Current status and prospect of extreme ultraviolet resists

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The lithography is an imaging technology utilizing radiations and chemical reactions. The radiations transfer the image information to the imaging materials and trigger chemical reactions for changing the molecular structures of imaging materials. In lithography used for manufacturing semiconductor devices, the wavelength of radiation was decreased to meet the market demands for high-performance digital devices. With the reduction of wavelength, the resolution of lithography increased. However, manufacturing of semiconductor devices should be cost-effective. The exposure dose is restricted to secure adequate throughput of products. Because the photon energy is inversely proportional to the wavelength, the photons available for imaging were significantly decreased upon the introduction of extreme ultraviolet (EUV) radiations with the wavelength of 13.5 nm to the lithography. With the reduction of feature sizes in the future, the photons available for fabricating a pattern will decrease further. With the decrease of photons, a shot noise became a serious concern in the development of next-generation EUV lithography.

When EUV photons are absorbed by resist molecules, photoelectrons are emitted. The photoelectrons further ionize resist molecules. Besides ionization events, the secondary electrons including photoelectrons lose their energy to thermal energy level (25-30 meV) through the excitation of electronic and vibrational states of resist molecules. The electrons with kinetic energy adequately larger than the ionization energy of molecules work as an oxidizing agent in a condensed matter. On the other hand, the thermalized electrons work as a reducing agent. In standard resists for the semiconductor lithography, called chemically amplified resists, the photoacid generator (PAG) is reduced by thermalized electrons and release the counter anions of acids. The protons of acids are typically supplied through the deprotonaion of oxidized polymer molecules. The generated acids diffuse and catalyze the deprotection of partially protected acidic polymer during post exposure baking (PEB). By the deprotection, the hydrophobic polymer becomes hydrophilic and soluble in a 2.38 wt% tetramethylammonium hydroxide aqueous solution (a standard developer in the semiconductor lithography). All of these processes are stochastic. The pinching and bridging of resist patterns caused by such stochasticity[1)] should be suppressed for the realization of highly resolving lithography. The current status and prospect of EUV resists are discussed in terms of stochasticity.

1) T. Kozawa, J. J. Santillan, and T. Itani, Jpn. J. Appl. Phys. **52**, 076502 (2013).

Biography

Takahiro Kozawa is a professor of SANKEN, Osaka University. He earned his BS and MS degrees in nuclear engineering from the University of Tokyo, and Ph. D. degree in chemical engineering from Osaka University in 1990, 1992, and 2003, respectively. His work is mainly focused on beam-material interaction and beam-induced reactions in resist materials.