DEVELOPMENT OF A PHOTOSENSITIVE POLYIMIDE PROCESS

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ABSTRACT

A six step lithographic process has been developed and characterized for Pyralin PI-2703D photosensitive polyimide from DuPont Electronics. The six basic steps are wafer preparation, coating, soft-bake, exposure, development, and cure. The problems encountered in obtaining a suitable immersion development process necessitated the fabrication of a spray development apparatus. The image quality resulting from these different development techniques was compared.

INTRODUCTION

Polyimides have been receiving a lot of attention in the microelectronics industry due to their high thermal and chemical stability, low dielectric constants, and planarization capabilities. These characteristics make them useful for several different functions. Two major uses are for interlayer dielectrics and passivation layers. Research has also been performed for their use as stress buffers to reduce the stress problems inherent in plastic packaging, and as alpha particle barriers. Alpha particles can cause soft errors in memory chips such as dynamic RAMs [1].

Photosensitive polyimides such as DuPont's Pyralin PI-2703D possess virtually all of the advantages of conventional non-photosensitive polyimides, while significantly reducing the number of processing steps required to create an image [2]. Non-photosensitive polyimides require an indirect method of pattern creation requiring steps to apply, dry, and strip the mask layer, while photosensitive polyimides can be patterned directly without the need for an additional masking layer. Figure 1 contrasts the processing steps required for a typical, conventional, non-photosensitive polyimide versus Pyralin PI-2703D.

The recommended standard lithographic process for Pyralin PI-2703D generally involves five steps; i.e., applying, soft-baking, exposing, developing, and then curing the polyimide. The basic component of the coating is a soluble polyimide precursor, a polyamic acid, which undergoes a free radical polymerization upon exposure to ultraviolet radiation. This creates a difference in the solubility between the exposed and unexposed regions. The

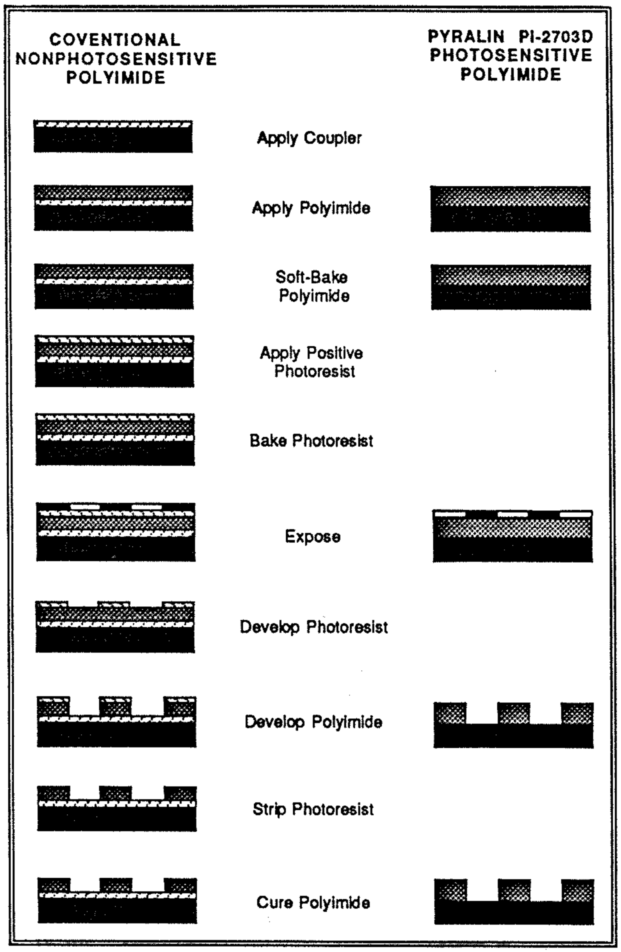

Figure 1: Processing steps for a conventional non-photosensitive polyimide versus Pyralin PI-2703 [1,2].

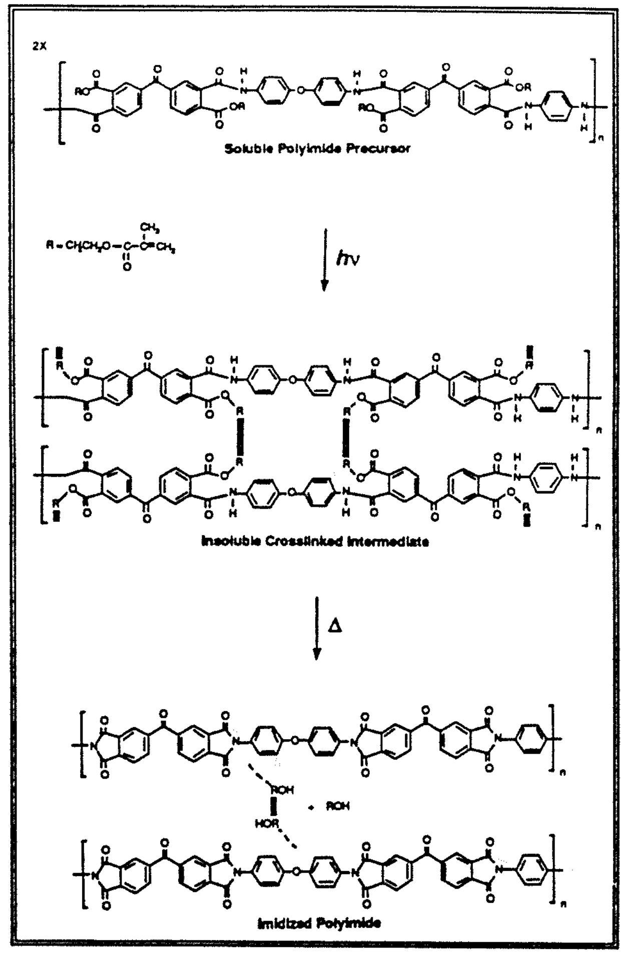

Figure 2: The general chemical reactions for each step in the Pyralin PI-2703D process [1].

unexposed regions can then be dissolved in a suitable developer, after which the remaining cross-linked intermediaries can be converted into a polyimide by a thermal cure. This thermal cure also serves to finish the removal of any residual solvents and the photoinitiator, completing the adhesion process [1]. The general chemical reaction for each of these steps is illustrated in Figure 2.

It is often difficult to achieve an optimum photosensitive polyimide process suitable for a manufacturing environment. Some of the most common processing difficulties encountered include: adequate substrate preparation for good polyimide film adhesion, achievement of the correct exposure because of the very slow photospeed, determination of the proper soft-bake to prevent either polyimide residue from adhering to the mask (caused by an insufficient soft-bake) or degradation of the photospeed and cracking (caused by an excessive soft-bake). A proper cure process is required to prevent cracking as well. Photosensitive polyimides require strict humidity control and have a relatively short shelf life [1].

This project involved the development and characterization of a six step lithographic process for Pyralin PI-2703D photosensitive polyimide: wafer preparation, coating, soft-bake, exposure, development, and cure. The wafer preparation step was added to the basic five step process to provide for better adhesion of the polyimide precursor to the wafer and to improve the uniformity of the coating.

EXPERIMENT

Three inch p-type (100) wafers were scribed for identification purposes. The wafer preparation process involved a standard RCA cleaning process followed by a dehydration bake in a convection oven at 115C to 120C for 20 minutes. The wafers were coated immediately after this preparation process.

Pyralin PI-2703, 1.0ml to 1.2ml, was dispensed statically onto the center of the wafers. The polyimide precursor was then spread at 800RPM for 5 seconds directly followed by a 60 second spin at 3000RPM. Immediately following the coat, a soft-bake was performed in a convection oven at 62C for 60 minutes. The convection oven was vented with forced air (not nitrogen). The wafers were kept in the horizontal direction during the soft-bake process in order to prevent reflow of the coated solution. The refractive index of the polyimide precursor was then measured by ellipsometry, and the uniformity of the coating was measured with a Nanospec.

The wafers were exposed using a Kasper Model 2001 contact aligner with a chrome exposure test mask. This mask contains several different types of exposure test structures. These structures include line space pairs and square contacts of various sizes. An exposure energy of 400mJ/cm^2 was used.

Three different types of development processes that were investigated included single bath immersion, multiple bath immersion, and spray development. The single bath technique was a 25 second immersion in Pyralin DE-6018 developer, and then a 1 minute and 15 second immersion in a xylene rinse. The multiple bath technique involved the following five steps in quick succession:

Step	Solution	Time
Developer #1	DE-6018	10 seconds
Developer #2	DE-6018 to xylene (3:1)	10 seconds
Developer #3	DE-6018 to xylene (1:1)	15 seconds
Developer #4	DE-6018 to xylene (1:3)	20 seconds
Rinse	xylene	1 minute & 15 seconds

The spray development apparatus was constructed using a wafer spinner and two air-brushes [3]. The air-brushes were mounted in holes in the wafer spinners cover to spray at approximately a 45 degree angle to the wafers surface. The air pressure for the air-brushes was 13PSI. The spin speed of the wafer was set to 3300RPM. The process involved a spray of DE-6018 for 25 seconds from one air-brush and a 20 second xylene spray from the other air-brush, with a 5 second overlap in the spray times.

The wafers were then spun dry for 1 minute on a wafer spinner at 3300RPM for all three development processes. The wafers were then inspected and pictures were taken with an optical microscope. The thickness of the coating was measured with an alpha step profilometer.

The cure process involved a convection oven bake for 30 minutes at 150C, a second convection oven bake for 30 minutes at 250C, and a 380C bake in a diffusion furnace (MiniBrute) for 60 minutes with a nitrogen flow of 3 liters/minute. The polyimide thickness was measured with the alpha step again.

RESULTS/DISCUSSION

The largest problem in achieving a process for Pyralin PI-2703D was to find a suitable development system. DuPont's recommended development technique is a spray type development system. The first development system attempted was a single bath immersion development. This resulted in hazing immediately upon rinsing the wafer, and left a large amount of polyimide precursor residue on the wafer. A multiple bath development process was then attempted in order to eliminate the hazing and residue. This process required a substantial amount of time in order to determine the correct development time and concentration for each bath. The final result was a process without hazing and less residue, however the development times were super critical to avoid hazing. This led, finally, to the construction of the spray development system. The resulting spray process left no hazing and virtually no residue, while allowing for significantly more process latitude. The results of all three development systems are depicted in Figure 3.

Figure 3: Line Space Pairs after development.

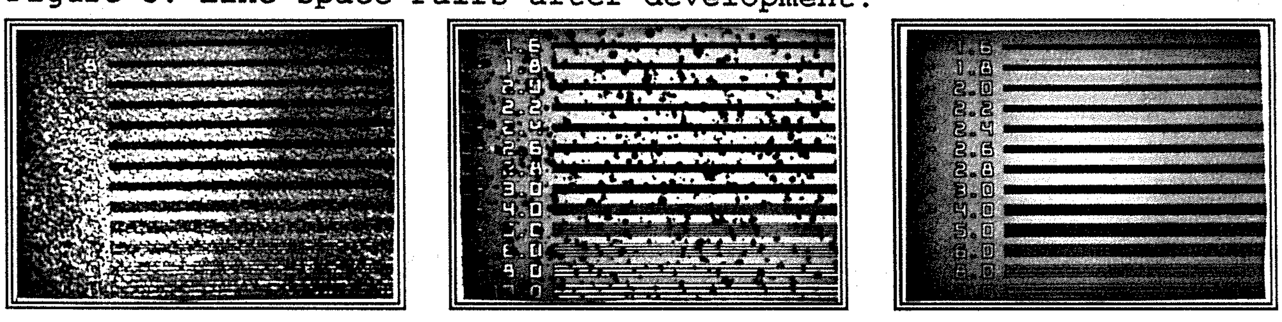

Figure 3a: Single bath immersion.

Figure 3b: Multiple bath immersion.

Figure 3c: Spray system.

The refractive index of the Pyralin PI-2703D coating after soft-bake was measured with an ellipsometer to be 1.63+/-0.05. This process produced a coating thickness of 3.0 to 3.3 microns.

The uniformity of the coating thickness across the wafer deviated by less then 7.4% from the average. It is important to note that proper wafer preparation is essential to achieve good adhesion of the polyimide precursor before the soft-bake. The thickness of the image before the cure step was measured to be 2.4 to 2.7 microns with the alpha step. The thickness of the final spray developed image, after cure, was 1.4 to 1.6 microns. The minimum resolution achieved with the spray development process, after cure, was 6 microns.

CONCLUSION

A workable process for Pyralin PI-2703D was achieved. This process involved the following steps: wafer preparation, coat, soft-bake, expose, develop, and cure. Three different types of development systems were investigated; i.e., single bath immersion development, multiple bath immersion development, and spray development. The spray development system provided the best image by significantly reducing the haze and deposited residue. The thickness of the final image was 1.4 to 1.6 microns. The current process does produce a workable image, however further work is still required to optimize this process. Subsequently, this process will enable Pyralin PI-2703D photosensitive polyimides to be used as the dielectric layer in a low contact resistance multilevel metal process [4,5].

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REFERENCES

[1] Pyralin PD Processing Guidelines PI-2700, pp.1-12, (DuPont Electronics 1988).

[2] Michael T. Pottiger, Solid State Technology, S1-S4, (December 1989).

[3] Dr. Dan Murray (private communication).

[4] P.K. Smith, T.O. Herndon, R.L. Burke, D.R. Day, and S.D. Senturia, Journal of the Electro-Chemical Society, 225-227, (January 1983).

[5] T.O. Herndon, R.L. Burke, and W.J. Landoch, in Polyimides Synthesis Characterization and Applications Volume 2, edited by K.L. Mittal (Plenum Press, New York, 1984), pp.809-826.