1284 CD
DOI: 10.1017/S1431927606065950

Microsc Microanal 12(Supp 2), 2006

Effects of Beam and Scan Parameters on 3-Dimensional Carbon Structure Growth Using Electron Beam Induced Chemistry

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Electron beam induced chemistry involves irradiating adsorbed precursor molecules with a focused electron beam to induce a chemical reaction that results in material removal or deposition of a non-volatile material. This technique offers much promise in the field of nanofabrication and provides a method free from ion implantation and other irradiation damage resulting from the use of focused ion beams. This work investigates deposition rates of amorphous carbon structures using various electron beam parameters. Amorphous carbon has high stiffness and high chemical resistivity [1], both desirable qualities for nanofabrication. The volumetric yields per unit charge ($\mu m^3/nC$) obtained were calculated using various electron beam currents, refresh times, and dwell times in order to determine the operating conditions yielding the maximum deposition rate.

All growth and subsequent imaging was performed in a Hitachi S-2500 thermionic SEM on a silicon substrate with a 25 keV beam, 50 percent pixel overlap, a total pressure of 5E-6 Torr and a phenanthrene partial pressure of 1E-8 Torr. Figure 1a is an image of the external precursor reservoir used which was heated to 200°C in all experiments. Figure 1b shows the hypodermic needle through which the phenanthrene was introduced to the substrate.

Figure 2a is a typical AFM height scan of a box pattern obtained using Tapping Mode © and figure 2b depicts a line scan cross-section illustrating the method used to calculate the volume. The full widths at half height were used as a measure of the length and width of the box, while the average of four selected points was used to calculate the height. The volume grown per unit charge ($\mu m^3/nC$) was then calculated for boxes grown under various beam currents (7-100 pA), box sizes (25 or 100 μm^2), dwell times (10-1000 μs) and total exposure times (600-9600 s).

Phenanthrene deposition rate generally increased as beam current was decreased and longer refresh times were used. Deposition rates of up to 0.013 $\mu m^3/nC$ were obtained using 7 pA beam current for deposition of 10 by 10 μm boxes. Figure 3a summarizes the volumes obtained per unit charge for various beam currents, box sizes, and total exposure times. Figure 3b depicts the effect of dwell time on deposition rate. While varying the dwell time and holding all other parameters constant, a general increase in deposition rate was seen as dwell time was decreased to 50 μs.

In summary, for electron beam induced deposition of phenanthrene, the deposition rate increases as beam current is decreased, refresh time is increased, and dwell time is decreased.

References:
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[2] S. Okada et.al., Jpn. J. Appl. Phys., Vol. 44, No. 7B (2005

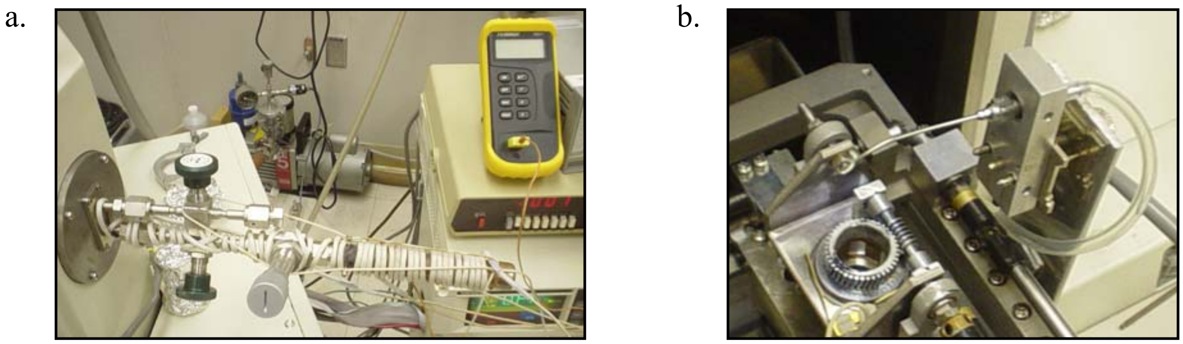

Fig. 1. Precursor introduction system including a.) reservoir and heating tape, which is fed through b.) tubing to a hypodermic needle where the sample sits.

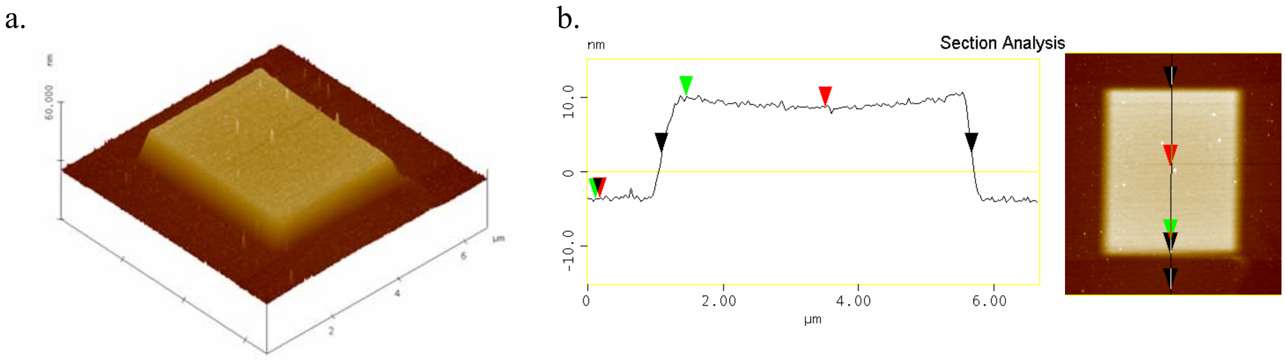

Fig. 2. a.) Typical AFM image of a 5 by 5 um box machined for 2400 s with a 25 kV, 20 pA beam, and a phenanthrene partial pressure of 1E-8 Torr and total pressure of 5E-6 Torr. Box volume was calculated by using b.) box profiles to determine the actual length, width, and height of the deposits. The calculated volume deposited per charge for this particular box was 5.2E-3 um^3/nC.

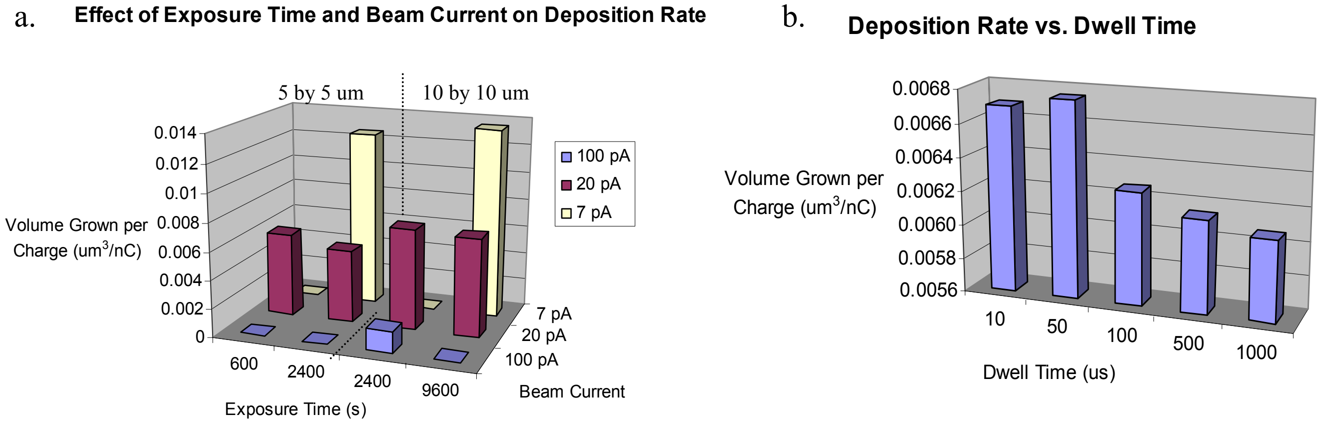

Fig. 3. a.) Chart showing the general trends of deposition rate with respect to beam current, exposure time, and box size (refresh time). Deposition rate appears to increase with lower beam current and larger box size (longer refresh rate). Chart b) shows how deposition rate varies with dwell time. Deposition rate tends to increase as dwell time is decreased.