Projection lithography below lambda/7 through DUV evanescent optical imaging

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An approach will be presented to allow for imaging down to 26nm using DUV (193nm) projection reduction lithography together with evanescent wave optical effects at the imaging plane. We reported earlier on solid immersion lithography (SIL) and evanescent wave lithography (EWL), where the physical limitations of imaging imposed by the refractive indices of the materials were surpassed through propagation beyond evanescent fields. This has allowed for the imaging into photoresist of half-pitch resolution below lambda/7. We will present in this paper the enhancement of image contrast though the use of high refractive index in the evanescent region (though the use of water and high refractive index fluids) together with the gauging of the gap requirements between a final optical element and the photoresist layer.

The projection system developed for evanescent wave imaging is comprised of an ArF 193nm excimer laser combined with a Talbot interference imaging system using a fused silica grating phase mask and sapphire collection optics with a refractive index of 1.92. The imaging system can be used at numerical apertures (NA) up to 1.90, allowing for half-pitch resolution near 25nm. As the numerical aperture surpasses the refractive index of the gap image media, the evanescent field decays with the disparity of refractive index (compared to the propagating media), the gap depth, and the propagating angle. We will show lithography results up to 1.86NA for 26nm half-pitch using image media including air (n=1.0), water (n=1.44), and a high index fluid (n=1.64) together with systematic gauge control to determine gap requirements and tolerances to achieve adequate image contrast into the resist. Gauging methods include both optical and mechanical approaches to achieving nm level gap resolution. Both the gap media and the photoresist present challenges at high NA. Although the real part of the resist refractive index is below the system numerical aperture, the imaginary component of the index (the extinction coefficient) allows for the propagation of the frustrated field into the resist film. Gap depths as large as 50nm can be tolerated using this approach, well beyond the levels associated with alternative very high resolution lithography schemes such as those using surface plasmons.