PEALD ALN: CONTROLLING GROWTH AND FILM CRYSTALLINITY

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ABSTRACT

The applications of aluminum nitride (AlN) thin films demand precise control over film growth and properties. With the advantage of self-limiting growth provided by atomic layer deposition (ALD), a few-nm-thin AlN films is possible to realize. Plasma-enhanced ALD (PEALD) can be used to grow highly pure AlN films at low temperatures compared to thermal ALD [1]. Earlier, our group reported on self-limiting growth and nucleation of ALD AlN, by both thermal and plasma processes [2]. The current work is focused on optimizing the ALD process window for PEALD AlN, material characterization, and growth of polycrystalline films that have a hexagonal wurtzite structure. Further, a predominance of (002) wurtzitic crystalline planes is observed, which is important for our planned applications with AlN.

The PEALD of AlN was performed using tri-methyl aluminum (TMA) and NH_3-plasma as the precursors, in a single-wafer commercial ALD reactor. The plasma power, deposition temperature and process pressure were maintained at 2 kW, 350 ºC and 1.2 mbar respectively. Standard 4-inch Si(111) wafers were used as substrates. Prior to the deposition, the wafers were cleaned by a standard cleaning procedure. AlN films were subsequently grown (and monitored real-time by *in-situ* spectroscopic ellipsometry (SE)), ranging from a few, up to 100 nm in thickness. The ALD window was determined in terms of the right temperature range and precursor pulse durations.

The as-grown AlN films were characterized chemically by x-ray photoelectron spectroscopy (XPS), structurally by grazing incidence x-ray diffraction (GIXRD) and atomic force microscopy (AFM), and optically by SE and high-resolution scanning electron microscopy (HR-SEM). XPS analysis showed near-stoichiometric compositions with Al and N contents at 46% and 53% respectively. Further, low O and C concentrations (both at $< 2\%$) were detected. AFM measurements revealed a surface roughness (rms) of $\approx$ 2.4 nm, for a 100 nm film thickness. GIXRD scans showed a strong wurtzite (002) peak with weaker (100) and (101) peaks; this indicated a growth preference towards the *c*-axis oriented wurtzite crystalline planes, as desired. We further studied several approaches that influence the film crystallinity. These include ALD at various temperatures and plasma powers, rapid thermal annealing of the samples after growth, *in-situ* treatment of the Si wafer with different plasma-precursors prior to deposition, and use of various buffer layers for better nucleation of AlN. These results will be reported in our full paper.

[1] Ozgit-Akgun, Cagla, et al., *Journal of Materials Chemistry C* 2.12 (2014): 2123-2136.
[2] Van Bui, Hao, et al., *Journal of Vacuum Science & Technology A* 33.1 (2015): 01A111.