Search for an Optimal Scintillation System for Spatial Phase Locked E-beam Lithography

Personnel

M. A. Finlayson, J. G. Goodberlet, J. T. Hastings, F. Zhang, and H. I. Smith

Sponsorship

DARPA and ARO

Spatial-phase-locked e-beam lithography (SPLEBL) requires a strong, high-contrast signal from a fine-period global-fiducial grid in order to achieve nanometer-level placement accuracy. One approach we have been pursuing is to employ a grid that consists of a spatial modulation of the output of a scintillator embedded in a host polymer. Optical signals have the advantages that they are readily distinguished from scattered-electron signals. Moreover, high-gain, low-noise amplifiers are available in the form of photomultipliers. Ideally, the distribution of the scintillator within the polymer host would be modulated by means of bleaching with interference lithography (IL), or a technique that, like IL, provides long-range spatial-phase coherence.

We have studied about 25 scintillator systems for their suitability in SPLEBL. Generally they consisted of 4 components: (1) an alkyl-benzene polymer host, whose primary role is to efficiently absorb energy from the incident electron; (2) a strong primary scintillator, such as anthracene or p-terphenyl, to which the energy absorbed by the polymer host is transferrred; (3) a wavelength-shifting secondary scintillator, such as 1,4-Bis(5-phenyl-2-oxazolyl) benzene (known as POPOP), whose role is to shift the emission to a longer wavelength, e.g., 420 nm, where the photomultiplier sensitivity is maximum; and (4) naphthalene, whose role is to enhance the energy transfer from polymer host to primary scintillator. In some cases the naphthalene was not added.

Under illumination with 351 nm radiation, which is used in our interference lithography system, all of the scintillator systems bleached, provided oxygen was present. The extent of bleaching was tested by measuring the subsequent output under electron-beam irradiation in an SEM. Analysis indicated that oxidation of POPOP was the main cause of bleaching. The bleaching effect was not strong in the case of 351 nm irradiation; typically it reduced the output only by a factor between 2 and 3. These experiments also identified Poly Vinyl Toluene host polymer that provided the highest brightness, about 3 times higher than the PMMA-based system we first investigated.

Bleaching under 220 nm irradiation, in the presence of air, was considerably more effective, reducing the scintillation output by factors of 10 to 80. This is believed due to increased damage to the host polymer by the ionizing 220 nm radiation. It is significant that the output of polystyrene-based systems was reduced only by the factor 3, which we attribute to its high ionization potential which would limit the extent of polymer damage.

Figure 7 shows the high contrast obtained when a grating (5 micron period) is bleached with 220 nm radiation in a PVT-based scintillator; a contrast of 7.5 was obtained. Irradiation with 351 radiation produced a contrast of only 1.4.

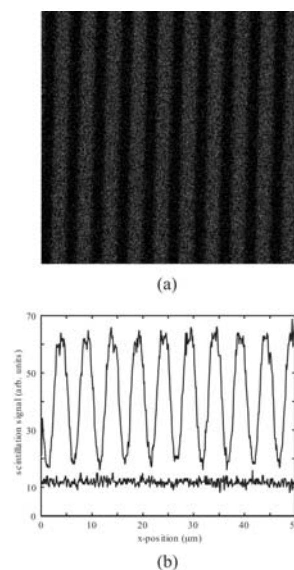

Fig. 7 (a): Scanning-electron micrograph of a grating bleached in a poly (vinyl toluene)-based scintillator; (b) averaged linescan of the image in (a) showing also the background level (lower trace).

Because most e-beam resists are also sensitive to ionizing radiation, such as 220 nm, these studies imply that if a scintillating global fiducial grid is to be used for SPLEBL the resist configuration will probably have to be a tri-level stack with the scintillator the bottom layer, and bleached in advance of the application of the e-beam resist.