The Effect of Surface Roughness on Chemical Vapor Deposition of Hexagonal Boron Nitride

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Abstract:

Hexagonal boron nitrite (h-BN) is a favorable substrate for graphene and other two-dimensional molecules due to its lack of inter-planar covalent bonds, smooth topology, insulating properties, and a near epitaxial lattice to graphene. Additionally because of its wide band gap, h-BN has potential applications in electronics as an insulator, in transistors, and in electroluminescent devices [1]. Our strategic goal for h-BN was to find a means to synthesize a large scale homogenous h-BN mono-layer with few gaps, breaks, or lattice defects. The focus of our project was to better understand the role of surface roughness when using chemical vapor deposition to grow h-BN on a catalytic metal and apply that knowledge to create high quality h-BN films. Our experiments showed flatter Ni surfaces lead to considerably more homogenous h-BN with fewer ad-layers and more uniform coverage than h-BN grown on rougher Ni surfaces.

Purpose and Introduction:

The purpose of our experiment was to determine the effect, if any, of catalytic metal's surface roughness on low pressure vapor chemical deposition (LPCVD) of hexagonal boron nitride (h-BN) [2]. H-BN was grown on two samples using the same growth conditions in the same system. Preliminary results show the smoothed sample exhibits a more continuous mono-layer of h-BN containing fewer ad-layers (h-BN layers on top of other h-BN layers).

The experiment took place in two steps. The first step was to determine if a smooth Ni surface would remain smooth despite being heated to 1050°C. After determining that the Ni film remained smooth despite the high heat, the second experiment compared the deposition of h-BN on smooth and rough Ni foils.

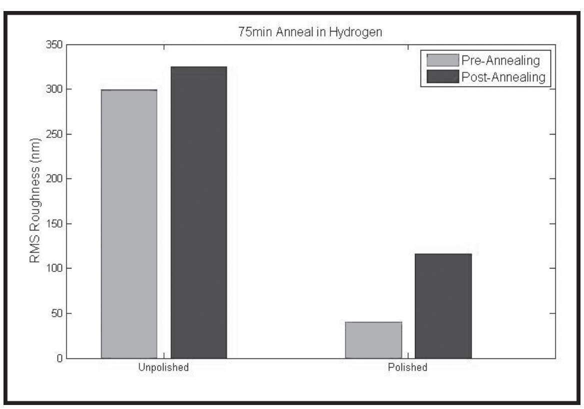

Figure 1: The roughness of the polished Ni sample more than doubled after annealing, but it remained at least three times smoother than the as received sample.

Experimental Procedure:

A. Polishing. Mechanical polishing was used to smooth the surface of a 25 μm thick 1-inch by 1-inch Ni film. To polish,

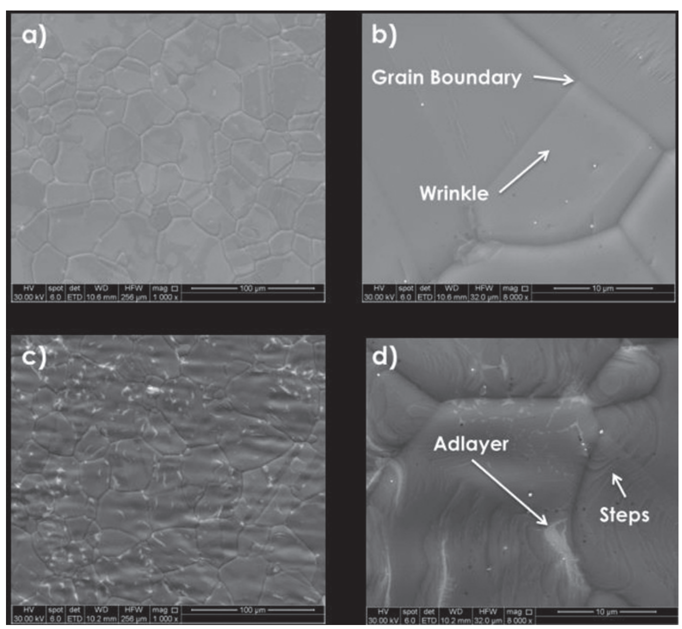

Figure 2: SEM images of h-BN on Ni Taken at 1,000x and 8,000x magnification. Images a) and b) show polished Ni. Images c) and d) show unpolished Ni.

a hand dremel and 1.0 μm grit alumina-based polish were used. The film was polished five minutes per inch, resulting in a surface roughness of 29 nm RMS from an as-received roughness of 300 nm.

B. Low Pressure Chemical Vapor Deposition. Our method of using LPCVD to deposit h-BN on Ni films involved heating the samples to 1050°C — the melting point of Ni is 1455°C. By bringing the temperature of the metal close to the melting point, the metal surface becomes semi-molten. Therefore, it was unclear if any smoothing done to the surface before annealing would have an effect on the surface after annealing.

After determining that the polished Ni film remained substantially smoother than the as-received Ni film, the next experiment involved the growth of h-BN on a polished Ni surface. LPCVD was used to grow h-BN. Our gas flow furnace, where the growth occurred, had a base pressure of 5 mTorr. An amonia boran vial was heated such that the resulting gas, along with methane, was flowed over the samples — resulting in h-BN being deposited on the Ni films.

Results and Conclusions:

It was shown, using an optical profilometer, that the smoothed Ni film remained substantially smoother than the rough nickel film after annealing (see Figure 1).

SEM images were used to compare the smooth and rough samples (see Figure 2). The h-BN on the polished sample showed a number of favorable attributes. The polished film seemed to have more uniform coverage of h-BN. There were fewer steps in the polished film — indicating a smoother surface and fewer ad-layers in the polished film.

While not verified, polishing a Ni surface prior to h-BN growth seemed to lead to fewer ad-layers and a larger continuous area of h-BN. Polishing not only smoothed the surface, but also lefts alumina particles, eliminated as received features, and cleaned the surface of contaminates. While it seemed that more favorable films resulted from polishing, it is not entirely clear that this was a result of a change in surface smoothness and not some other effect of the polishing.

Future Work:

Polishing leaves residual contaminants on the film — identified as Al_2O_3 by energy dispersive x-ray spectroscopy. Eliminating this extra variable could lead to more decisive evidence that a change in surface smoothness is responsible for the changes in h-BN growth and not some other product of the smoothing procedure. Using a smoothing technique that doesn't use a polishing compound, such as pressure induced surface deformation that does not leave contaminates on the Ni surface, would be illuminating [3].

Shifting grain boundaries and other effects resulted in changes in smoothness post-annealing. The effects of theses shifts might be reduced by annealing at or above the growth temperature and then applying a smoothing procedure followed by growth of h-BN. Furthermore, the use of glassy metal may allow for a smoother surface.

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