A COMPARISON BETWEEN RESIST HARDENING USING A CONFORMABLE MOLD AND PLASMA RESIST IMAGE STABILIZATION: TECHNIQUES TO ENHANCE RESIST THERMAL STABILITY

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ABSTRACT

KTI-820, a positive photoresist was hardened utilizing two different methods. The PRIST technique involved the exposure of the patterned resist to a plasma containing CF4 plus Helium followed by a 210C, 30 min postbake. The RHCM technique involved the encapsulation of the patterned resist with a PMMA mold followed by a 210C, 30 min postbake and subsequent PMMA removal. The performance of hardened structures on multilayer substrates was investigated for both dry etching and ion implantation processes. The results indicate that the RHCM technique is the superior method. Scanning electron micrographs showed a minimum amount of pattern distortion while nanoline measurements show a minimum change in linewidth dimension.

INTRODUCTION

The advent of submicron feature geometry places greater demands on conventional positive resist materials. Subjecting wafers to elevated temperatures or high power density environments (ie, high current implantation and high throughput single wafer etching) runs the risk of softening the resist which can lead to image distortion. Techniques are needed to maintain pattern integrity and sufficient etch resistance. Thermal stability, the ability of a resist material to maintain its image at elevated temperatures, can be enhanced by crosslinking generally termed resist hardening [1].

Crosslinking increases the molecular weight of the binder which translates into an increase in the glass transition temperature of the resist. If the temperature of the wafer exceeds the glass transition temperature of the resist, the resist will flow. Thus, an increase in the glass transition temperature will yield an increase in thermal stability. For example, with the well known diazi-sensitized novolac resist system, the resist pattern starts to deform at 120C. After hardening, the resist can withstand a temperature beyond 200C and still retain its shape [2].

One method of achieving resist hardening involves the use of deep UV radiation to crosslink the resist [3]. The short wavelength radiation is strongly absorbed by the binder at the surface of the resist. The resist is converted to a ketene, which in the absence of moisture, will react with the resin and crosslink. Surface hardening works well with small features but with large features the skin is not sufficiently rigid to hold the bulk of the resist [4]. Hardening by electron beam or ion beam bombardment can crosslink the resist, but at the risk of radiation damage to the semiconductor devices on the wafer. The two methods of proposed study include resist hardening using a conformable mold (RHCM) as developed by B.J. Lin [5] and plasma resist image stabilization (PRIST) as developed by W. Ma [6].

Resist hardening using a conformable mold is a technique that consists of coating an imaged layer with a thicker polymer layer, which acts as a mold to stabilize the image during high temperature baking. With the mold in place, the resist image is baked to a temperature higher than its glass transition temperature. The temperature and the molding material are chosen so that only the resist image is crosslinked [7]. Because of reenforcement from the mold, the resist image remains intact after hardening. The key factor in preventing the positive resist image from reflowing during the 210C bake is the homogeneously distributed stress from the mold. This process is depicted in Figure 1.

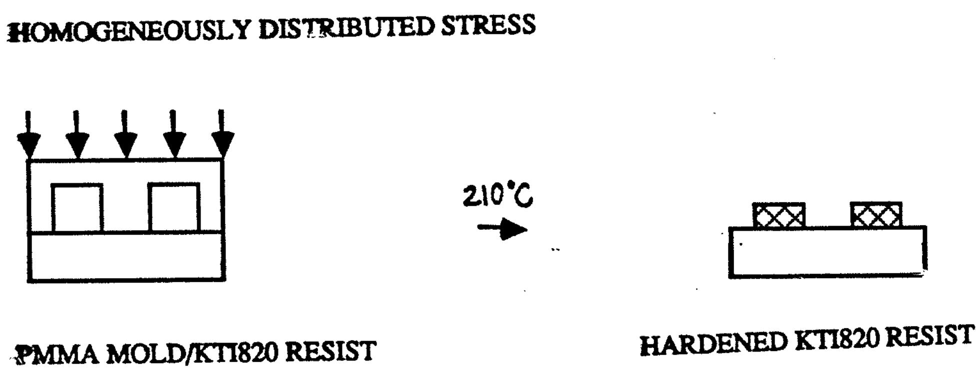

Figure 1: Cross-section of RHCM Sequence.

This process offers the advantage of hardening the resist throughout the bulk. A second novolac image can be delinated on top of the hardened image without any interfacial effects. This method is sensitive to surface topology. The mold must be of sufficient thickness to cover the highest point of the bottom resist.

The plasma resist image stabilization technique can effectively stabilize the resist image at a temperature in excess of 210C without any measureable change in dimension [8]. The typical PRIST treatment is exercised in a fluorine plasma. When the resist polymer is subjected to the CF4 plasma, the polymer can undergo free radical formation and hydrogen abstraction to form volatile products. This creates a heavily fluorinated

polymer which has increased thermal stability. The mechanism is shown in Figure 2. Although the PRIST technique is capable of maintaining the original resist profile it is possible to get deformation at the surface which can be controlled somewhat by adjusting power and time parameters. The PRIST process is sensitive to reactor design. The addition of helium as a dilutant allows for the improvement in process capability.

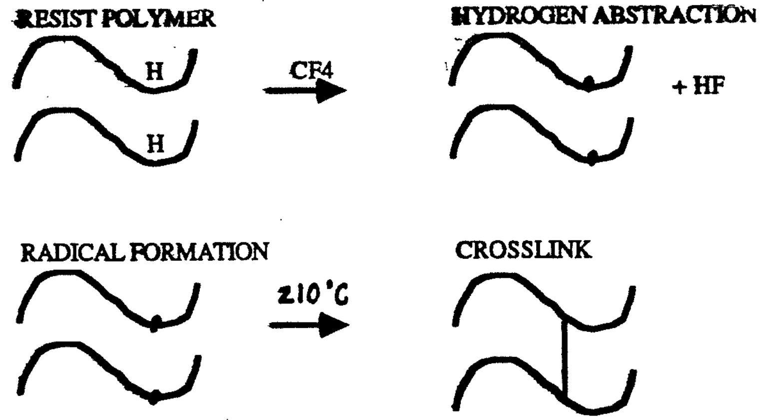

Figure 2: Crosslinking Mechanism Using PRIST.

A comparison will be made between a typical developed resist pattern and resist patterns that have been subjected to the RHCM and PRIST treatments as illustrated in Figure 3.

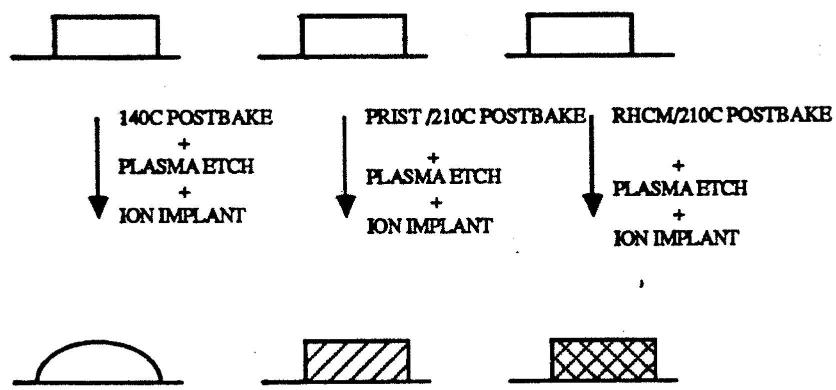

Figure 3: Expected Profiles Of Resist Lines For Various Schemes.

EXPERIMENT

Three inch silicon wafers were obtained and cleaned in BOE solution. An oxide growth in dry O2 for 25 min at 1100C resulted in 750A of SiO2. Approximately 4000A of polysilicon was deposited on the wafers. The wafers were coated with 1.1 microns of KTI-820 positive photoresist on a GCA Wafer Track and were exposed at 55mJ/cm2 on a Kasper Aligner. The mask that was used contained lines and spaces of varying dimensions from one to ten microns to produce the image in the resist. All the wafers were hand developed using 1:1 ZX-934 for 40 sec.

Wafers were subjected to a 140C, 2 min postbake. Other wafers received the PRIST treatment. The wafers were subjected to a gas mixture of 4:1::He:CF4 for two minutes. This was done using the Plasmaline plasma asher. Following the plasma exposure the wafers were baked for 30 min at 210C. Another set of wafers received the RHCM treatment. PMMA was hand coated four times at a spin speed of 2700rpm for 30 sec. Thickness measurements were taken using the Nanospec. The wafers were then baked for 30 min at 210C. PMMA was removed by a 25 min ultrasonic rinse in acetone followed by a DI rinse.

Polysilicon was etched in the Tegal using a gas mixture of 3:1::SF6:O2 for 1 min. The oxide was removed in a BOE solution for 2 min. The wafers were then implanted with boron using a dose of 3E14cm-2 and an energy of 60keV. Resist thickness measurements were taken after each step. Following ion implantation, processing was completed. SEM analysis was conducted on 10 um lines as this feature size was obtainable with all treatments. Linewidth measurements were done using the Nanoline.

RESULTS/DISCUSSION

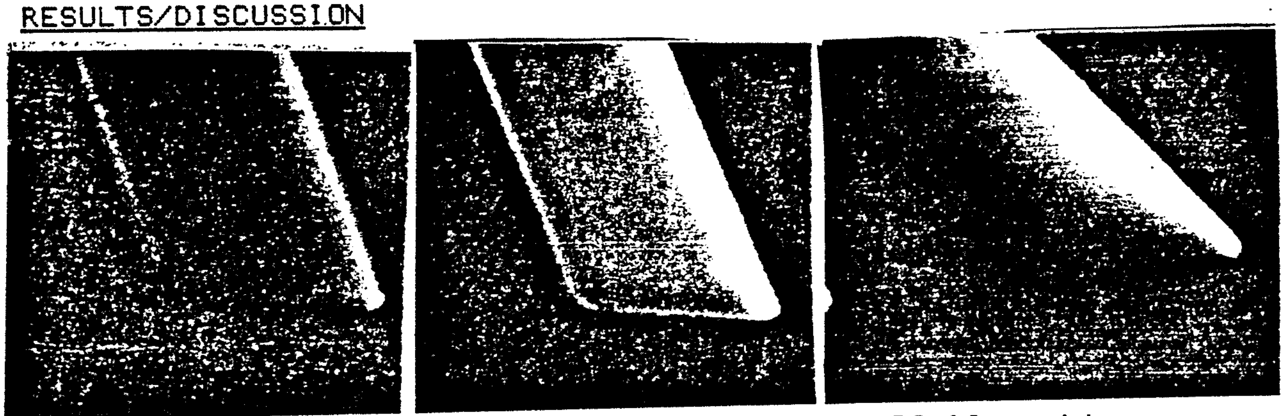

Figure 4: Scanning Electron Micrographs Of 10 um Lines.

Figures 4a-c show cross sections of 10um lines and spaces. It is evident that there is a difference in profiles which provides an indication of how well each technique stood up to processing conditions.

Figure 4a shows patterns that received the RHCM treatment. The sidewalls are fairly steep and the top is flat. Linewidth measurements of the original 10um lines showed a decrease by 3.5%. Figure 4b shows patterns which resulted when the sample received the PRIST treatment. There is a slight resist flow with some rounding of the initially sharp edge. There was a change in linewidth by 11.1%. Figure 4c shows untreated patterns that received a standard RIT postbake at 140C for 2 min. Note that the resist has flowed considerably as indicated by the rounded profile. The linewidth changed by 6.7%. Optical micrographs were not able to distinguish the differences between wafers that received the PRIST and standard postbake techniques. The resist has flown for both of these methods while the resist that was

treated with the RHCM technique was able to retain its shape.

The PRIST technique encountered adhesion problems at smaller geometries. This is believed to be due to the delay in processing between develop and postbake and not due to the actual plasma treatment.

The RHCM technique achieved a higher degree of thermal stability and conservation of lateral dimension than did the PRIST technique. This was to be expected because the RHCM process hardens the resist throughout the bulk while the PRIST process hardens the resist only at the surface due to limited crosslinking penetration. One of the problems encountered with this treatment was difficulty in removing the PMMA mold after the hardbake. In order to optimize this process, further experimentation is needed and could include varying the resist material, the developer type, and the baking conditions.

CONCLUSIONS

Of the two hardening methods studied, the RHCM technique proved superior to the PRIST technique in terms of achieving thermal stability for positive photoresists. SEM analysis showed that the resist was able to retain its shape throughout the bulk after being subjected to both dry etching and ion implantation processes. In addition, the RHCM technique showed a minimum change in linewidth dimension when compared to the other techniques. This process is compatible with existing processes and is also simple to execute. The equipment required is inexpensive. Although removal of the PMMA mold was difficult after the hardbake, stripping of the hardened resist in an oxygen plasma was not a problem. Further experimentation is needed in order to optimize this process.

ACKNOWLEDGMENTS

Special thanks are extended to Mike Jackson, Bruce Smith, Dick Lane, Matt Matessa, Pat Brennan, Eric Lehner, Gary Runkle, and Scott Blondell.

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