Pulsed laser deposition of single layer, hexagonal boron nitride (white graphene, h-BN) on fiber-oriented Ag(111)/$SrTiO_3$(001)

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We report on the growth of 1–10 ML films of hexagonal boron nitride (h-BN), also known as white graphene, on fiber-oriented Ag buffer films on $SrTiO_3$(001) by pulsed laser deposition. The Ag buffer films of 40 nm thickness were used as substitutes for expensive single crystal metallic substrates. *In-situ*, reflection high-energy electron diffraction was used to monitor the surface structure of the Ag films and to observe the formation of the characteristic h-BN diffraction pattern. Further evidence of the growth of h-BN was provided by attenuated total reflectance spectroscopy, which showed the characteristic h-BN peaks at $\sim$780 cm^{-1} and 1367.4 cm^{-1}. *Ex-situ* photoelectron spectroscopy showed that the surface of the h-BN films is stoichiometric. The physical structure of the films was confirmed by scanning electron microscopy. The h-BN films grew as large, sub-millimeter sheets with nano- and micro-sheets scattered on the surface. The h-BN sheets can be exfoliated by the micromechanical adhesive tape method. Spectral analysis was performed by energy dispersive spectroscopy in order to identify the h-BN sheets after exfoliation. The use of thin film Ag allows for reduced use of Ag and makes it possible to adjust the surface morphology of the thin film prior to h-BN growth. © *2016 AIP Publishing LLC*.
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I. INTRODUCTION

Boron nitride (BN) is a wide band gap ($\sim$5 eV) refractory ceramic often used in high temperature applications such as lubricants due to its chemical stability.[1] Single layer, hexagonal BN (h-BN), also known as white graphene, is a polymorph of interest with a breadth of applications such as photonic, thermo-electronic, and heterostructure devices.[2–4] It has a hexagonal crystalline structure with lattice constant of $\sim$2.5 Å. With roughly a 1.5% mismatch with respect to the lattice of grapheme,[5] the similarity of h-BN to graphene has played a key role in the growth and characterization of both materials on their own as well as the intercalation of h-BN and graphene layers to create novel nano-structures.[6–8] A variety of complex physical and chemical techniques have been used to grow h-BN on diverse ceramic and semiconductor substrates,[9–16] which often bind in a highly interactive manner with the BN film. Nonetheless, the study of h-BN as an isolated system is of importance for potential applications, similar to those of graphene, where conductivity is an issue (i.e., gating devices). Hence, it is important to understand the fundamental properties of the electronic and geometric structure of h-BN in a weakly interactive environment. We used an approach to the synthesis of h-BN that was similar to the deposition of graphene on single crystal Ag. There, the weak interaction between film and substrate allows for the study of graphene as an isolated system.[17]

It has been shown that crystalline Ag surfaces provide ideal metallic platforms for the study of h-BN properties, which is, in particular, due to the vanishing BN-Ag interface energetics, observed both, theoretically and experimentally.[18] In contrast, most other transition metals form highly interactive interfaces with monolayer and bulk BN to the extent that BN often forms superstructured lattices rather than a 2D hexagonal polymorph.[19–28] Although the use of single crystal Ag substrates is viable for the growth of h-BN, it is impractical in the large scale given the high cost of these substrates. In order to circumvent this issue, we have used thin, crystalline, Ag films as growth platforms as substitutes for expensive, single crystal, Ag substrates. We have synthesized h-BN films by Pulsed Laser Deposition (PLD), a state of the art thin film synthesis technique,[29] on 40 nm thick, fiber-oriented Ag(111) buffer layers on $SrTiO_3$(001). The h-BN films were characterized *in-situ* via Reflection High-Energy Electron Diffraction (RHEED) and *ex-situ* by Attenuated Total Reflectance (ATR), Photoelectron Spectroscopy (PES), Energy Dispersive Spectroscopy (EDS), and Scanning Electron Microscopy (SEM).

II. EXPERIMENTAL DETAILS

The experimental growth chamber, shown in Figure 1, is attached to a pumping assembly that includes a turbomolecular pump and an ion pump. The chamber pressure was lower than 2×10^{-9} Torr during deposition. The substrate surface temperature was measured using an optical pyrometer through an IR transmissive viewing port. A Staib Instruments RH15 RHEED system consisting of a remotely controlled electron gun and a phosphor screen was arranged on an axis parallel to the surface of the sample. RHEED patterns were collected with an electron beam energy of 15.2 keV and a current of $\sim$0.2 μA. The electron beam diameter was $\sim$300 μm and was incident at an angle of $\sim$2°.

