Aluminum Oxides as metamaterials for enhancement of 193nm lithography

A. Estroff, N. Lafferty, A. Bourov, R. Frankel, B. W. Smith
Rochester Institute of Technology
82 Lomb Memorial Drive, Rochester, NY 14623

The unique properties of metamaterials, namely their negative refractive index, permittivity, and permeability, have gained much recent attention. Research into these materials has led to the realization of a host of applications that may be useful to enhance optical nanolithography. This becomes especially intriguing at the 193nm wavelength of the ArF excimer, where materials bound between metallic aluminum and stoichiometric aluminum oxide (Al_2O_3) exhibit metamaterials behavior. This provides for not only real opportunities to explore the potential of the use of such materials for image enhancement, it does so with easily obtainable materials (aluminum-rich oxide) at a desirable lithographic wavelength (193nm).

A metamaterial, in terms of electromagnetism, can be defined as a material with a negative refractive index. For TM and TE polarized light, this correlates to a negative permittivity and negative permeability respectively. Image enhancement is achieved by amplifying the evanescent wave, normally lost in traditional imaging, and restoring its contribution to the image.

A structure that acts as an optical superlens[1,2] can be created in a photoresist stack by placing a contrast enhancement layer (CEL) on top of the stack comprised of a polymeric spacer, an aluminum-rich oxide superlensing layer, and a photoresist. The CEL is opaque, but bleaches to become more transparent upon exposure, thus it can be patterned lithographically to form a transient high resolution image. In a subsequent exposure, the superlensing film stack beneath the CEL relays the sub-wavelength evanescent wave into the imaging medium.

Additionally, by sandwiching a classically opaque thin aluminum slab between two dielectric layers, an angular and polarization selective pupil filter can be created. The behavior of this pupil filter is similar to those using phase or transmission methods[3], but has the advantage of being able to be placed at multiple locations in the optical system. Initial results of this pupil filter show an increase in contrast through pitch of nearly 50% in line/space patterns and almost 100% for contacts/islands.

[1] N. Fang *et al*, Science, **308**, 534 (2005).
[2] J. B. Pendry, Phys. Rev. Letters, **85** (18), 3966 (2000).
[3] H. Fukuda, T. Terasawa, S. Okazaki, J. Vac. Sci. Technol. B, **9** (6), 3113 (1991).