Multi-Trigger Resist for Electron Beam and Extreme Ultraviolet Lithography

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Remarkable progress has been made in the semiconductor industry with advances in integrated circuit technology. This has been driven by development of lithography techniques capable of high resolution patterning, which include EUV, DUV, and electron beam, and also new generations of high-resolution high sensitivity resist materials.

Extreme ultraviolet lithography (EUVL) at 13.5 nm is the most likely to be the chosen post-optical technique for patterning sub 20 nm half-pitches for chip manufacturing, [1] with high-volume manufacturing deployment expected imminently. Along with addressing issues regarding the availability of EUV power sources, the most challenging necessity in promoting the EUVL as industrial lithographic technique for high-volume production has been the need for improvement of resist performance, or the development of novel resist materials capable of meeting industry requirements for ultimate resolution while maintaining a good sensitivity and low line edge roughness. [1]

Whilst efforts are to develop candidate EUV resists there is another non-trivial factor to consider in this process: mask production. The increase in the resolution of the main exposure tools currently being used for high-volume production of semiconductor devices has pushed the resolution of the chemically amplified resist used in electron beam mask writers towards 16 nm half-pitch. [2] Direct-write electron beam mask patterning is an indispensable technology owing to its fine focusing characteristics and high precision spatial control of charged particles, which photolithography does not posses. However, direct-write is time-consuming unlike projection exposure in the photolithography. It requires highly sensitive resists in order to reduce the patterning time of complicated mask patterns. In addition to sensitivity, the roughness of the developed resist sidewall also plays an important role in the fabrication of photomasks and molds. [2]

Traditional resists have enabled a half-pitch of 22 nm in production. However, chemically amplified resists can naturally limit the ultimate resolution in the resist due to acid diffusion, and to post exposure instability in the patterned regions. [1] In addition, for sub 10 nm patterning the LER and LWR become critical parameters that put an additional constraints on chemically amplified resist. Recently, attention has focused on the development of non-chemically amplified resists for lower lithography nodes, such as an MAPDST-MMA copolymer that contains a sulfonium group to give their material the sensitivity for electron beam radiation. A resolution of 20 nm in 1:2 line/space patterns was achieved. [1]

We are working on the development of a new negative tone molecular resist platform for electron beam lithography as well as extreme ultraviolet and optical lithography. We have previously reported the performance of the xMT resist, which shows a good combination of sensitivity, low line edge roughness and high-resolution patterning. [3] In order to overcome the limitations induced by acid diffusion we have recently investigated and introduced a new mechanism in our resist, named the multi-trigger concept.

In a Multi-Trigger Resist, multiple distinct chemical reactions must take place simultaneously and in close proximity for the amplification process to proceed. Thus, at the edge of the feature, where the density of photo-initiators that drive the chemical reactions is low, the amplification process is self-terminating, rather than requiring a quencher. This significantly reduces blurring effects and enables much improved resolution and line edge roughness while maintaining the sensitivity advantages of chemical amplification. Here we present results obtained so far where the behaviour of the resist is driven towards the multi-trigger regime by manipulating the resist formulation. We demonstrate a resolution of 13 nm half-pitch in semi-dense (1:1.5 line/space) and 22nm diameter pillar patterns in electron beam and 16 nm half-pitch resolution in dense (1:1 line/space) patterns in EUV using the MTR material with an improvement in the LER value in the higher MTR formulations.

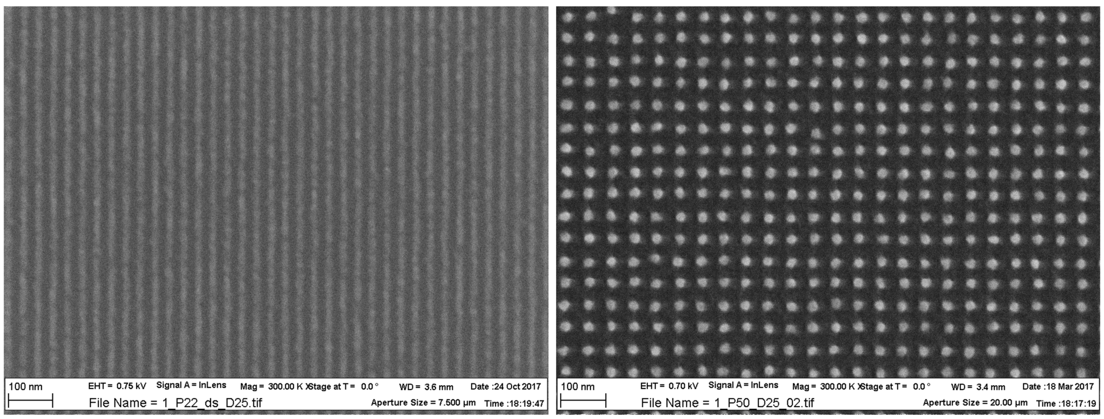

Fig.1 SEM images of patterned MTR resist in electron beam lithography a) CD 13.0nm at pitch 33nm, LER 5.8nm, b) pillars diameter 22.6nm at pitch 50nm

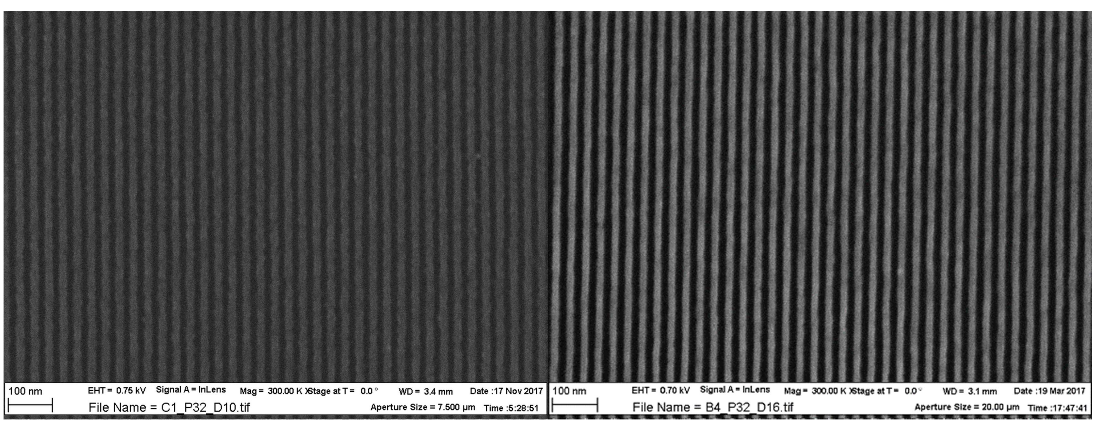

Fig.2 SEM images of patterned resist in EUV lithography: a) standard MTR formulation, 46mJ/cm^2, CD 15.8nm, LER 3.86nm b) higher MTR formulation 47.4mJ/cm^2 CD 14.6nm, LER 2.06nm

References

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