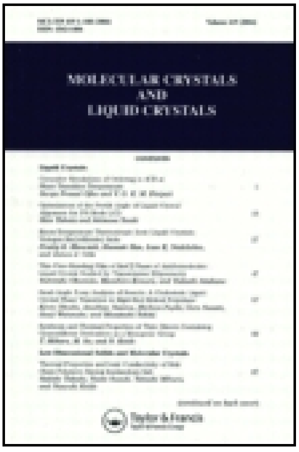

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High-Resolution Electron Beam Lithography with Langmuir-Blodgett Films

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HIGH-RESOLUTION ELECTRON BEAM LITHOGRAPHY WITH LANGMUIR-BLODGETT FILMS

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Abstract Novel positive resists of poly(methylphenyl methacrylate) and poly(methylphenyl methacylate)-co-(methyl methacrylate) were synthesized and their performance as electron beam resists was evaluated, initially with spin-cast films and then with Langmuir-Blodgett(LB) films on silicon substrate, for optimum sensitivity and resolution. The fine patterns were formed at the dose range of 250-350 $\mu C/cm^2$, and developed in the solution made of various ratio of MIBK/IPA mixture. The best resolution was 80 nm for the PMPMA resist and 0.14 μm for the P(MPMA-MMA) resist.

INTRODUCTION

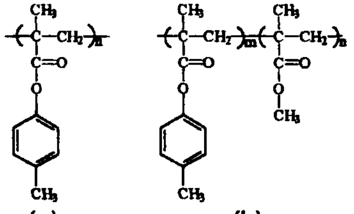
Electron-beam lithography[1] is one of the favoured techniques for submicrometer device fabrication because of its direct writing capability, but the major limitation of the resolution is imposed by electron scattering. These resolution limiting effects generally become more serious with increasing resist thickness. Therefore, to improve the resolution in electron beam lithography, the use of ultrathin resists with thickness of 50 nm or less has been proposed in elsewhere.[2-5] As a means of organizing molecular assemblies, Langmuir-Blodgett(LB) films[6-8] have many potential applications such as molecular electronics, nonlinear optics and conducting thin films.

Currently PMMA resists are widely being used in fabricating fine patterns by electron beam lithography because of its best resolution capability. However, PMMA resist does not have good thermal stability and sensitivity. Therefore, it is desirable to design a new electron beam resist with improved thermal stability and high sensitivity. In order to improve the thermal stability and sensitivity of polymer resists, the model structure of PMMA was chosen to be modified.[9]

In general, the thermal stability of resist could be enhanced by introducing a phenyl ring component into the resist structure. In this study, a number of poly (methylphenyl methacrylate) (PMPMA) and poly (methylphenyl methacylate)-co-(methyl methacrylate) (P(MPMA-MMA)) were synthesized.

EXPERIMENT

PMPMA and P(MPMA-MMA) were prepared by free radical solution polymerization.[10] Figure 1 shows the structures of PMPMA and P(MPMA-MMA). The substrate for spin-casting and LB film deposition was 4 inch p-type(100) silicon wafer. PMPMA and P(MPMA-MMA) resist with a thickness of 40-50 nm(measured by ellipsometer and Nanospec.) were prepared by spinning the resist solution at 5000 rpm for 30 sec. The LB film deposition was performed by using a Lauda film balance FW2. The Langmuir monolayer was compressed at the surface pressure of 20 dyn/cm at 25 ℃. Spin-cast PMPMA and P(MPMA-MMA) films and PMPMA LB films were exposed with a Cambridge EBMF 10.5 system. The exposure was carried out at 30 keV accelerating voltage, 80 nm beam diameter and 0.5 nA beam current. The dose range for this study were 50-700 μC/cm². After exposure, PEB(post-expose baking) was performed at the temperature range from 110℃ to 160℃. PMPMA and P(MPMA-MMA) were developed in a solution made of 1:1 and 4:6 MIBK/IPA mixtures.



(a) (b)

FIGURE 1 Structures of a)PMPMA and (b)P(MPMA-MMA)

AFM images of the sample[11,12] were obtained by using a Autoprobe M5 of Park Scientific Instruments (PSI). Microfabricated cantilevers with spring constants of 0.40 N/m were purchased from PSI. At the end of the cantilever, a silicon nitride tip smaller than 10 nm in radius was mounted.

RESULTS AND DISCUSSION

Table 1 shows physical properties of synthesized PMPMA and P(MPMA-MMA). PMPMA with a low molecular weight (Mw=150;000) shows the better resolution capability. Figure 2 and 3 are AFM images and height profiles of spin-cast PMPMA films as a positive

TABLE 1 Physical properties of synthesized electron beam resist.

	Mw	PDI	Tg	Tid
PMPMA	337,000	2.50	127.91	270.06
	150,000	1.44	132.00	293.36
P(MPMA-MMA)	39,000	1.86	129.81	161.10

electron beam resist at a dose of 350 μC/cm^2. The size of the smallest lines in Figure 2 is 80 nm, and the smallest size is 0.14 μm in Figure 3. Initially designed patterns with the smallest linewidth was 50 nm.

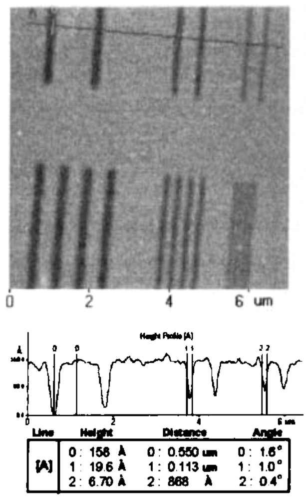


FIGURE 2 AFM image of patterns with spin cast PMPMA films at a dose of 350 μC/cm^2 (PEB:110 °C)

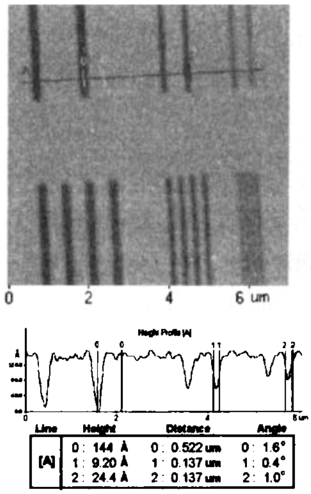


FIGURE 3 AFM image of patterns with spin cast PMPMA films at a dose of 350 μC/cm^2 (PEB:120 °C)

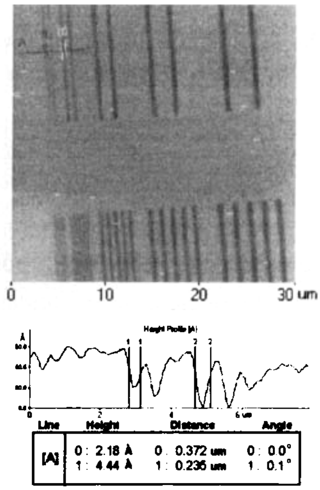


FIGURE 4 AFM image of patterns with spin cast P(MPMA-MMA) films at a dose of 250 μC/cm^2 (PEB:110 °C)

Post expose bake (PEB) temperature is very important for electron beam lithography process.[13,14] PEB temperature of Figure 2 was 110 °C and that of Figure 3 was 120 °C. These films were performed at other PEB temperature, and PEB temperature of 110 °C was better than that of 120 °C. Electron beam lithography was performed at the various dose range of 50 - 700 μC/cm^2, and the suitable dose condition was 250 - 350 μC/cm^2 to achieve small linewidths. In case of the dose of lower than 250 μC/cm^2, the fine pattern was not formed. Figure 4 shows AFM image and height profiles of spin-cast P(MPMA-MMA) films as a positive electron beam resist at a dose of 250 μC/cm^2. The smallest line in Figure 4 is 0.2 μm. The resolution of P(MPMA-MMA) was not better than that of PMPMA.

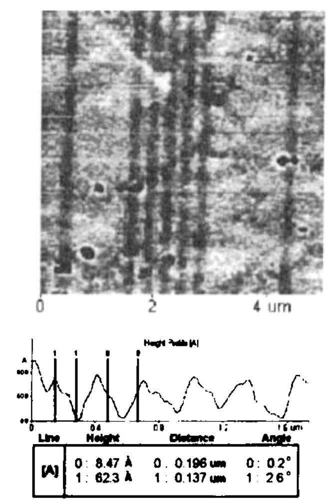


FIGURE 5 AFM image of patterns with PMPMA LB films at a dose of 250 μC/cm^2(PEB:110 °C)

After evaluating spin-cast PMPMA resist, the morphology of Langmuir-Blodgett films and its patterns were evaluated. There are several deep defects on the mono- and bilayer LB films. Once multilayer LB films formed on silicon substrate, the surface of film appears as a random pattern. In the case of PMPMA, deposition type was Y-type.[10] Ellipsometric results indicate that the average layer thickness per layer is 10 Å. Figure 5 shows an image of patterns with 10 layers of PMPMA LB films. Height profile of Figure 5 shows that the smallest size of pattern is 0.2 μm.

CONCLUSIONS

In this work, we have demonstrated that new resist PMPMA and P(MPMA-MMA) can be used as electron beam positive resists at a more high resolution and be compatible with the subsequent processing. Spin cast PMPMA was capable of 80 nm pattern and the resolution of P(MPMA-MMA) and PMPMA LB films was 0.2 μm. Even the surface of LB films is rough with some holes, but 0.2 μm pattern was formed and the LB films can be used as electron beam resist.

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