Investigation of Inter-diffusion between Layers in Cryogenic Enhanced Electron Beam-Induced-Deposition

M. Bresin, K. A. Dunn
College of Nanoscale Science and Engineering, University at Albany-SUNY, 251 Fuller Road, Albany, NY, 12203
Kdunn1@uamail.albany.edu

M. Toth
FEI Company, 5350 NE Dawson Creek Drive, Hillsboro, Oregon 97124

Electron beam-induced-deposition (EBID) is a site specific and maskless deposition process where gaseous precursor adsorbs onto a substrate and is decomposed in the presence of an electron beam.[1] Recent work has shown that EBID can be modified with cryogenic substrates to increase the sticking probability and residence time of the gaseous precursor, such that a multi-layer condensed phase film is produced. Subsequently, the electron beam can be used to define arbitrary shapes which remain after desorbing unirradiated material. Using the technique outlined schematically in Figure 1, the authors have shown that the surface morphology of EBID structures can be tailored by adjusting the electron beam fluence used for deposition.[2] Figure 2a shows a deposit formed with a variable electron fluence exposure overlay, where changes in the surface morphology correlate to the accumulated electron fluence. Figure 2b shows the same deposit in cross-section, demonstrating thickness scaling with the beam fluence. To describe these effects, significant diffusion (~microns) was thought to occur during reheating to room temperature. This hypothesis was tested using multilayer material stacks to determine the extent of intermixing, which is critical to future applications such as *in-situ* functional device fabrication.

Experiments were performed using an FEI Nova 600 Nanolab dual beam system with a LN_2 cryogenic stage, enabling substrate temperatures of $-155\pm5^{o}C$. Two standard EBID platinum precursors, WCO_6 and $MeCpPtMe_3$, were first condensed (one layer at a time) onto the cooled substrate using a capillary-style gas injection system (GIS). Next, gas flow was terminated and the condensate stack was irradiated with an electron beam to induce precursor decomposition. When the substrate was returned to room temperature, any unreacted precursor desorbed and was removed by the pumping system. An SEM image of the precursor stack is shown in Figure 3a after the sample was reheated to room temperature. Preliminary TEM results shown in Figure 3b indicate a well defined separation between Pt and W films beyond ~10nm of the interface. Based on this work, an updated formation mechanism model will be discussed as well as the effects of adjusting the heating rate at which the sample is returned to room temperature.

---

[1] I. Utke, P. Hoffmann, and J. Melngailis, J. Vac. Sci. Technol. B **26**, 1197 (2008).
[2] M. Bresin, M. Toth, B. L. Thiel, and K. A. Dunn, J. Mat. Res. **26** (in press) (2011).

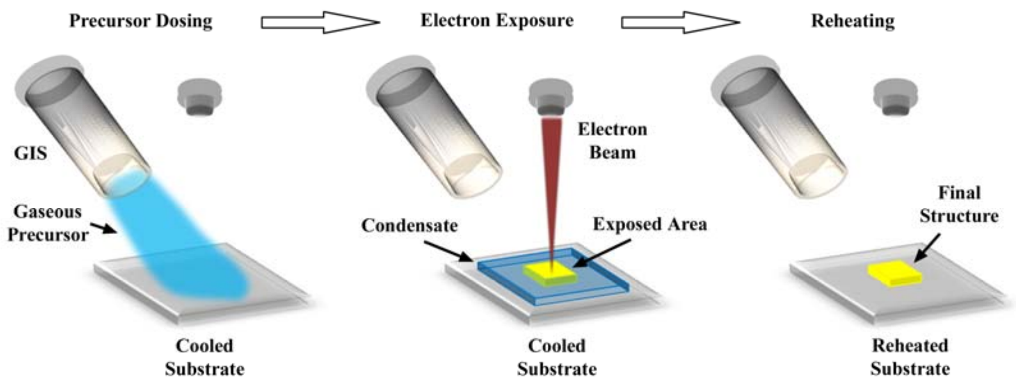

Figure 1: Schematic diagram illustrating the steps in the cryogenic EBID process.

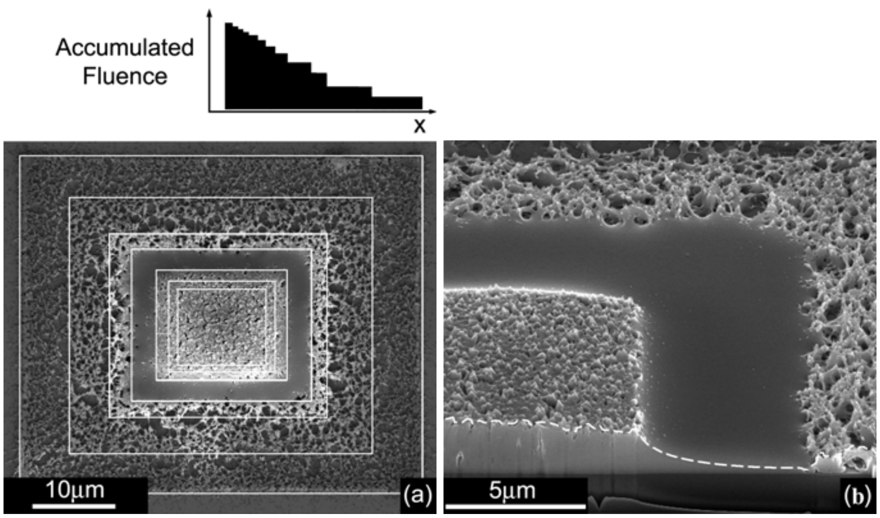

Figure 2: Cryogenically enhanced EBID deposit after reheating step. (a) Top-down SEM image with white line overlay to indicate changes in electron fluence. (b) Cross-section SEM image illustrating thickness variation of the deposit.

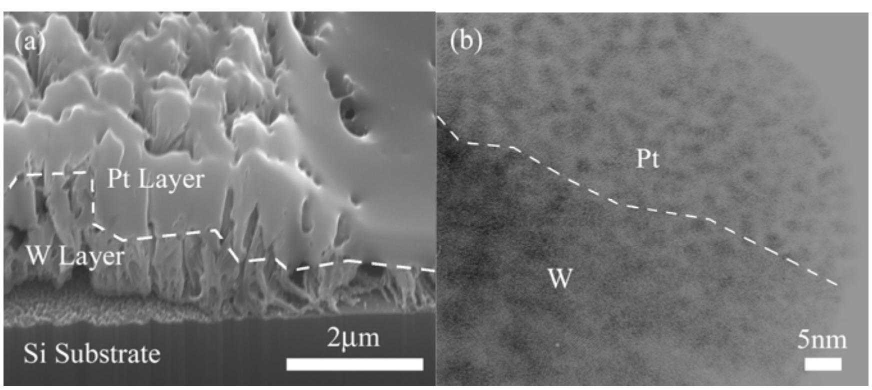

Figure 3: Pt on W stack. (a) SEM cross-section. (b) TEM of stack interface.