Hexagonal boron nitride nanowalls deposited on Si and CVD diamond substrates with an unbalanced RF sputtering

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Abstract:

Hexagonal boron nitride nanowall thin films were deposited on Si(100) substrates using a $Ar/N_2/H_2$ gas mixture with an unbalanced RF sputtering. The effects of various experimental parameters were investigated. The relative quantity of defects was measured by a non-destructive infrared spectroscopy technique that characterized the hydrogen incorporation at dangling nitrogen bonds at defect sites in the deposited films. Despite the films deposited at different substrate tilting angles, the nanowalls of those films were found to consistently grow vertical to the substrate surface, independent of the tilting angle. This reveals chemical processes, rather than physical ones, governing the growth of those wall orientations. Such observations also reveal that the crystallinity of those nanowalls is tunable by varying the growth parameters. Ultimately, evidences of hydrogen desorption during vacuum annealing was also given, based on measurements of infrared stretching (E_{1u}) and bending (A_{1u}) modes of the optical phonon, and the H-N vibration mode.

Moreover, hBN nanowalls were also deposited on nanocrystalline chemical vapor deposition (CVD) diamond films and amorphous silicon nitride (Si_3N_4) membranes. The hBN nanostructures were found to grow vertically with respect to those substrate surfaces. To provide further insight into the nucleation phase and possible lattice distortion of the deposited films, the structural properties of the different interfaces were characterized by transmission electron microscopy. Disordered BN phases nucleated on both types of Si and Si_3N_4 substrates where a clear transition zone between the substrate and hBN nanowall layers is visualized. However, those disordered phases were surprisingly suppressed at the interface with a nanocrystalline CVD diamond film, leading to a direct coupling of the hBN phase with the diamond surface, independent of the vertical orientation of the CVD diamond grains. To explain these observations, a growth mechanism is proposed in which the hydrogen terminated surface of the nanocrystalline CVD diamond film leads to a rapid formation of the hBN phase during the initial stages of growth, contrary to the case of Si and Si_3N_4 substrates.

Our obtained results are vital to fabricate hBN nanostructures with low defects that are enable to repel pure water and adsorb various substances, *i.e.* oils, organic solvents and dyes. Hence, those structures are of interest for quantum sensing [1] and water cleaning applications [2]. As these results bring a better understanding of the growth of hBN nanowalls used a magnetron RF sputtering, we believe that our observations will be of great interest for the broad readership of *Nanotechnology & Materials Science*. We look forward to addressing the questions and comments of specialized experts and audiences.

[1] I. Aharonovich and M. Toth, *Science* **358**, 170 (2017)
[2] A. Pakdel, Y. Bando, D. Golberg, *Chem. Soc. Rev.* **43**, 934 (2014)

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