



Determining inelastic mean-free path of low-energy (<100eV) electrons in optical and electron photoresists

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Photolithography now uses EUV (13.5 nm) rather than DUV (193 nm) light to enable smaller features, making the fundamental processes in photoresists increasingly important. Chemical activation is not directly photon-mediated. Instead, photon absorption creates high-energy primary electrons, whose relaxation produces a cascade of low-energy secondary electrons that mediate activation [1].

As feature sizes shrink, the electron inelastic mean-free path (IMFP)—the length scale over which primary and secondary electrons deposit energy in a photoresist—may limit the resolution of EUV, soft-X-ray photolithography, and e-beam lithography. We aim to determine the IMFP from fundamental material properties rather than inferring it from direct lithographic patterning. This approach clarifies how strongly the IMFP limits resolution and provides an additional metric for designing photoresists with improved patterning performance.

We combine Electron Energy Loss Spectroscopy (EELS), Inelastic X-ray Scattering (IXS), and ab-initio calculations based on Time-Dependent Density Functional Theory (TDDFT). Because the IMFP cannot be measured directly, it is derived from the energy loss function (ELF) [2]. The ELF is commonly obtained by fitting and extending optical data with analytic models. However, these models rely on the Born and random-phase approximations and omit exchange-correlation effects important for low-energy scattering [3]. We use IXS and ab-initio calculations to assess these contributions in photoresists and develop improved models for determining the electron IMFP in three materials used in optical and electron lithography: polymethyl methacrylate (PMMA), hydrogen silsesquioxane (HSQ), and tin-oxo cluster photoresist (MOR).

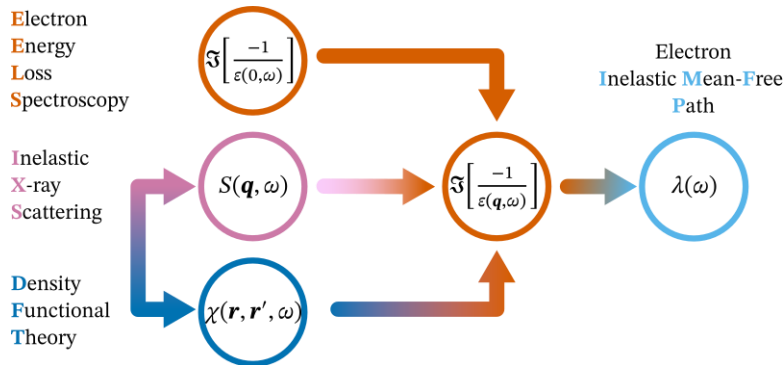


Figure 1. Relationship among the methods and quantities used to determine the electron inelastic mean-free path, λ . EELS yields the energy loss function, extended with analytical models; IXS yields it from the measured structure factor through the fluctuation–dissipation theorem; and ab-initio TDDFT yields it from the calculated response function. The resulting energy loss function determines λ .

Acknowledgements

The authors wish to acknowledge Danilo de Simone, Olivier Richard, Patrick Carolan for valuable discussions.

References

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