BN Electron-Enhanced ALD at Room Temperature and Prospects for Area Selective Deposition

Steven George [1], Jaclyn Sprenger [1], Andrew Cavanagh [1], and Huaxing Sun [1]
[1]University of Colorado, U.S.A.

Electron enhanced atomic layer deposition (EE-ALD) can drastically reduce the temperatures required for film growth through electron stimulated desorption (ESD) of surface species. The ESD process creates highly reactive “dangling bond” surface sites. Precursors can then adsorb efficiently on the dangling bonds. Our earlier work has demonstrated the EE-ALD of polycrystalline GaN [1] and amorphous Si [2] at room temperature. Film growth was performed using alternating exposures of the appropriate precursors and low energy electrons(~100 eV) from an electron flood gun.

Our more recent work has studied boron nitride (BN) EE-ALD at room temperature [3]. The BN EE-ALD was performed using sequential exposures of borazine ($B_3N_3H_6$) and electrons at energies of 50-450 eV. The BN film growth was characterized by in situ ellipsometry. The highest growth rates of ~3.2 Å/cycle were obtained at electron energies of 50-150 eV. The BN EE-ALD growth was self-limiting at higher borazine and electron exposures. High-resolution transmission electron microscopy revealed polycrystalline BN films with the basal plane of the hexagonal crystal in approximate alignment with the surface of the silicon wafer. The growth rate of ~3.2 Å/cycle was consistent with the deposition of one BN monolayer per cycle.

Area selective growth was demonstrated by depositing BN EE-ALD films on trenched structures. Using an electron flux at normal incidence to the surface, the electron beam leads to growth on horizontal surfaces and minimal growth on vertical surfaces that are parallel to the electron flux. STEM/EELS images of the trenched structures coated with BN films showed that the BN film thickness at the top and bottom of the trench was much larger than on the sidewalls. The directionality of the electron flux leads to topographical area selective deposition. These results suggest that bottom-up-fill maybe possible for the EE-ALD of other materials, such as metals, in vias and trenches with vertical sidewalls.

[1] J.K. Sprenger, A.S. Cavanagh, H. Sun, K.J.Wahl, A. Roshko, S.M. George, Chem.Mater. 28, 5282 (2016).

[2] J.K. Sprenger, A.S. Cavanagh, H. Sun, S.M.George, J. Vac. Sci. Technol. A 36, 01A118 (2018).

[3] J.K. Sprenger, H.Sun, A.S. Cavanagh, A. Roshko, P.T. Blanchard and S.M. George, J. Phys. Chem. C 122, 9455 (2018).

This work was supported by the Defense Advanced Research Projects Agency (DARPA).