Resolution Limits and Process Latitude of Deep-Ultraviolet Conformable Contact Photolithography

C. P. Fucetola and D. J. D. Carter
The Charles Stark Draper Laboratory, 555 Technology Square, Cambridge, MA 02139
J. G. Goodberlet
Light, Innovation and Lithography Company, 23 Martin Street, Melrose, MA 02176

Conformable contact photolithography (CCL) is a cost-effective means for full-wafer printing of nanometer-scale features. CCL improves upon traditional contact printing[1,2] by utilizing a conformable, embedded-absorber mask (EAM)[3] and an optimized tri-layer resist stack to enhance printing resolution. At Draper Laboratory, we have patterned dense 65 nm lines into 90-nm-thick resist with CCL, as shown in Figure 1.

In this paper, we present results from an experimental and simulation study of the process latitude and resolution limits of conformable contact photolithography. Dense and isolated features ranging from several hundred nanometers in size to below 100 nm were exposed using CCL and traditional chrome-on-glass conformable photomasks with a deep-ultraviolet source. Numerical simulations of the experiments were performed using a finite-difference time-domain electromagnetic solver[4]. Experimental results and simulations were then analyzed for linewidth as a function of dose. We found that CCL has a resolution limit below 100nm, and demonstrated experimentally and numerically that CCL with EAM provides higher resolution and broader process latitude than chrome-on-glass photomasks.

Figure 2 shows the importance of an optimized resist stack for CCL. Plots of simulated optical intensity profiles in single-layer PMMA and PMMA in an optimized resist stack are shown. An intensity node develops in the single layer PMMA on silicon (top), which at finer linewidths results in high intensity across the bottom of the resist, potentially leading to lateral undercutting during development. For the optimized tri-layer stack (bottom), the exposure intensity is uniform throughout the resist layer, persisting to smaller feature size.

Figure 3 shows the contrast improvement afforded by the EAM configuration. Simulated resist intensity profiles (averaged in Z) are plotted for chrome-on-glass (red curves) and EAM (blue curves), showing improved contrast which persists to smaller feature sizes with the embedded-absorber mask configuration.

Experimental and simulation results which show improved process latitude for CCL with optimized trilayer resist and EAM will be presented.

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[1] H.I. Smith, *Rev. Sci. Instrum.* **40**, 729 (1969).
[2] J.C. White *et al.*, *Appl. Phys. Lett.* **44**, 22 (1983).
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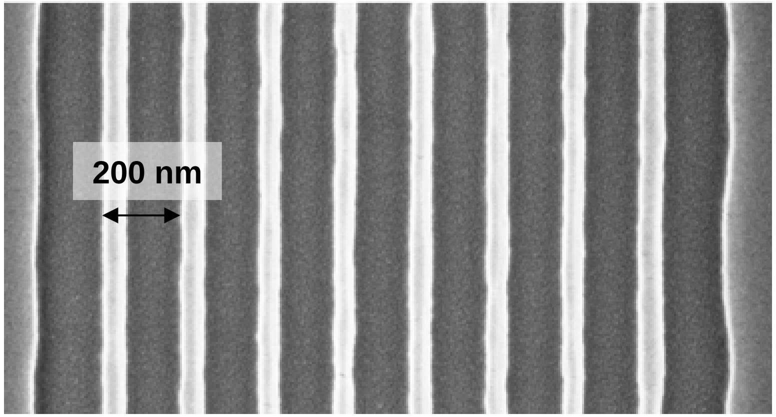

Figure 1: Scanning-electron micrograph of 65 nm lines on 200 nm pitch patterned with deep-ultraviolet conformable contact photolithography into 90 nm PMMA on SiO_2 and anti-reflection coating on silicon.

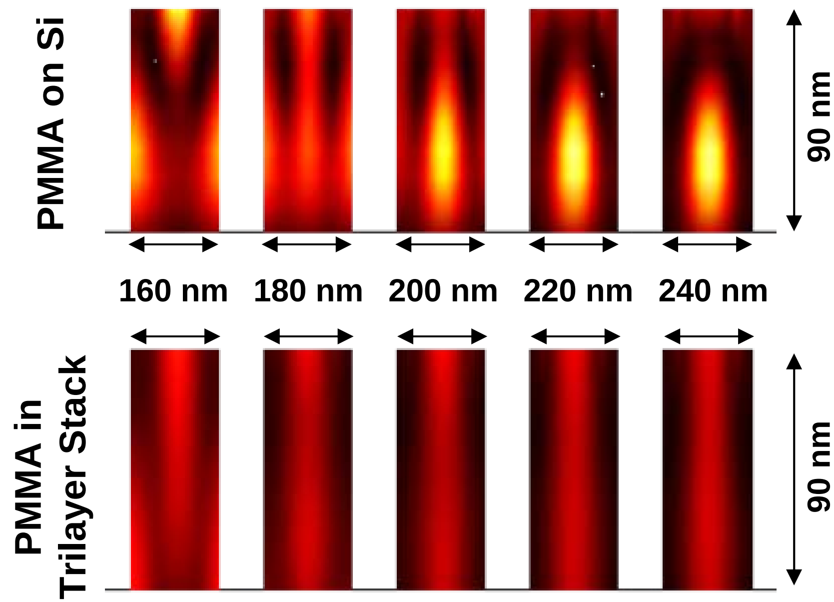

Figure 2: Resolution improvement with optically-optimized resist stack. Simulated optical intensity in PMMA for deep-ultraviolet exposures of 1:1 gratings with a chrome-on-glass conformable photomask. TOP: PMMA on silicon. BOTTOM: PMMA/SiO_2/ARC on silicon. Clearly the optically-optimized stack results in an improved optical intensity profile in the resist and a smaller minimum resolvable feature size. ***Note that x scale is normalized to the grating pitch to clarify intensity profiles for smaller structures.***

Figure 3: Contrast improvement with embedded absorber mask (EAM). Simulated average optical intensity in PMMA resist for varying dense grating exposures. Both chrome-on-glass conformable photomasks (red lines) and EAMs (blue lines) were simulated. Clearly the EAM exhibits higher contrast which persists to smaller feature size.