ADHESION CHARACTERIZATION OF PHOTO-DEFINABLE EPOXIES ON HIGH ASPECT RATIO STRUCTURES FOR HIGH PERFORMANCE APPLICATIONS

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Keywords:

Abstract:

The adhesion effects of the two different photo-definable epoxies processed on different thin films treated with various wet-chemical and plasma treatments have been studied. Adhesion is critical in backside processing and the assembly of semiconductors. These high aspect ratio structures (HARS) are exposed to a variety of chemicals and mechanical stresses. Regardless of the wet treatment, if no oxygen plasma treatment was used prior to coating, the adhesion was negatively impacted.

One epoxy (KMPR) demonstrated significant improvements in adhesion over a second epoxy (SU8) on silicon nitride, even before a long cure process. The enhancement of the surface polarity contributable to the change in molecular structure of the KMPR was the most important factor in the adhesion improvement.

INTRODUCTION

Thick photo-definable epoxies such as SU8 and PMMA have been used for years for creating high-aspect ratio structures for sensors, actuators, and robots used in micro-electromechanical systems (MEMS) as well as for IC packaging, bump plating and etch masks (wet and dry). These epoxies exhibit multiple processing challenges that require extreme process controls with very little process margin, including cleanliness of the incoming substrate, film thickness, film uniformity, de-hydration bakes, post coat bakes (PCB), exposure, post exposure bakes (PEB), develop and final cures, all of which impact adhesion.

Improving and maintaining the adhesion of SU8 to various thin films, such as nitride, oxide, and metals (Au, Al, Cu) has been elusive. Small variations in surface conditions can greatly affect the adhesion of SU8. The importance on adhesion cannot be overemphasized as shear values as high as 40gms on block structures can result in the SU8 delaminating from nitride surfaces as seen in Figure 1.

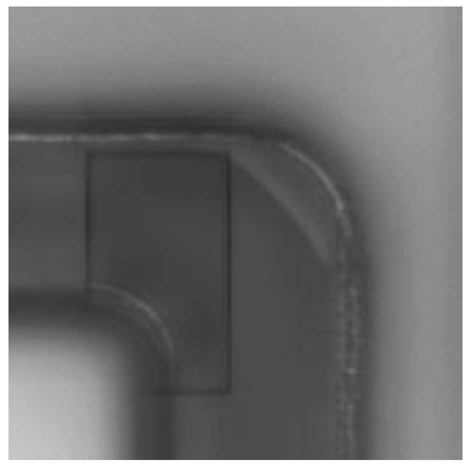

Figure 1: Delamination

In this study, various surface treatments were explored to improve the adhesion of SU8 to plasma enhanced chemical vapor deposition (PECVD) silicon nitride. Further KMPR (MicroChem Corp., Newton, Ma, USA) was studied as an alternative to SU8. KMPR showed superior adhesion as compared to SU8 without the long, high temperature cures normally associated with epoxies.

EQUIPMENT

The equipment used to process the wafers for these experiments included the EVG150 coat/develop system, EVG620 expose system, Blue M inert environment convection oven, Matrix plasma ash equipment, and various wet clean sinks and tools.

Adhesion measurements were made using a Royce Instruments Model 552 Shear Test system.

METHODOLOGY

Test wafer were produced by depositing silicon nitride on Si wafers. Some of the wafers were processed through coat and PCB on an EVG150 system using SU8. The SU8 was then removed and replaced with KMPR and more test wafers were through coat and PCB using the same parameters as used for the SU8. The final resist thickness for both resists was targeted at ~ 80µ.

Wafers from each split were then exposed on an EVG620 aligner using a pattern that included 120 µ X 120 µ block structures and ring structures with outer wall dimensions of ~ 280µ X 185µ and wall thicknesses of ~ 20µ. Wafers were exposed at various doses ranging from 500 to 1200 mJ/cm^2 in 100 mJ/cm^2 increments. These wafers were then processed through PEB and develop on an EVG150 system using the same process for all wafers. The SU8 coated wafers and some of the KMPR coated wafers were then cured in a Blue-M oven for ~ 5 hrs at max temperature of 200ºC.

Adhesion measurements were taken for both the ring and block structures using the Royce Shear Tester.

A follow up test was processed using production wafers for the substrate. Again, the majority of the wafers from the lot were through coat and PCB using the standard SU8 process. The SU8 was replaced with KMPR in the EVG150 system and more of the productions wafers were through coat and PCB using the same parameters as for the SU8 but using the KMPR resist.

The SU8 wafers were exposed using the standard exposure process and the production mask. The KMPR wafers were exposed at doses varying from 800 to 1200 mJ/cm^2 in 100 mJ/cm^2 increments. Then all wafers went through the standard PEB, develop, and cure processes.

RESULTS

Figure 2 shows the results for the test on silicon nitride pilot wafers. There does not appear to be a direct correlation between increased exposure dose and increased adhesion at the exposure doses used. However, in all cases the adhesion of the KMPR for both ring and block structures is significantly better than that for SU8. The ring structures improve between 1.6X and 3.2X for the KMPR and the block structures between 1.8X and 2.6X.

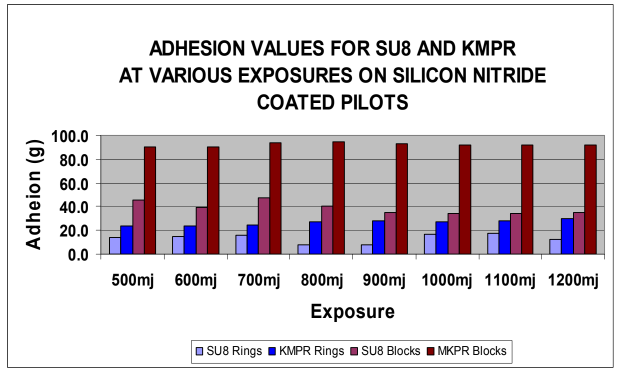

Figure 2: Adhesion Data for KMPR vs. SU8 on Pilot Wafers

Figure 3 shows the data for the tests processed using production wafers. In this case the block structures show an improvement of 2.3X to 2.6X for the KMPR and the ring structures an improvement of 4X to 5X. In this case there does appear to be a slight trend in increasing adhesion with increasing exposure for the KMPR on both the block and ring structures.

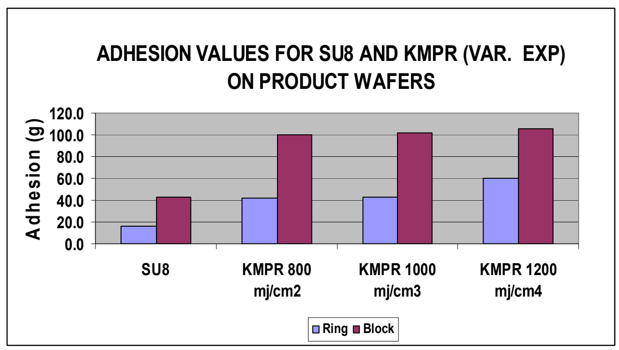

Figure 3: Adhesion Data for KMPR vs. SU8 on Product Wafers

One other result is also notable. Upon visual inspection of the KMPR after cure, it was noted that the wall structures appeared to be somewhat distorted due to shrinkage. This was confirmed via SEM inspection as seen in Figure 4.

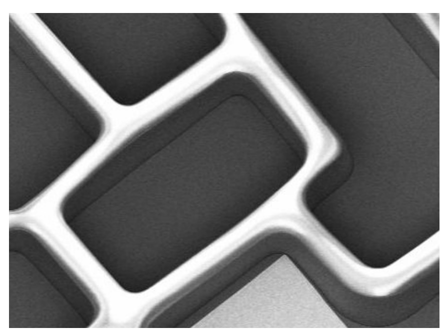

Figure 4: Wall Distortion After Cure

CONCLUSIONS

KMPR can be processed using the same or very similar conditions to those used for SU8. Both SU8 and KMPR exhibit minimal change in adhesion once the exposure dose gets past 500mJ/cm^2, although KMPR appears to plateau at ~700mJ/cm^2 and SU8 appears to peak at that same dose. On both silicon nitride coated pilot wafers and production wafers KMPR exhibits a significant improvement in adhesion when compared to SU8.

The one noted issue with KMPR, the shrinking during cure, can be attributed to the difference in molecular structure of the base resins used for the two materials. This is also the factor that causes the increased adhesion. It is believed that this shrinkage can be controlled with some minor process adjustments.

With the improvements in adhesion exhibited by KMPR it has been determined that further testing is warranted to determine the process conditions which will minimize the post cure shrinkage. If this post cure shrinkage can be brought under control, then KMPR will be a viable alternative to SU8 with the benefit of improved adhesion.

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ACRONYMS

PCB: Post Coat Bake
PEB: Post Exposure Bake
MEMS: Micro-ElectroMechanical Systems
PECVD: Plasma Enhanced Chemical Vapor Deposition