Increasing critical collapsing of sub-60 nm patterns

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In this study, we investigate the pattern collapse mechanism of dense lines with Critical Dimension (CD) under 60 nm printed with Extreme Ultra Violet (EUVL) and Electron Beam Lithographies (EBL) into ESCAP Chemically Amplified Resist (CAR): MET1K.

As reported, pattern collapse simulation models using either elastic[1] and/or plastic[2] properties of the resist do not allow to predict collapse of these dense lines. Therefore, we developed 2 new models considering the adhesion properties of the resist film on the HMDS primed silicon substrate[3]. By comparing simulated to experimental critical height (H_c) at which collapse occurs, pattern collapse behaviour of EUVL and EBL patterns is attributed to their unsticking of the substrate under the capillary pressure (figure 1). Furthermore, elastic behaviour of the patterns appeared to be negligible as long as resist lines present a critical aspect ratio lower than 3.

Improving the critical aspect ratio of sub-60 nm EUV and E-Beam patterns was therefore targeted by increasing resist/substrate adhesion. By spin coating an appropriate organic BARC layer under the exposed resist, work of adhesion calculated with Owens-Wendt method was increased from 37 mJ/m^2 to 49 mJ/m^2. Furthermore SEM observation of the collapsed patterns confirms that resist patterns are “embedded” in the BARC coated substrate, proving that collapse is, in this case, ruled by plasticizing of the resist (figure 2). However, no significant improvement of the critical height was observed when using a BARC under-layer (figure 3). Thanks to simulation, we demonstrate that in this case, the limiting factor is the mechanical properties, specifically the yield stress of the resist, which are too low to avoid lines deformation. In conclusion, to match the ITRS specifications for the 32nm node realization, both adhesive and mechanical properties of the resist have to be enhanced.

[1] K. Tanaka et al., Proc. of SPIE, Vol. 5039, pp. 1366, 2003.
[2] K.Yoshimoto et al., J. of Appl. Phys., Vol. 96 (4), pp.1857-1865, 2004.
[3] A.Jouve et al., Proc. of SPIE, Vol. 6154, to be published.

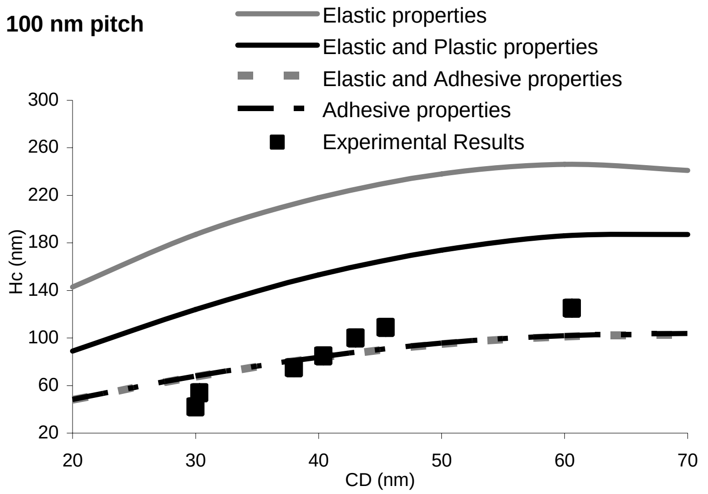

Figure 1: Critical height of MET1K dense lines (100 nm pitch) simulated with 4 various models compared to EBL experimental results.

(a) MET1K deposited on HMDS primed silicon wafer

(b) MET1K deposited on BARC

Figure 2: SEM observation of collapsed lines of MET1K resist printed with EBL and deposited on various substrates. (a) Resist deposited on HMDS primed silicon wafer and (b) Resist deposited on organic BARC.

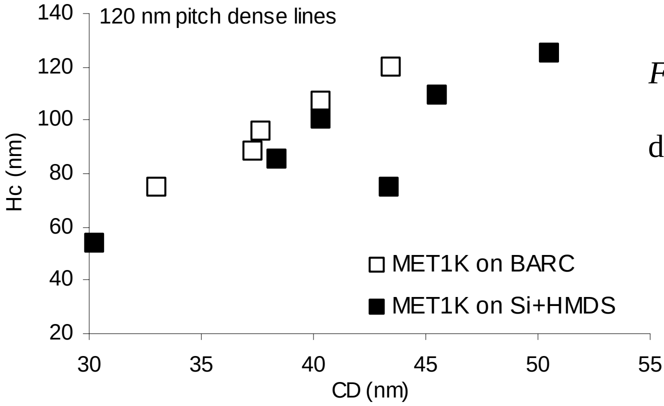

Figure 3: Critical height of 120 nm pitch dense lines deposited either on organic BARC, or on HMDS primed silicon wafer.