Non-PFAS Biomass non-CAR for sub-15 nm SRAF Patterning on High-NA EUV Mask

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The transition to High Numerical Aperture (High-NA) EUV lithography presents a profound challenge for EUV mask patterning, demanding sub-15 nm Assist Feature (SRAF) resolution for adequate Depth of Focus (DoF). Current mask lithographic performance is constrained by the intrinsic resolution limit of Chemically Amplified Resists (CAR), as Multi-Beam Mask Writer (MBMW) technology contributions have reached saturation within these materials. To overcome this, we have pioneered a Main-Chain Scission (MCS) type non-CAR specifically for High-NA EUV mask applications, which fundamentally eliminates pattern blurring caused by acid diffusion. Collaborating with Oji, this novel material is engineered as a PFAS-free biomass resist, aligning advanced nanofabrication with global environmental and human safety considerations.

Preliminary data validated the material's high intrinsic resolution, resolving an HP 8.4 nm L/S pattern on a Si wafer.[1] Leveraging this, the resist was subjected to premier performance validation on an EUV mask using 50 keV VSB and MBMW tools. Following development, the material resolved an iso-space CD of 28.2 nm. Subsequent hard mask and final absorber etch processes confirmed final iso-space CD of 13.8 nm and 17.7 nm (Figure 1), respectively, achieving performance comparable to the leading high-resolution CAR reference. Additional evaluation identified material limitations, including scum formation and sub-optimal etch resistance. To address these, a comprehensive process optimization was implemented, including Post-Exposure Bake (PEB) tuning and under-layer integration. This optimization yielded dramatic improvements: resolution was enhanced by 56.0% and Space Width Roughness (SWR) was reduced by 23.5% (Figure 2). Also, we are continuing molecular engineering efforts with Oji, focusing on molecular weight optimization and the new polymer structure design to further enhance etch durability. This work significantly accelerates the material development pipeline for High-NA SRAF patterning, marking a vital step toward realizing the ultimate resolution required for next-generation semiconductor manufacturing.

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[1] K. Morita, Y. Tanaka, Y. Tanaka and M. Asai, Potential of biomass EUV non-CAR type resist for high-NA EUV lithography, Proc. SPIE, 12498, 1249815-1 (2023).

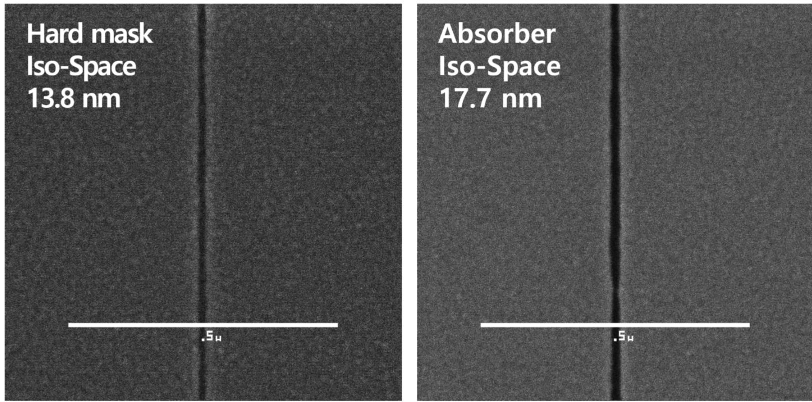

Figure 1: Lithography performance of the Oji non-PFAS biomass resist on an EUV mask exposed with 448.8 uC/cm^2 at 50 keV. The scanning electron microscopy (SEM) image (left) shows iso-space with a CD of 13.8 nm after hard mask etch, and CD of 17.7 nm after absorber etch (right).

	Ref.	w/ PEB	w/ Under-layer
Under-layer	X	X	O (AL412 23 nm)
PEB	X	O (90 °C)	X
Iso-Line (nm)/ Design CD (nm)	34.1/33	15.0/30	16.1/30
L/S (nm)/ Design CD (nm)	36.1/34	30.7/25	35.3/27
Iso-Space (nm)/ Design CD (nm)	28.2/21	26.5/12	22.4/12
SWR (nm)	3.4	3.0	2.6

Figure 2: SEM analysis of the resolution and SWR of the Oji non-PFAS biomass resist on an EUV mask. The results compare the baseline performance (without PEB and under-layer) with the enhanced performance achieved by applying the optimized PEB temperature or by introducing an under-layer.