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A New Photobleachable Positive Resist for KrF Excimer Laser Lithography

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A new photobleachable positive resist for KrF excimer laser lithography has been developed. The resist is composed of 2-diazo-1,3-dicarbonyl photoactive compound as an alkaline dissolution inhibitor, an alkali-soluble styrene polymer as a main polymer and diethylene glycol dimethyl ether as a coating solvent. It has an excellent property for contrast and photobleaching with KrF excimer laser light and we achieved high aspect ratio half-micron pattern fabrication in 1 μm thickness using the new resist.

1. INTRODUCTION

KrF (248 nm) excimer laser lithography is most exciting technology for lower submicron VLSI in recent years. The technology has a capability of a pattern fabrication below 0.5 μm. The resist pattern profile, however, is degradated because of strong photoabsorption of a conventional naphthoquinonediazide-novolac resin type positive deep UV resist to KrF excimer laser light and this phenomenon is remarkable in thick (about 1 μm) resist film[1). Therefore, the complicated multi-layer-resist system has been proposed[2).

We have developed a new photobleachable positive resist for KrF excimer laser lithography to overcome the above mentioned problems.

In this paper, the characteristics of the new resist are presented and the lithographic evaluation with KrF excimer laser stepper is demonstrated.

2. MATERIAL CHARACTERIZATION

2-diazo-1,3-dicarbonyl photoactive compound (Fig. 1) and an alkali-soluble styrene polymer were used as the alkaline dissolution inhibitor and the main polymer, respectively. The coating solvent was diethylene glycol dimethyl ether. The 2-diazo-1,3-dicarbonyl compound excellently bleaches at around 248 nm (Fig. 2) and the polymer has a high transmittance of 70 % in 1 μm thickness at 248 nm.

Fig. 3 shows the effect of the concentration of the diazo photoactive compound on contrast values and remaining resist thickness in unexposed regions. The contrast values are assessed by measuring the slope of the linear portion of the curve obtained by plotting the thickness of the relief image as a function of the logarithm of the KrF excimer laser exposure energy[3). The development was done with a 60s immersion in 0.10 % tetramethylammoniumhydroxide (TMAH) solution. As shown in Fig. 3, the contrast value is maxima (1.85) when the concentration of the diazo compound is 15 wt% and remaining resist thickness hardly increases when it exceeds 15 wt%.

Fig. 4 shows sensitivity as a function

of the concentration of the diazo compound. Sensitivity is defined as the exposure energy to result in complete removal of the resist in the exposed areas with the minimum resist loss in the unexposed regions. It is found in Fig. 4 that the larger exposure energy is required for the less than 10 wt% diazo compound.

From these results, it was concluded that the new resist which contains the 15 wt% diazo compound based on the alkali-soluble styrene polymer would be most suited for KrF excimer laser lithography. This resist composition was subjected to spectroscopic and lithographic evaluation.

The exposure characteristics of the new resist in 1 µm thickness is shown in Fig. 5. The loss of resist thickness in unexposed regions under developing was hardly observed. Contrast value was 1.85 and it was much higher than conventional naphthoquinonediazide-novolac resin type deep UV positive resist (1.34).

Fig. 6 shows the UV spectrum characteristics of the resist in 1.0 µm thickness on a quartz substrate before and after photobleaching. The data clarifies that strong photobleaching occurred at 248 nm with KrF excimer laser irradiation.

Table 1 summarizes the characteristics of the new resist in comparison with conventional naphthoquinonediazide-novolac resin type deep UV positive resist. It can be seen from this table that the new resist has superior capability for KrF excimer laser lithography.

3. LITHOGRAPHIC EVALUATION

The new resist was spin-coated to a thickness of 1.0 µm on a silicon wafer. Exposure was done with a KrF excimer laser stepper (NA 0.36) we manufactured[4]. After exposure, the resist film was developed with a 60s immersion in 0.10 % TMAH solution.

Fig. 7 demonstrates 0.5 µm lines pattern of the resist. High aspect ratio patterns of such thick resist film were successfully obtained using this new resist. These good results are attributed to the high contrast value and great photobleachability of the resist.

4. CONCLUSION

The new resist composed of strongly photobleachable 2-diazo-1,3-dicarbonyl photoactive compound, the transparent alkali-soluble styrene polymer for KrF excimer laser light and diethylene glycol dimethyl ether has been developed. It has an excellent property for contrast and photobleaching with KrF excimer laser light and we achieved high aspect ratio half-micron pattern fabrication in 1 µm thickness using the new resist. Therefore, we are convinced that this new resist could make possible simple and efficient single-layer-resist system for KrF excimer laser lithography.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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Fig.1 Chemical structure of the 2-diazo-1, 3-dicarbonyl photoactive compound (R, R'; substituents).

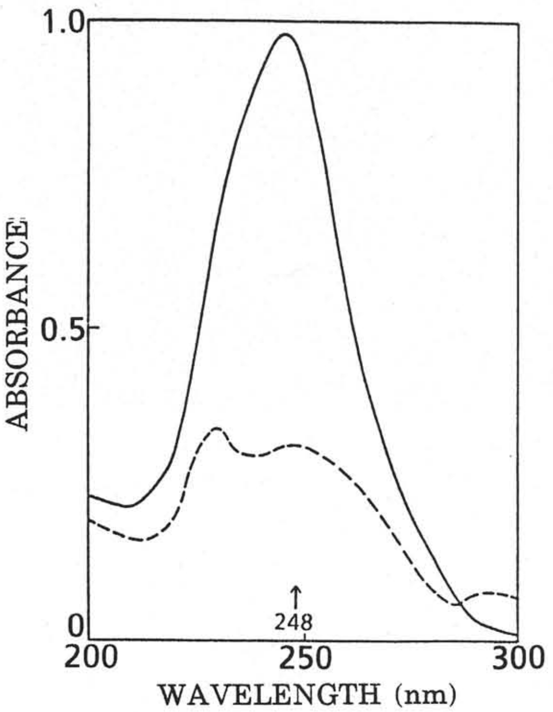

Fig.2 UV spectrum characteristics of the 2-diazo-1,3-dicarbonyl photoactive compound before (solid line) and after (dashed line) bleaching with KrF excimer laser irradiation.

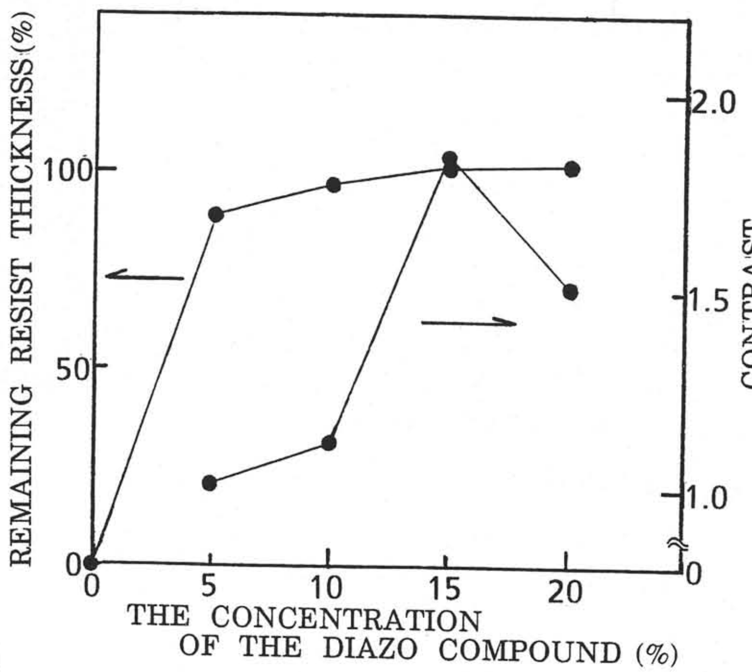

Fig.3 Effect of the diazo concentration on contrast value and remaining resist thickness in unexposed regions.

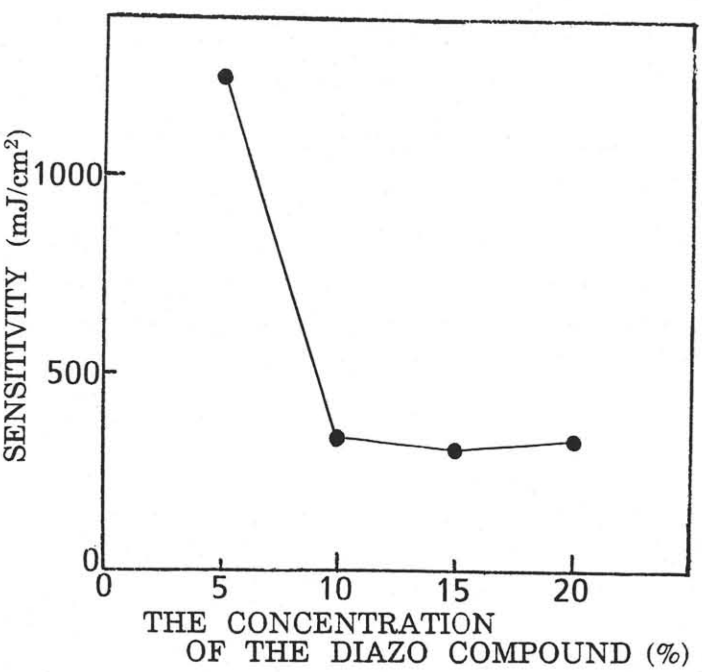

Fig.4 Effect of the diazo concentration on sensitivity.

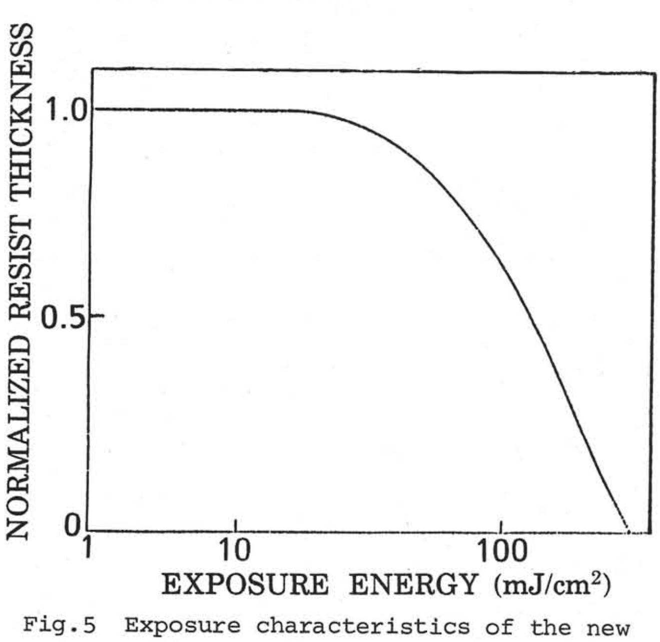

Fig.5 Exposure characteristics of the new resist in 1.0 μm thickness with KrF excimer laser irradiation.

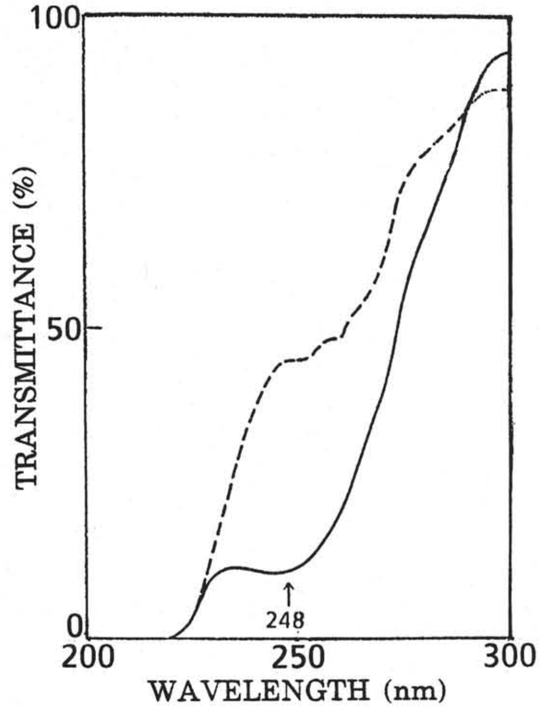

Fig.6 UV spectrum characteristics of the new resist in 1.0 μm thickness before (solid line) and after (dashed line) bleaching with KrF excimer laser irradiation.

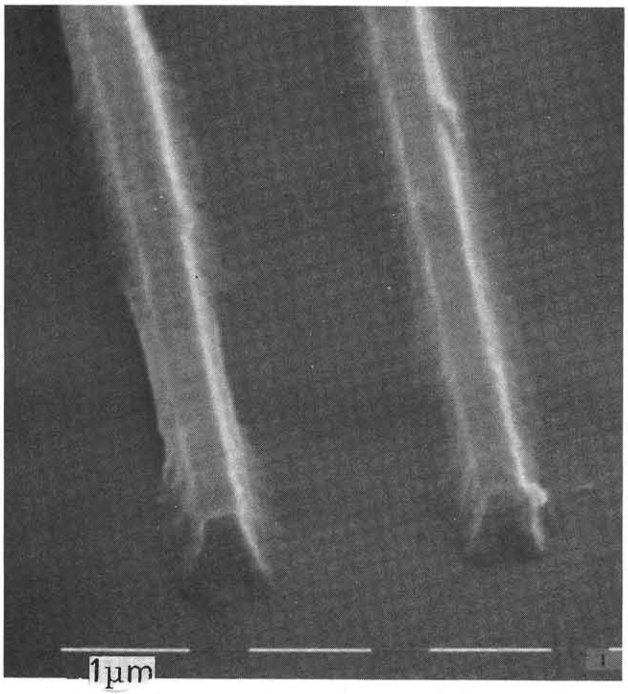

Fig.7 SEM photograph of 0.5 μm lines pattern of the new resist in 1.0 μm thickness.

Table 1 Summary of the characteristics of the new resist in comparison with conventional naphthoquinonediazide-novolac resin type deep UV positive resist

	TRANSMITTANCE at 248nm (%)		CONTRAST	REMAINING RESIST THICKNESS IN UNEXPOSED REGIONS (%)
	before bleaching	after bleaching		
NEW RESIST	10.7	45.3	1.85	100
CONV.	9.3	10.0	1.34	90