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A-2-6 Negative Patterning of AZ1350J by Electron-beam Desensitization of Photo-sensitive Compound

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Electron-beam (EB) lithography, which is used for photo-mask making, is now being extensively studied for direct wafer writing application. Among other things, EB resist materials and processing techniques for direct device fabrication have yet to be established.

This paper reports the discovery of a unique property in the photoresist AZ1350J after EB exposure and its successful application to direct device fabrication in the micron linewidth range. It was found that EB desensitizes AZ1350J to UV light and that the reaction between EB and the resist produces a polymer film insoluble in an ordinary developer. It is therefore possible to form negative resist images on EB-exposed portion by disolving the rest of the resist by flood exposure to UV light and normal development procedures.

The negative resist patterns of AZ1350J formed by this ELectron-beam DEsensitization of photo-Resist process (ELDER) are shown in Fig. 1. High resolution capability of 0.75 μm lines and spaces is possible with this process. These lines have very smooth edges, which is attributable to the high γ-value and absence of swelling during development. The sensitivity and γ-value of AZ1350J as a negative EB resist are 3×10^{-5} C/cm^2 and 3.5, respectively, as seen in Fig. 2. The 3.5 γ-value is outstandingly high compared with those for other negative EB resists.

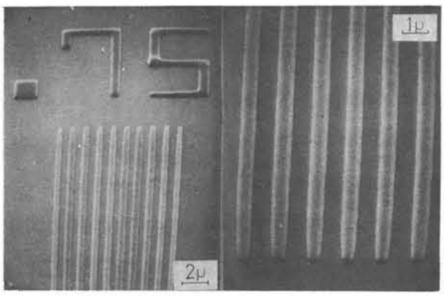

Fig. 1 SEM micrograph of negative patterns of AZ1350J formed by ELDER process

The negative patterns of AZ1350J were found to retain excellent dry-etch resistance. A SEM micrograph showing the aluminum wiring patterns of a MOS LSI with 1 μm minimum spacing over the whole device topography is shown in Fig. 3.

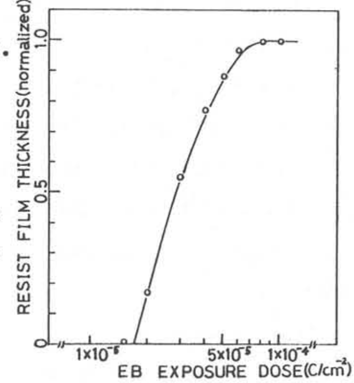

Fig. 2 EB sensitivity curve of AZ1350J

Infrared spectral analysis was carried out to investigate the mechanism of chemical reactions induced by EB and UV light.

It is known[1] that the photo-sensitive compound in AZ1350J, orthonaphthoquinonediazide (ONQDA), is decomposed by UV light producing 3-indencarboxylic acid (3-ICA). 3-ICA makes the exposed portion of the polymer soluble in a basic developer, which accounts for the positive behavior of AZ1350J in UV lithography. This photo-chemical reaction is observed as changes in the infrared spectra in Fig. 4. The absorption band at 2100 cm^{-1} disappears and a new band emerges at 1720 cm^{-1} after UV exposure (curves C and C'). The most remarkable effect of EB exposure on AZ1350J is that it decomposes UV-sensitive ONQDA. This is clearly seen from the diminished peak at 2100 cm^{-1} (curve B), supporting the observation of desensitization to UV light.

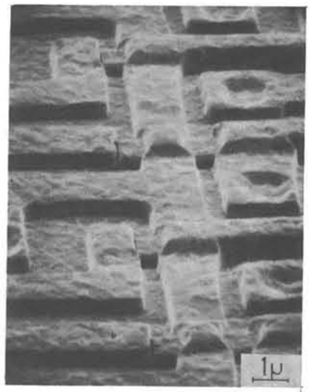

Fig. 3 SEM micrograph of aluminum wiring patterns dry-etched with an AZ1350J mask

The infrared spectra also indicate that EB exposure produces little 3-ICA (curve B'), in conformity to the knowledge that the sensitivity of AZ1350J as a positive EB resist is very low.[2] It is therefore obvious that the major product of EB exposure, which renders the resist insoluble in a basic developer, is not 3-ICA. However no identification of this product has been made yet.

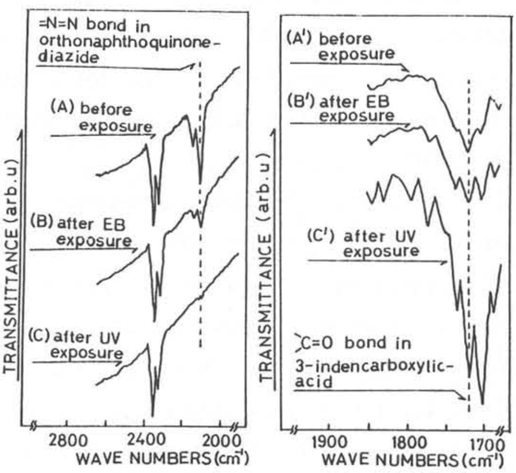

Fig. 4 AZ1350J infrared spectra

It should be noted that the negative patterning mechanism in ELDER is distinct from the cross-linking reaction in ordinary negative resists. Many of the features of the negative AZ1350J patterns formed by ELDER can be explained by this fact. For example, vacuum curing effct which is peculiar to cross-linking resists and detrimental to linewidth control was not observed.

In conclusion, the ELDER process technology, a new concept in EB lithography, is capable of fabricating devices with less than 1 μm linewidth. This mechanism also offers the possibility of exploring an entirely new family of negative EB resists.

(References)

1) J. Pacansky and J. R. Lyerla, IBM J. Res. Develop., Vol. 23, p. 42 (1979)

2) J. M. Shaw and M. Hatzakis, IEEE Trans. Electron Device, Vol. ED-25, p. 425 (1978).