T_cSUH Bi-Weekly Brown Bag Seminar

Texas Center for Superconductivity at the University of Houston

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"The Shadow of a Carbon Nanotube"

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Room 102, University of Houston Science Center
12:00 Noon – 1:00 p.m.

Abstract

The features of ion beam proximity lithography include sub-nanometer limits for diffraction, penumbra, and resist scattering. Further, by using atoms, which have essentially the same interaction with resist and mask materials as ions, the technology becomes immune to fixed and mobile charge, either in the mask or on the wafer. Thus, *atom beam lithography* (ABL) seems ideal for prototyping and later manufacturing nanoscale integrated circuits. The fundamental challenge is to fabricate a stencil mask with atomically smooth sidewalls in a membrane that is thick enough (e.g. 0.5 µm) to stop the atoms. We have shown that a *scattering mask* can bypass this issue. A thin evaporated film was used to shrink the openings of a conventional stencil mask and, while not thick enough to actually stop the particles, enough were scattered into the walls of the mask to generate very good exposure contrast. This approach gives the possibility of using very thin, potentially self-assembled, scattering layer structures to form complex, high density masks. An important open question is how thick these features need to be for faithful atom beam replication. In this talk, we report the ability of a carbon nanotube, 18 nm in diameter, to cast a well–defined shadow in a broad beam of energetic (30 keV) helium atoms. When imaged in resist and engraved into silicon dioxide, the projected replica retains the natural smoothness of the nanotube and shows, for the first time that ultra-thin, self-assembled structures can be used as masks in nanoscale printing.

Experiments were carried out using a 30 keV atom beam proximity lithography system. Briefly, a beam of helium atoms, generated by charge transfer scattering in the extraction region of a duoplasmatron ion source, drifts through a 10 M long tube, and impinges on a stencil mask where the transmitted beamlets transfer the mask pattern to the substrate. The mask was prepared by sprinkling a dry nanotube powder onto a 3 µm thick silicon stencil mask with 1 µm wide openings. The mask was clamped, with 5 µm thick cleaved mica spacers, to a silicon substrate coated with 44 nm thick thermal SiO_2 and 50 nm thick PMMA resist. After exposure, the PMMA was developed and the resist pattern transferred into the oxide to a depth of 37 nm by CHF_3-RIE. Atoms incident upon the thick regions of the mask are absorbed while scattering generates image contrast for the nanotube. Experimental data will be presented, showing a 20 nm wide nanotube suspended over an opening in the stencil mask, with its image after resist removal, engraved into oxide. Also shown is linewidth versus exposure dose, normalized to the critical dose, of a different tube, 18 nm in diameter. Since printed and nominal linewidth are generally equal at twice the critical dose, the difference between these values, about 4.6 nm, is a measure of pattern bias, perhaps an artifact of metrology, resist development, and/or etching. After subtracting the bias from the measured data, a threshold development model with a blur of 5 nm (FWHM) describes the experiment reasonably well. Thus, the ultimate resolution may be near 4 nm. This result shows that the edges of a nanotube, just a few atomic layers thick, generate enough scattering to be printed. I will report experiments to better understand the pattern bias issue and to determine the resolution limit.

Bio

Dr. Jack Wolfe received his Ph.D. degree in Physics from the University of Rochester in 1973. He joined the University of Houston in 1976 where he has pursued his interests in thin film deposition, plasma etching, charged particle optics and lithography. His service activities include a 3-year term as Interim Dean of the Cullen College of Engineering. In 1999, he served as Program Chair of the 43 rd International Symposium on Electron, Ion and Photon Beams and Nanofabrication (EIPBN).

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