Characterization of Single Component Molecular Glass Resists

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Abstract:

Molecular glasses (MGs) are materials that exist in an amorphous state below their glass transition temperature, which allows us to study their glassy properties and behavior as photoresists. This research explored single component MG photoresists designed for future use in physical vapor deposition studies. This study investigated the critical doses, etch resistance rates, and electron beam lithography performance of three MGs. The CM-CR6 MG photoresist was identified as the most suitable candidate due to its relatively high etch resistance and high resolution patterning of 80 nm line and space patterns.

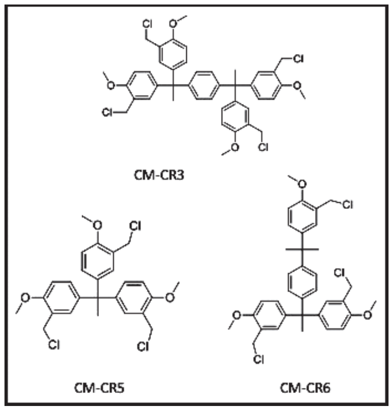

Figure 1: Structures of MG resists.

Introduction:

MG photoresists have specific characteristics like small molecular size, ability to form films, and high glass transition temperatures (Tg), which make them strong candidates for next generation lithography [1]. As polymeric photoresists are reaching their limits in feature size and roughness, attention has turned to small molecule photoresists like MGs [2]. To help optimize MGs in the lithography process, fundamental studies of their glass-forming properties can be explored using physical vapor deposition. For this, new single component molecular glasses must be designed and characterized before deposition studies are conducted. Figure 1 displays the chemical structures of the chloromethylated Cornell resists (CM-CR) that were studied. Using this model resist system, we can characterize their lithographic performance using contrast curves, etch resistance rates, and patterning through electron beam lithography.

Experimental Procedure:

The MG resist was dissolved in 2-butanone, making a 5 weight percent (wt%) solution. If necessary, 5 wt% with respect to resist of photoradical initiator, 2,2- dimethoxy-2-phenyl-acetophenone (DPAP) was added to the solution. The resist was filtered through a 0.2 μm membrane filter onto a HDMS primed silicon wafer and spun at 2000 rpm for one minute. The wafer then underwent a post apply bake for one minute at 100°C.

For the contrast curves, the resist was first flood-exposed using the ABM contact aligner with 254 nm broadband light, and developed for one minute in 1-butanol. The film thickness was then measured as a function of dose using the Woollam spectroscopic ellipsometer. For the etch resistance studies, the resists were flood exposed as mentioned previously, and then plasma etched on the Oxford 80+ plasma etcher for varying amounts of time. Film thickness was measured as a function of etch time, and the rate determined in nanometers per minute. To study the patterning capabilities of the photoresists, they were exposed using the JEOL 9500 electron beam (e-beam) lithography system. Their performance was evaluated using scanning electron microscope images, and SuMMIT software was used to calculate the line edge roughness (LER) and line width roughness (LWR).

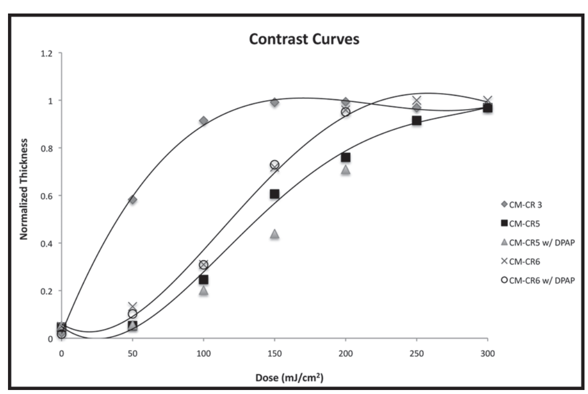

Figure 2: Contrast curves.

Results and Conclusions:

The contrast curves for the three MGs are shown in Figure 2. They did not display a desired steep slope, however the critical doses were identified for CM-CR3, CM-CR5, and CM-CR6 as 150 mJ/cm^2, 300 mJ/cm^2, and 250 mJ/cm^2 respectively. The addition of DPAP did not affect the critical dose of CM-CR5 or CM-CR6, and therefore, the experiment was not carried out with CM-CR3. This deep ultra-violet light behavior is not ideal however; this information is essential for quick testing of other properties.

The etch resistance of each resist were measured and compared to poly(hydroxystyrene) (PHOST), an industry standard (Figure 3). With CHF_3/O_2 etch gas, the etch resistance rates of the three MGs were the slowest and are comparable to PHOST, making CHF_3/O_2 the most favorable etch gas for this system.

The e-beam patterning performance is one of the most important aspects of these MGs. CM-CR6 showed patterns down to 80 nm 1:1 line:space with a low LER of 3.8 nm and LWR of 5.9 nm. The addition of DPAP allowed for comparable results using less than half of the original required dose, as seen in Figure 4. CM-CR3 was also able to pattern down to 80 nm 1:1 line:space, but had higher LER (5.0 nm) and LWR (9.3 nm) compared to CM-CR6. CM-CR5's performance was poor compared to CM- CR3 and CM-CR6, as it was only able to pattern down to 150 nm 1:1 line:space.

From these results, CM-CR6 was recognized as the most suitable resist for future use, due to its e-beam patterning performance and its proficient etch resistance. Future Work In general MG photoresists have shown promise but have not been optimized. Therefore future characterization and further optimization is needed to make MG photoresists a viable option for next generation lithography.

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References:

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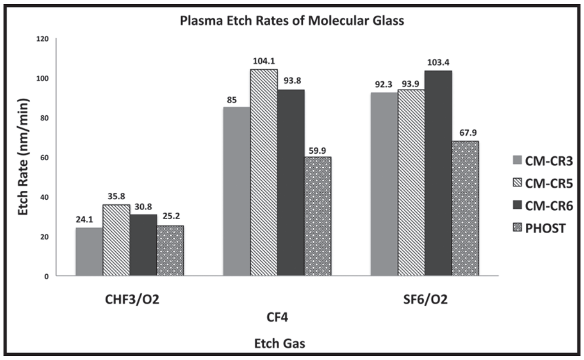

Figure 3: Etch resistance study.

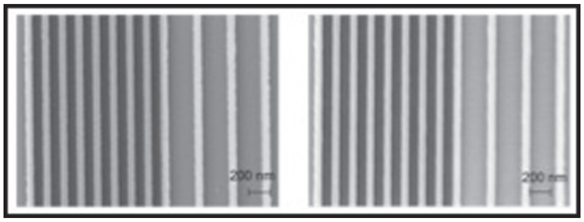

Figure 4: SEMs. Left: CM-CR6 without DPAP with a dose of 1250 mJ/cm^2. Right: CM-CR6 with DPAP with a dose of 500 mJ/cm^2.