Identifying EUV Attenuated Phase Shifting Mask Absorber Materials using EMA Modelling

Rajiv Sejpal and Bruce W. Smith
Microsystems Engineering, Kate Gleason College of Engineering,
Rochester Institute of Technology, Rochester, NY 14623
rns4256@rit.edu

As currently employed, EUV lithography uses binary Tantalum (Ta) based materials as a mask absorber, generally with thickness ranging from 55-70 nm. By extending existing Ta mask absorber technology, next generation technology nodes may suffer image contrast loss from mask 3D (M3D) effects including, among other things, so-called shadowing and best focus shifts. Materials engineered for EUV attenuated phase shifting masks (AttPSM) may have the potential to improve aerial image contrast by introducing desirable 3D diffractive interference, reducing some M3D effects and allowing for a potential decrease in absorber thickness [1].

In an attenuated phase shifting mask (AttPSM), the transmission and phase shift of the absorber are regulated by layout design requirements. By using material refractive index ($n = 1 - \delta$) and extinction coefficient ($k = \beta$) properties at 13.5nm, the suitability of elemental candidate materials are identified. Figure 1 shows the plot of this k-n space for a variety of materials with 5%, 10% and, 15% AttPSM transmission regions, and phase shift zones within each for 180°, 200° and, 220°. While the complex refractive index ($n - ik$) influences both phase and transmission, in this regime the influence of n on phase and k on transmission dominate, while lower n values lead to lower absorber thickness.

As few single component materials meet necessary phase and transmission requirements, candidate AttPSM absorbers are likely alloys and compounds. The selection of such materials is carried out using effective media approximation (EMA), based on materials and composite complex dielectric constant values ϵ [$(n + ik)^2$] [2]. In EMA, the effective dielectric constant (ϵ_{eff}) of any arbitrary mixture is bound by the region defined by the ϵ of its constituent elements (Weiner bounds). Additionally, the ϵ_{eff} is a function of the fractional weight of its constituents. Therefore, a solution space which is dependent on the phase shift, transmission and the thickness of absorber need first be determined. Weiner bounds and hence the ϵ_{eff} of the alloy that overlap the solution space can then be identified. In this paper, we will present the results of the interrogation into potential candidates that can meet EUV phase, transmission, and thickness requirements, while achieving the necessary stability and processing attributes. Material combinations satisfying these optical and physical properties will be considered as potential EUV AttPSM absorber candidates through additional 3D image performance modelling.

[1] R. Sejpal, V. Philipsen, A. Armeanu, C.-I. Wei, W. Gillijns, N. Lafferty, G. Fenger, and E. Hendrickx, *Exploring Alternative EUV Mask Absorber for IN5 Self-Aligned Block and Contact Layers*, in *Photomask Technology 2019*, Vol. 11148 (International Society for Optics and Photonics, 2019), p. 111481B.

[2] D. E. Aspnes, *Optical Properties of Thin Films*, Thin Solid Films **89**, 249 (1982).

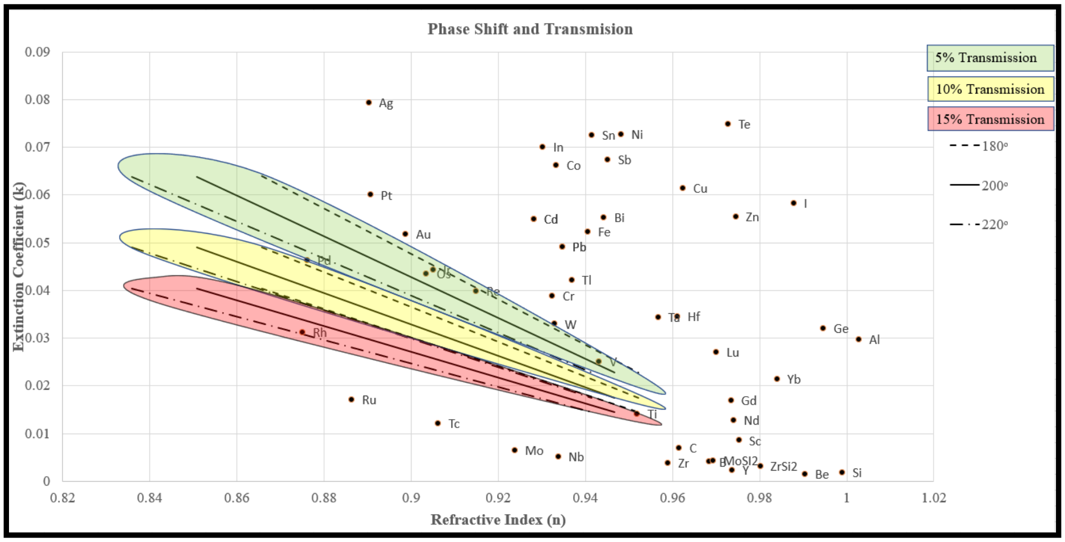

Figure 1. n&k plot at 13.5nm wavelength for 5%, 10% and, 15% transmission at 180°, 200° and, 220° phase shifts.