MULTILAYER RESIST IMAGING METHODS

By

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ABSTRACT

A trilayer imaging system, using DuPont Pyralin polyimide as a planarizing layer, an Allied Chemical Accuglass Spin On Glass barrier layer, and an imaging layer of Kodak 820 positive photoresist, has been previously investigated at RIT. This system failed to perform as expected when the polyimide coating lifted off the metal layer it was designed to mask. This project investigates the process previously used and makes an attempt to qualify it. Along with this, a process is proposed which uses the polyimide as a lift-off material in a reversal process using the same materials and equipment.

INTRODUCTION

The realization of single layer resist limitations in current manufacturing has brought about an increase in research on multilayer resist techniques. Multilayer resist systems exceed state of the art single layer performance characteristics. Enhanced resist sensitivity [1], resolution, contrast, etch resistance, profile tailoring, and compatability with existing optical and electron beam exposure systems are some of the advantages of trilayer systems [2].

In this report a multilayer resist process is described and compared to a reverse lift-off imaging process using the same chemistries. Spin-on-glass is used as an isolating layer between a polyimide planarizing layer and a positive photoresist imaging layer. The processing steps are listed below.

Forward Process [3]

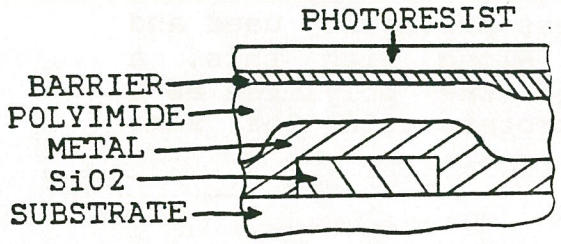
1) Grow and pattern SiO2 on wafers
2) Deposit aluminum
3) Coat with planarizing layer (DuPont Pyralin Polyimide)
4) Apply spin on glass (Allied Chemical Accuglass 103)
5) Coat and pattern photoresist (Kodak Microposit 820)
6) Etch spin on glass (HF diluted 10:1)
7) Etch polyimide (O2 Plasma)
8) Etch aluminum
9) Remove trilayer system

Reverse Process:

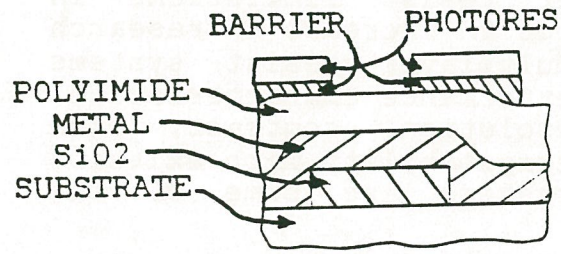
1) Grow and pattern SiO2 on wafers
2) Coat with planarizing layer (DuPont Pyralin Polyimide)
3) Apply spin on glass (Allied Chemical Accuglass 103)
4) Coat and pattern photoresist (Kodak Microposit 820)
5) Etch spin on glass (HF diluted 10:1)
6) Over-etch polyimide (O2 Plasma)
7) Deposit aluminum
8) Remove polyimide (lift-off)

Refer to Figures 1 and 2 for the crossection diagrams of the forward and reverse processes.

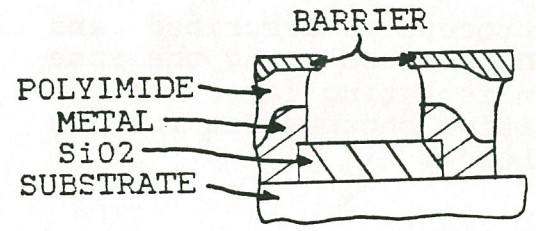
FIGURE 1: FORWARD PROCESSING STRUCTURES



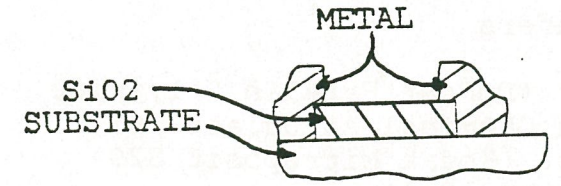
STRUCTURE INCLUDING IMAGING LAYER, BARRIER LAYER, PLANARIZING LAYER, METAL, AND SiO2 STEP.



STRUCTURE FOLLOWING IMAGING OF RESIST AND ETCHING OF BARRIER LAYER

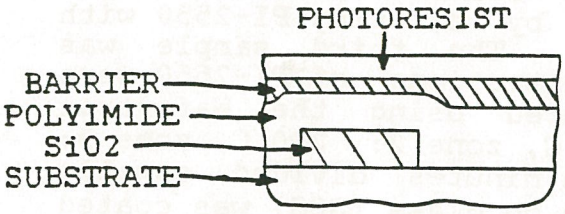


PROFILE AFTER ETCH OF PLANARIZING LAYER AND METAL

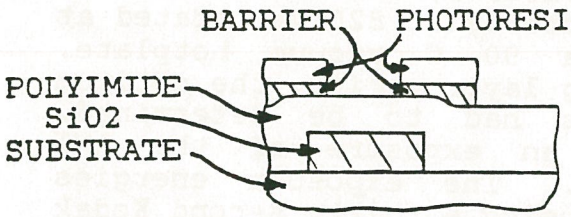


RESULTING METAL PATTERN FOLLOWING SOLVENT TREATMENT

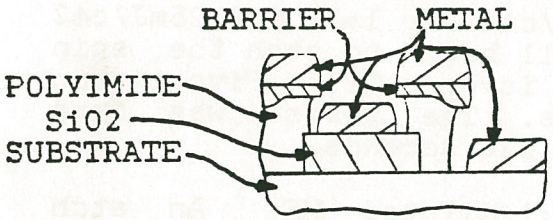
FIGURE 2: REVERSE PROCESSING STRUCTURES



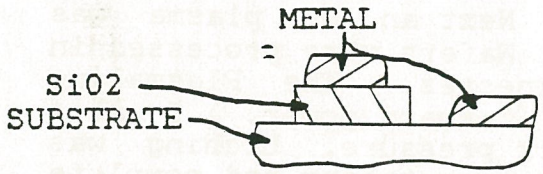
STRUCTURE INCLUDING IMAGING LAYER, BARRIER LAYER, PLANARIZING LAYER, AND SiO2 STEP.



PROFILE FOLLOWING IMAGING OF RESIST AND ETCHING OF BARRIER LAYER



LIFT-OFF STRUCTURE AFTER PLANARIZING LAYER ETCH AND METAL DEPOSITION



FINAL PROFILE AFTER LIFT-OFF IN SOLVENT

The planarizing capability of the system is of great importance in determining the resolution of the transferred image. To test this, various step heights of silicon dioxide are prepared on the samples. Imaging over this topography using a resolution test mask determines the limits of the system. Visual inspection, linewidth measurements, and SEM photographs provide the data to compare the two processing methods. Along with this, the planarizing effect is observed while the polyimide viscosity is reduced using a thinner.

EXPERIMENTAL

The experimental procedure was broken down into three portions. At first a great deal of preparation was made in order to design the experminetal processes. Several papers dealing with multilevel imaging systems were obtained. A limited review of the literature and previous in-house work, revealed previous processing difficulties, such as SOG cracking [4].

Initially, the forward process was investigated using ten three inch wafers. While attempting to qualify the process, planarizing over topography was not a concern. Therefore, an oxide step was not grown on the surface of the first six wafers. Aluminum was evaporated on the cleaned silicon surfaces. Two samples of polyimide were prepared by diluting PI-2550 with thinner T9039 in 1:4, and 1:1 ratios. The third sample was undiluted PI-2550. The three concentrations of PI-2550 were coated on the wafers. This film was cured using the Wafertrac three zone belt oven (zone 1: 190 C, zone 2: 250 C, zone 3: 190 C). Total time in the oven was ten minutes divided equally within the three zones. Next the spin on glass (SOG) was coated and baked using the same speeds, temperatures, and times as the planarizing layer. Kodak positive photoresist 820 was coated at 5000 rpm and baked for 120 seconds on a 90 C vacuum hotplate. Since the thickness of the planarizing layer varied, the optimum exposure for each of the three samples had to be determined. Using Kasper contact aligner 2, an exposure of the AMI resolution mask was made on the wafers. The exposure energies required in order to clear the resist using a thirty second Kodak ZX934 (diluted 1:1 with D.I. water) development were found to be approximately 15mJ/cm2 for 1:4, 20mJ/cm2 for 1:1, and 25mJ/cm2 for straight PI-2550. The developer will begin to etch the spin on glass if excessive development time is used [5]. Five micron features were well defined on all wafers. The resist was hard baked on a vacuum hotplate at 140 C for 120 seconds.

The spin on glass was etched in 10:1 diluted HF. An etch time of 90 seconds allowed for total removal of the SOG and a very slight undercutting of the resist. Next an 02 plasma was used to etch the exposed polyimimde. Wafers were processed in pairs related by their polyimide thicknesses. The Plasmaline asher was operated using 200 watts forward power, > 5 watts reverse power, 1 unit 02 flow, and 5 Torr pressure. Etching was monitored every three minutes to prevent overetching and complete the etch to the metal surface. This also helped to reduce the substrate temperature that increases during plasma etch and causes the SOG to crack [4].

Selected areas of the metal layer were then etched using aluminum etch at 40 C for approximately 2 minutes (etching is monitored visually). However, during this etch the entire metal layer was removed. This result was observed on all wafers processed with this procedure.

Six cleaned wafers were processed using the reverse (lift-off) procedure. Here again while attempting to qualify the process no Si02 surface topography was created. The silicon surface was coated with the same three concentrations of the polyimide and identical curing temperatures and tims were used. A SOG layer of approximately 1000 angstroms was applied, as in the forward process, using a 5Krpm spin speed for 30 seconds and the same three zone bake. Due to the lack of available Kodak developer, Shipley photoresist 1400-27 was coated at 4Krpm and prebaked for 90 seconds at 90 C on a vacuum hotplate. The

adjusted exposure energies in order to facilitate a 45 second development were 60 mJ/cm2 for 1:4, 70mJ/cm2 for 1:1, and 75mJ/cm2 for the unthinned Pyralin polyimide wafers. Development in Shipley 351 diluted 1:4 revealed good imaging down to 5 micron lines and spaces but also caused cracking of the SOG in the developed regions. The cracked SOG was then etched away in 10:1 diluted HF. A one minute etch time was sufficient and even slightly undercut the photoresist mask. Three minute 02 plasma step etches were used as before with the same power and pressure values. The polyimide etched to the substrate, without cracking of the SOG, for the samples with the thinner planarizing layers. The wafers that had been coated with unthinned polyimide would not etch to the substrate after 21 total minutes in the plasma at which time the SOG displayed cracking.

Aluminum was then evaporated over the structures. Half a pellet of aluminum was placed into the filiment in an attempt to coat a thin (about 1000 A) layer. The aluminum layer formed a continuous coating over the structures with the thinnest planarizing level (the 1:4 thinned samples). The 1:1 samples appeared under a microscope to have achieved the profile shown in Figure 2. Figures 3 and 4 are SEM photographs of this structure.

FIGURE 3

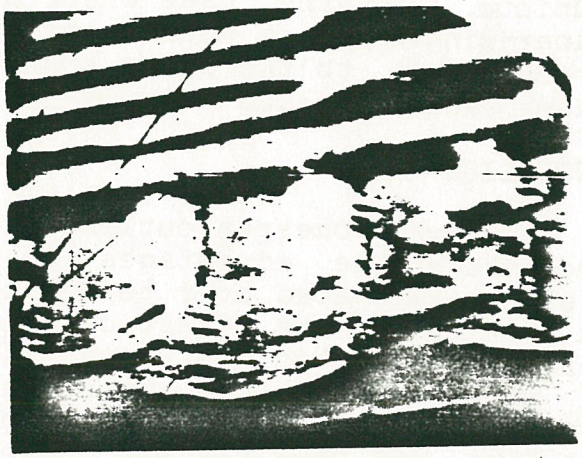


FIGURE 4

RESULTS & DISCUSSION

As stated earlier, no positive results were obtained with the forward imaging process. Since the polyimide planarizing layer lifted from the metal surface during the metal etch process, all of the aluminum was etched. Two reasonable explanations can be made for this mishap. First, possibly the polyimide film was not properly cured to insure its stabilized condition. However, this is unlikely since the polyimide was cured in the same manner when it was used in the reverse process where it functioned sufficiently. A second reason may be that DuPont's Pyralin polyimide does not naturally adhere well to metal surfaces. This assumption is supported by the recommendation of an adhesion promoter to be applied under the polyimide. Recommended adhesion promoter VM-651 was not available at the time of processing. If further attempts are made to either qualify this process, or use this polyimide as a dielectric layer in a multimetal structure, the effect of an adhesion promoter will have to be investigated.

The reverse process was used to produce the desired trilayer structure. With a planarizing layer of 1:1 thinned PI-2550 with T9039, The lift-off structure was fabricated. However, upon inspection of the profile using SEM photography, it was observed that an excessively thick metal layer conformally coated the entire wafer making lift-off impossible (see figure 4). A thinner coating of metal should produce the profile shown in figure 2. The samples with the thinnest planarizing layer (1:4 PI-2550/T9039), were also conformally coated by the deposited aluminum. In the case where unthinned PI-2550 was used as the planarizing layer, a difficulty arose while attempting to etch through this to the wafer surface. The extended time in the O2 plasma caused the SOG mask layer to begin to crack.

CONCLUSION

The two processes outlined in this report were designed to demonstrate the advantages of multilevel imaging processes for metal layers coated over topography. Both are relatively simple and do not make drastic demands of lab processing time. Therefore, repeated tests, evaluation, and process refinement are all possible. Future work on this subject should include investigation of adhesion promoters for the polyimide to metal interface and possibly the use of a thick photoresist coating as the planarizing layer. Photoresist adeqately adheres to metal and lifts-off in acetone, or after a flood exposure, in developer.

ACKNOWLEDGEMENTS

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