Developer Soluble Hard Mask for Advanced Patterning

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Introduction

The demand of CD shrinkage is pushing the numerical aperture, exposure wavelength, k1 value and OPC to the limit of the current photolithographic technology. Lower k1 value in Rayleigh's law has been successfully achieved by reducing photoresist thickness since the insertion of ArF photolithography. Photoresist with thickness of 100 nm or below is not uncommon in film stacks for extreme photolithography processes nowadays.

The etch budget of the thin photoresist is enhanced by inserting one or more hard mask layers into the stack. Nevertheless, the photoresist has to be thick enough to transfer the patterns to the first hard mask layer by plasma etch. Unfortunately, there is hardly any HM material that will etch multiple times faster than photoresist by any etch chemistry.

We are reporting a novel pattern transfer process that employs a developer soluble hard mask. The hard mask is patterned in the same process of photoresist development. No plasma etch is required in the process of patterning the hard mask.

Experimental

The prototype developer soluble hard mask is a titanate based material. The hard mask has been characterized with plasma etch, TMAH etch and imagiability, together with routine tests such as shelf life, spin-bowl compatibility, and manufacturability.

Results and Discussion

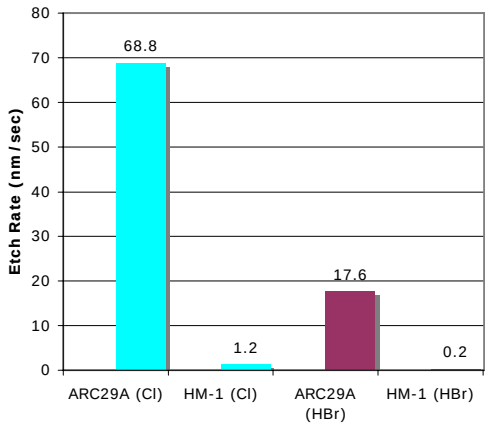

Figure 1. Reactive ion etch rate of ARC29A and HM-1 by chlorine and HBr.

Figure 1 shows that the developer soluble hard mask has a very slow etch rate by chlorine or HBr. This property is essential for the HM to transfer the patterns to the next layer, either the final substrate or a carbon rich film.

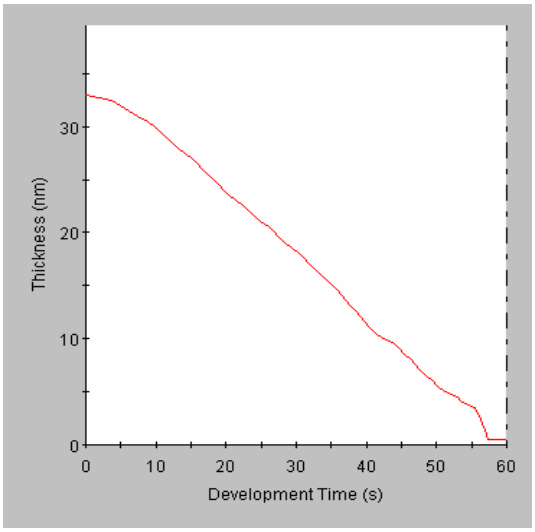

Figure 2. Development curve of HM-1 in 0.26 N TMAH.

Figure 2 shows that the HM is soluble in developer with an appropriate rate. The development rate can be adjusted through formulation and cure temperature.

As the first generation material, HM-1 dissolves isotropically in TMAH developer. Due to the nature of isotropic etch, the hard mask patterns can be trimmed in the development process. This trimming effect is extremely useful for the double patterning technology.

Conclusions

We are actively collecting photolithographic data on HM-1. If the process is feasible, the photoresist is reduced to an imaging layer and its thickness is pushed to the ultimate limit. This new process and material are not limited to the advanced pattering technologies. In essence, the benefit is much more significant when the i-line or DUV resist is reduced to, say, 40 nm.