Characterization of Graphene Growth on Pt<111>

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Abstract:

Characterization of sizable graphene sheets grown on metal surfaces is key to understanding the interaction between graphene and the substrate for future applications. It is confirmed by Auger electron spectroscopy (AES) and helium ion microscopy (HIM) that graphene was successfully grown on Pt<111> surface through segregation. The graphene consisted of single-layer graphene across the majority of the substrate with various sections of bi-and tri-layer graphene islands and Pt patches. X-ray photoelectron spectroscopy (XPS) reveals the C1s peak from graphene on Pt<111> has lower binding energy than those from graphite (HOPG) and graphene on Ni<111>, suggesting that graphene on Pt<111> has a weaker interaction than other substrates. Topographic images and cross-section data from atomic force microscopy (AFM) depicted that graphene islands are 1.10 nm lower than the surrounding Pt region, in spite of the fact that graphene is grown on Pt. This observation speculated that water adsorption on the Pt region may indicate the nanoscale hydrophobicity of graphene and nanoscale hydrophilicity of Pt<111>.

Introduction:

Graphene, as a single layer of carbon atoms arranged in a honeycomb lattice, has many electronic and physical properties desired for potential applications [1,2]. For graphene to be employed in various prospective applications, large-scale fabrication of graphene on transition metal substrates need to be analyzed [2]. Graphene grown on Pt<111> provided data on the weak bonding interaction with the platinum substrate and aided in the understanding of properties of graphene. Surface segregation of carbon-doped metals has the capability of producing large sheets of graphene on Pt<111>. The produced graphene consisted of a single-layer majority with fractions of bi-and tri-layer graphene islands and platinum sections. Image measurements showed growth of graphene on Pt<111> and suggested a possible relationship between the hydrophobicity of graphene and hydrophilicity of platinum.

Figure 1: Schematic of segregation method.

Experimental Procedure:

Carbon was doped into a pristine platinum sample by holding the crystal in high purity carbon powder at 800°C in high vacuum for 40 days, which yielded a 0.017 atomic percent concentration of carbon. Afterwards, it was heated to 1000°C for one minute and cooled to prompt segregation of graphene. Figure 1 illustrates the process of surface segregation and the importance of slowly cooling the sample to prompt larger amounts of graphene growth.

Auger electron spectroscopy (AES) was employed to observe growth as well as helium ion microscopy (HIM) since it provided
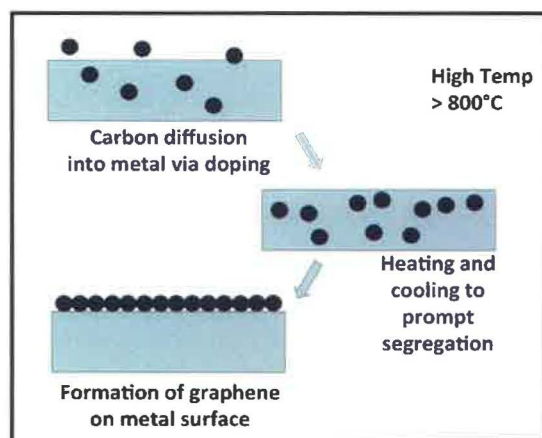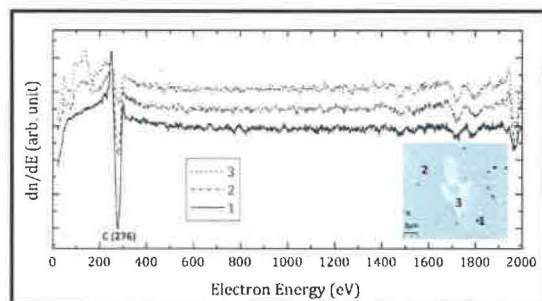

Figure 2: Carbon and Pt peaks (graph) from points 1, 2, and 3 on the SEM image.

better material contrast and depth. The characterization techniques included scanning tunneling microscopy (STM) to measure the surface morphology in the atomic scale, AFM that highlighted the topography, potential and mechanical property distributions, and x-ray photon spectroscopy (XPS) to analyze the interaction between graphene and the substrate.

Results and Conclusions:

Figure 2 represents the scanning electron microscope (SEM) image of the center of the surface and identifies three different point spectroscopy on the sample. The corresponding graph depicts the peaks of carbon and platinum at points 1, 2, and 3. Measurements of the peak heights indicate that section 1 contains the highest amount of carbon and least amount of platinum while section 3 observes the opposite. The data calculates section 2 as having higher quantities of carbon than platinum, leading to the assumption that section 2 is a single-layer sheet of graphene. Element mapping confirmed the assumption and identified section 1 as multi-layer graphene and section 3 as platinum.

Figure 3 shows the binding energy in the carbon peak for graphene grown on Pt<111> as measured with XPS. The

dash peak represents the higher binding energy of multi-layer graphene, HOPG. Graphene grown on Ni<111> has a range of 284.7 to 285.0 eV, which indicates that nickel has the stronger interaction with graphene [3]. The peak position was sensitive to the environment and changed how graphene settled on the substrate.

Figure 4 portrays the topography and potential of graphene on Pt<111>. The topographic image obtained by AFM proved difficult to distinguish the divisions of graphene and platinum. However, the potential image depicted in the Kelvin probe force microscope mode clearly identifies the dark area to be graphene and the lighter area to be platinum. An interesting observation shows the darker islands of graphene in the topographic image to be lower than the platinum sections, even though graphene was grown on top of the platinum surface. The corresponding graph displays the cross section to determine that the graphene was 1.10 nm lower than platinum on the substrate. The reason for this peculiar observation might be explained by expansion of the platinum sections due to oxidation, since graphene is stable in air while metal surfaces are generally not. However, the possible scenario of an oxide layer being on the surface was excluded due to the lack of oxygen peaks in the Auger data. A more plausible speculation is the formation of water layer on platinum. If a water layer was present on the surface, the conclusion could indicate the hydrophobicity of graphene and hydrophilicity of platinum.
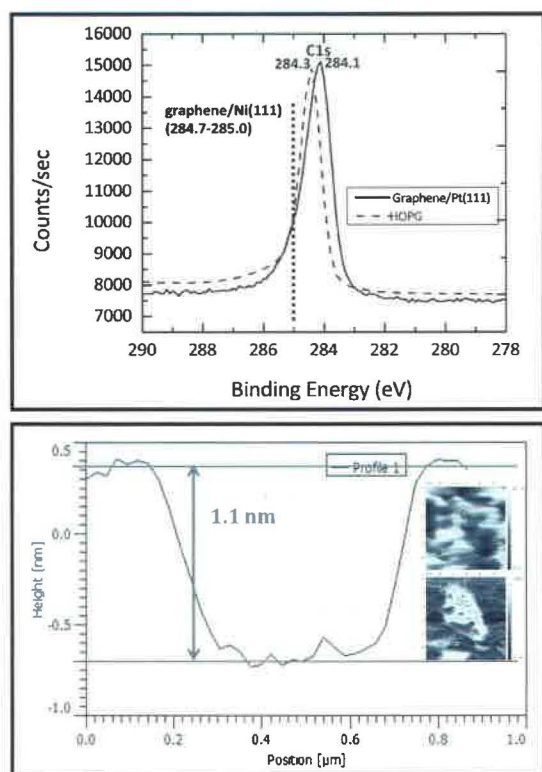

Figure 3, top: Comparison of graphene interaction on Ni<111> and Pt<111>. Figure 4, bottom: Cross section between graphene and Pt (graph), topography (top image), and potential (bottom image).

Future Work:

Water admitted on the sample should be considered to clarify the hydrophobicity of graphene and hydrophilicity of Pt to support the experimental data collected thus far. Furthermore, experimental studies regarding graphene grown on Ni<111> should be conducted to compare the shift in energy bonds with XPS imaging.

Acknowledgments:

References:

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Materials