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Conductive E-Beam Resist

H.Watanabe and Y.Todokoro

Kyoto Research Laboratory, Matsushita Electronics Corporation

Kyoto 601, Japan

Conductive E-beam Resist, CER has been developed. CER consists of ammonium poly (p-styrene sulfonate), AmSS which has ion conductivity. CER is negative working upon irradiation with e-beam. The sensitivity is 110 μC/cm^2 and the contrast value (γ) is 1.5. The sheet resistivity of 2 um CER is about $10^8 \Omega/\square$. The use of CER realizes a simple e-beam writing process on an insulating substrate. We have fabricated 1 μm lines and spaces on a quartz substrate by using CER.

1. Introduction

E-beam lithography has been widely used for mask fabrication and submicron device fabrication. One of the problems for e-beam lithography is charging. Buildup of residual electric charge causes pattern distortion and alignment error on an insulating substrate. Charging is also a problem for conductive substrate when the multi-layer resist is used, since the electrons may not penetrate to a conductive substrate. Metal and silicon films were used to avoid these problems [1-3]. However, a fabrication process of such films are not compatible with a lithographic process. And metal films would be potential sources of contamination.

This paper describes the Conductive E-beam Resist, CER, which eliminates the charging effect without an additional process.

2. Experimental

A. Material

CER consists of ammonium poly (p-styrene sulfonate), AmSS. The chemical structure of AmSS is shown in Fig.1. AmSS is the salt of sulfon-styrene anion base and positively charged ammonium ion, and so AmSS has ion conductivity.

B. Process

CER was spun on to silicon or quartz wafers to give a nominal thickness of 0.5-2 μm, and baked in a convection oven at 100-300°C for 30 min. The wafers were exposed on an e-beam exposure machine at 25 kV. The exposed wafers were developed in water for 60 s. To compare the charging effects on an insulating substrate, αM-CMS (Toyo Soda) was used as the conventional, negative e-beam resist.

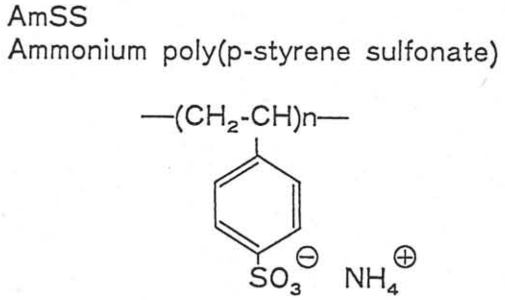

Fig. 1 Chemical structure of AmSS.

3. Results and discussion

Typical spin speed and film thickness curve for CER after baking at 200 °C is shown in Fig.2. The thickness of CER can be adjusted to produce coating of 0.2-2 μm thickness by changing the spin speed at different solid content. The refractive index of CER is 1.55.

Baking temperature effects on conductivity of CER have been studied. Figure 3 shows the resistivity of 2 μm CER film, changing the baking temperature as a parameter.

The sheet resistance of 2 μm CER baked at 200°C is 6×10^{7} Ω/□. The sheet resistance of CER increases gruadually with the increase of baking temperature below 250°C, and increases rapidly above 250°C.

A sensitivity curve of CER prebaked at 100, 120, 150, 200°C on a silicon substrate is shown in Fig.4. The sensitivity of CER baked at 200 °C is 110 $\mu C/cm^{2}$ and the contrast value γ is 1.5. The sensitivity decreases with decreasing the prebake temperature. The sensitivity and contrast value are summarized in Table 1.

Figure 5(a) shows the typical failure of resist patterns caused by e-beam charging on insulating substrate. The patterns are written in 0.5 μm αM-CMS at a dose of 35 $\mu C/cm^{2}$ on a quartz substrate. The patterns are deformed due to charging of e-beams. On the other hand, the use of CER prevents charging effects as shown in Fig.5(b). The patterns are written in 0.5 μm CER on a quartz substrate at a dose of 250 $\mu C/cm^{2}$. Patterns without distortions are delineated on a quartz substrate.

Figure 6 shows the lines and spaces patterns in 0.5 μm CER on a quartz substrate. Minimum lines and spaces of 1 μm are fabricated. Resist edge profiles of 2 μm lines and spaces in CER on a quartz substrate are shown in Fig.7. By using CER, fine patterns can be delineated on an insulating substrate.

Table 1. Sensitivity and contrast value

Prebake temperature (°C)	Sensitivity (μC/cm)	Contrast value
100	690	0.9
120	340	1.4
150	180	1.5
200	110	1.5

4. Conclusions

Conductive e-beam resist, CER has been developed. The performance characteristics of CER have been described. CER has both conductivity and e-beam sensitivity. The sheet resistance of 2 μm CER is about 10^{8} Ω/□. The sensitivity is 110 $\mu C/cm^{2}$ and 1 μm lines and spaces are fabricated in CER.

CER eliminates the charging effects, while retaining the simplicity and cost effectiveness of conventional processing. CER has wide applicability for e-beam mask fabrication and direct wafer writing on an insulating substrate.

Acknowledgments

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References

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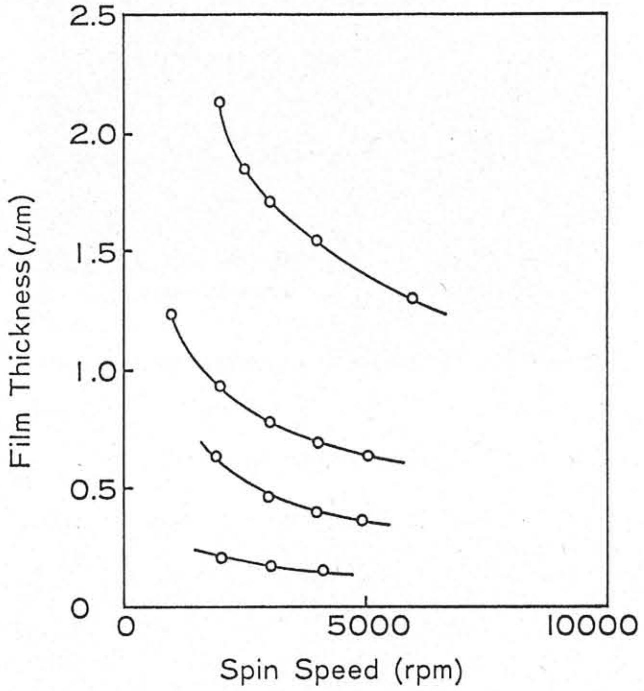


Fig. 2 CER film thickness vs. spin speed.

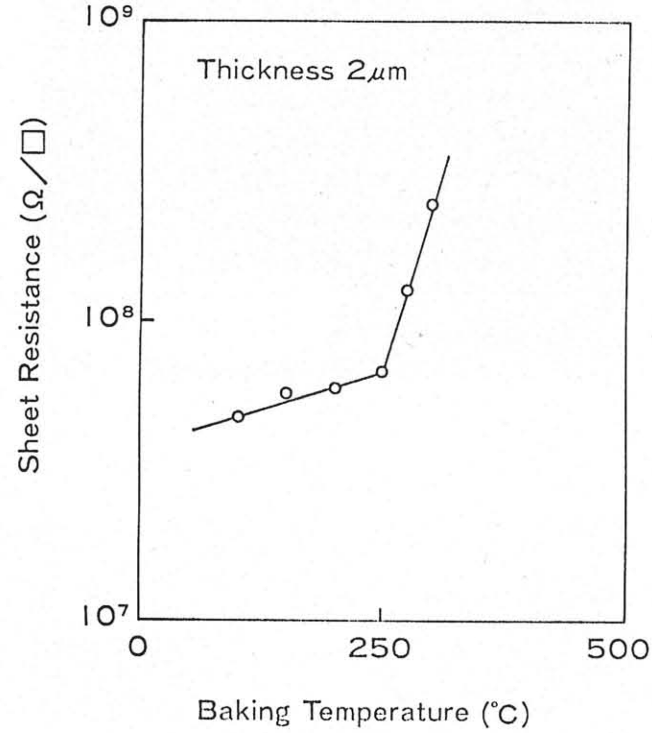


Fig. 3 Resistivity of CER vs. baking temperature.

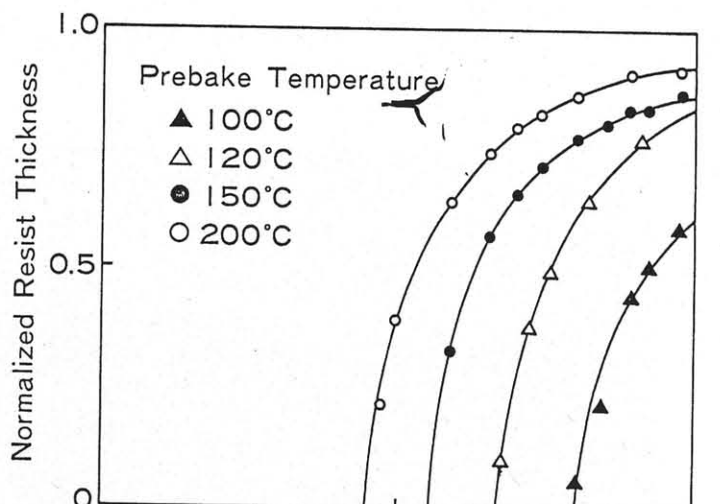
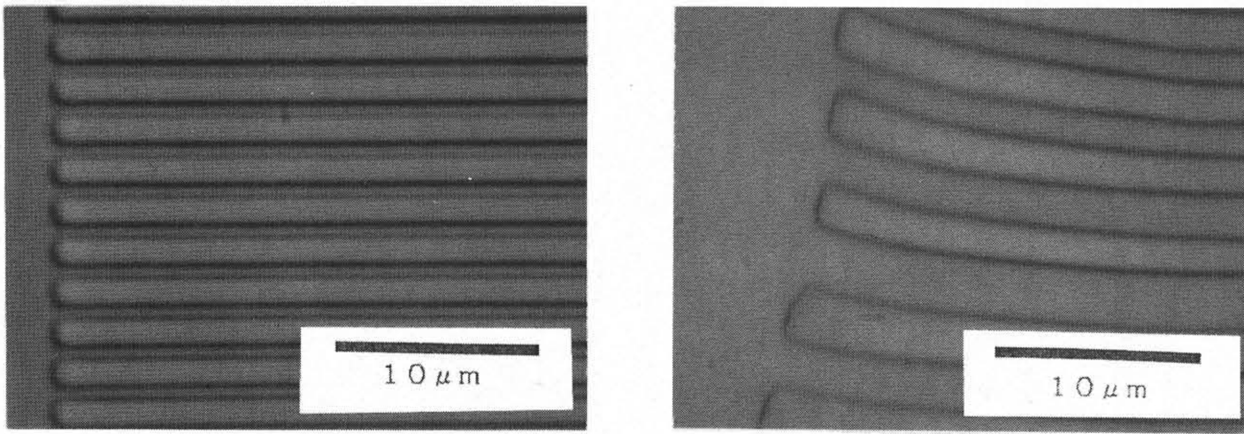


Fig. 4 Sensitivity curve of CER.



(a) (b)

Fig. 5 Resist patterns in (a) CER and (b) αM-CMS on a quartz substrate.

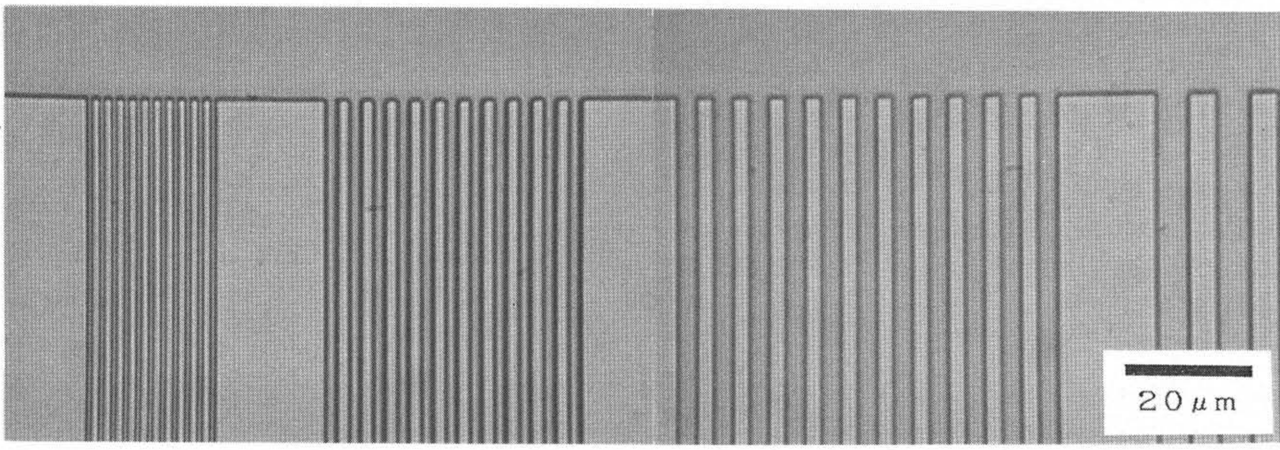


Fig. 6 Lines and spaces in CER on a quartz substrate.
Minimum lines and spaces are 1 μm.

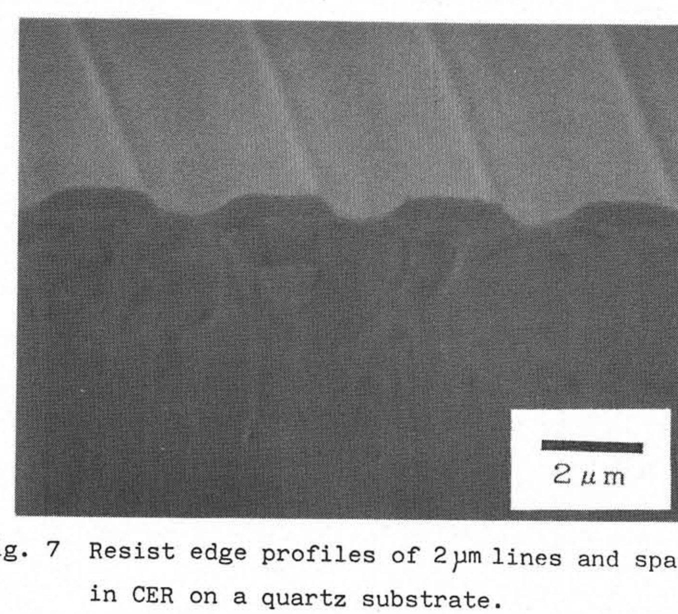


Fig. 7 Resist edge profiles of 2 μm lines and spaces in CER on a quartz substrate.