loop servomechanism in the instrument’s upper stage, and can be kept constant or linearly increasing, ranging from 0.5 mN to 500N. Friction force (F_x), normal load (F_z), wear and acoustic emission (AE) can all be measured and recorded at a total sampling rate of 20 kHz. All these parameters, in addition to the calculated coefficient of friction, are recorded and displayed in real time during the test. Details of the CMP Tester were discussed elsewhere [1,2].

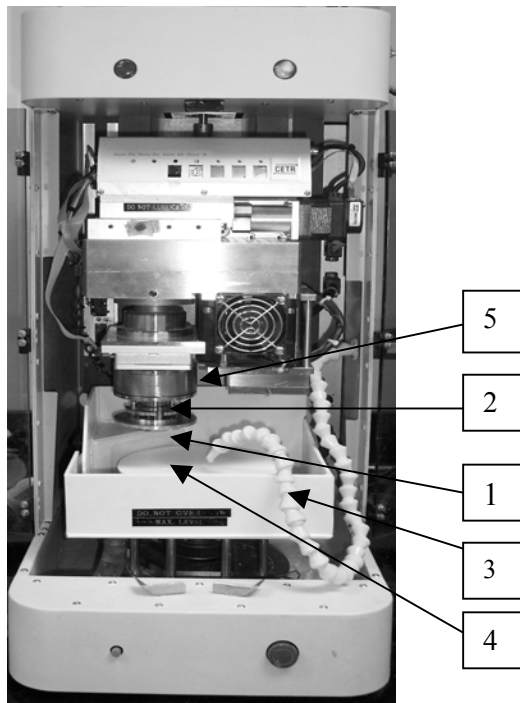


Fig. 2. CMP Tester Model CP-2:

- 1. AE sensor, 2. Upper rotational assembly, 3. Slurry feeding, 4. Platen with pad, 5. Force sensor.

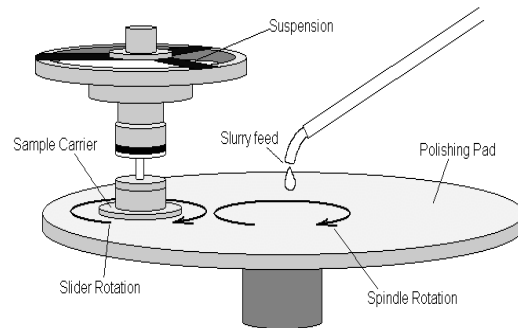


Fig. 3. Schematic of CMP process

Over 100 polymers have been tested, including numerous unfilled and filled PPS (poly-phenylene-sulfide), PC (poly-carbonate) and PEEK (poly-ether-ether-ketone) resins, carbon fiber reinforced (CFR) Arlon, as well as a new proprietary material S1.

The polymer samples were polished on 6" coupons of the same Rodel IC1000 CMP pad, with oxide (SS12) and tungsten (SW-2000) slurries made by Cabot Microelectronics; hydrogen peroxide (3% volume) was added to the SW2000 prior to polishing. A fresh pad coupon and fresh supply of slurry was used for each test. Each new pad underwent a 20-min. break-in with DI water and a conditioning disk at 0.5-psi down-pressure and then conditioning in slurry for 5 min. Each sample was then test-polished at the pressure of 5 psi, pad speed of 325 rpm, slider oscillations of 10-mm stroke at 5 mm/s for 1 hour. During these 1-hour polishing tests, the pad was continuously conditioned at the 0.5-psi pressure.

Another set of experiments was performed on two samples with varied down-force and velocity. A Rodel IC1000/SubaIV polishing pad and an oxide D7000 slurry were used. The test sequence included varying pressure from 2 to 6 psi and pad speed from 50 to 250 rpm in 3 steps, while slider motion was constant at 1 mm/s. In between the samples pad was conditioned with DI water for 1 min.

Results and Discussion

The output parameters were the wear of the ring materials and coefficient of friction (COF), the latter included average value and standard deviation. Typical COF and wear data for four types of tested polymers is presented in Figures 4 and 5. One can see that ranking of most of the materials stays the same in both tungsten (a) and oxide (b) slurries, with PC and PPS samples exhibiting the highest wear, friction and oscillations, most PEEK samples being substantially better, and the S1 samples having the lowest

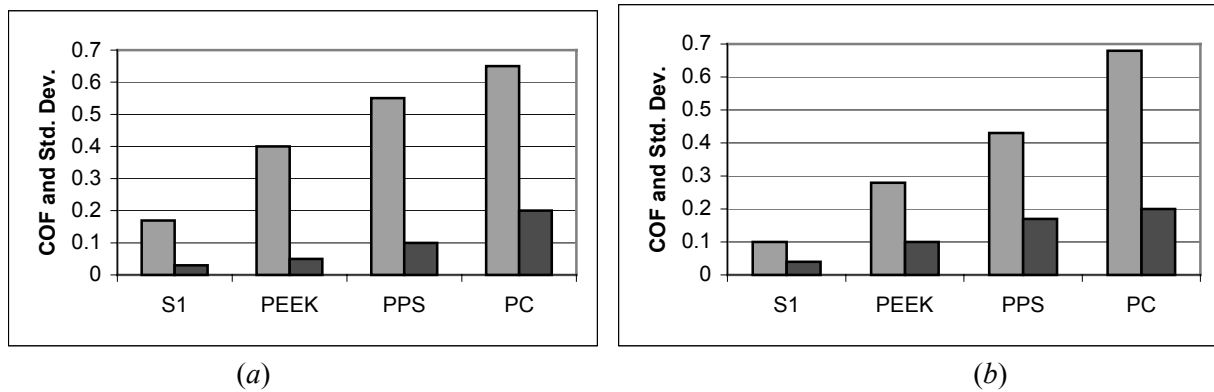


Fig. 4. COF with (a) SW-2000 and (b) SS-12 Slurries

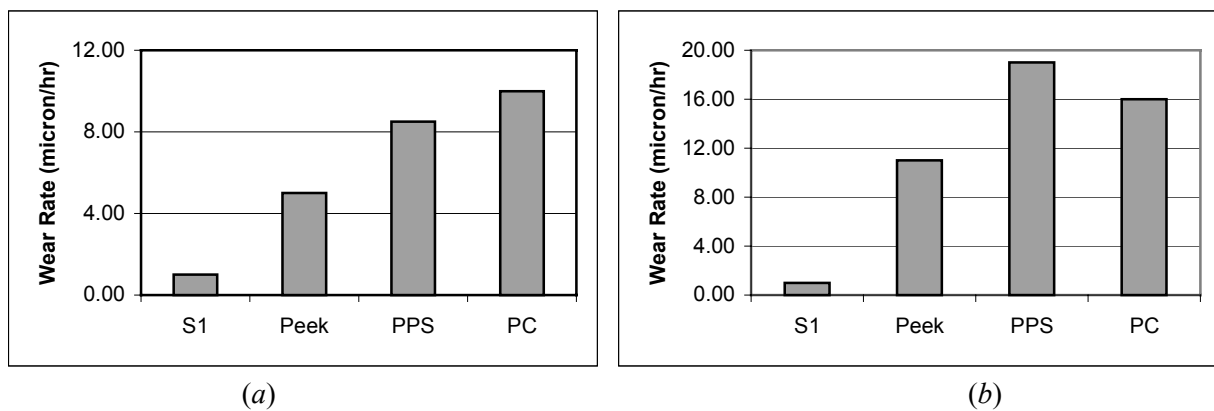


Fig. 5. Wear Rate with (a) SW-2000 and (b) SS-12 Slurries

wear, friction and oscillations. Most PC samples had the highest wear and friction, though some of them

were slightly better than the PPS samples with SS12 slurry. Tribological properties of the S1 samples were especially advantageous in terms of wear rate.

Results of testing with varying polishing conditions are shown in Table I. The AE, which is a measure of intensity of polishing, increases with the increase of the platen rotation, while COF decreases. Both COF and wear were lower for the S1 samples than for CFR samples.

Table I. AE, COF and Wear during polishing two plastic samples

Sample	psi	rpm (Upper)	rpm (Lower)	AE	COF	Relative Wear
S1	2	50	45	0.72	0.58	1.00
	2	250	245	1.82	0.52	
	4	50	45	0.17	0.48	
	4	250	245	0.56	0.49	
	6	50	45	0.25	0.48	
	6	250	245	0.70	0.46	
CFR	2	50	45	0.24	0.78	1.64
	2	250	245	0.65	0.61	
	4	50	45	0.32	0.60	
	4	250	245	1.16	0.60	
	6	50	45	0.37	0.58	
	6	250	245	1.44	0.57	

Conclusions

1. While wear rate is an important factor to be considered in choosing material for a retaining ring, the friction coefficient and its fluctuations, that indicate how well it dampens process vibrations, should also be specified and measured.
2. Among tested samples from several polymer groups, material S1 performed the best per all the three criteria of coefficient of friction, standard deviation of friction and wear; PEEK materials were the second best, PPS and PC materials were the worst.
3. Ranking of polymer materials was mostly the same with both oxide and tungsten slurries.
4. Testing retaining ring materials is most effective and inexpensive on the bench-top CMP Tester with in-situ friction, wear and contact acoustics measurements.
5. So-called combinatorial tribological testing with programmable speeds and loads allows for fast determination of material characteristics in wide ranges of process conditions.

References

1. A. Sikder, etc., Jour. Elec. Mater., **30**, 1520-1526 (2001).
2. N. Gitis and M. Vinogradov, Proceedings of 2nd ICMI, Santa Clara, CA (2001).