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DC plasma chemical vapor deposition of standing multi-layer graphene nanowalls on diamond and silicon

1. Yon-hua Tzeng[a*], Wai Leong Chen[a], Chiahao Wu[a], Jui-Yung Lo[a], and Chiuan-Yi Li[a]
2. Chia-hao Tu[a], Waileong Chen[b], Hsin-Chiao Fang[a], Yon-hua Tzeng[b*] and Chuan-Pu Liu[a]

1. [a]Institute of Microelectronics, National Cheng Kung University, Tainan, Taiwan
2. [a]Department of Materials Science and Engineering, National Cheng Kung University, Tainan, Taiwan
   [b]Institute of Microelectronics, National Cheng Kung University, Tainan, Taiwan

tzengyo@mail.ncku.edu.tw

1. Yonhua Tzeng*, Wai Leong Chen, Chiahao Wu, Jui-Yung Lo, and Chiuan-Yi Li, The synthesis of graphene nanowalls on a diamond film on a silicon substrate by direct-current plasma chemical vapor deposition. Carbon 53, pp. 120-129 (2013). (IF:5.87, Rank: 23/241 in Materials Science)
2. Chia-hao Tu, Waileong Chen, Hsin-Chiao Fang, Yonhua Tzeng* and Chuan-Pu Liu*, Heteroepitaxial nucleation and growth of graphene nanowalls on silicon. Carbon 54, pp. 234-240 (2013). (IF:5.87, Rank: 23/241 in Materials Science)

Graphene and diamond both exhibit outstanding physical and chemical properties and are promising for a wide range of applications from electronics to electrochemical reactions. Thermal chemical vapor deposition of graphene on catalytic substrates such as copper usually results in graphene films lying on the substrates. On the other hand, plasma assisted chemical vapor deposition involves electric fields in the plasma sheath and the directional radical flux, which under proper conditions lead to the growth of standing graphene films. Most of these standing graphene films are multiple-layer graphene with small graphene domains. The thickness of the multi-layer graphene becomes smaller and smaller near the top edge. Under some conditions, one or few layer graphene is formed as the top edge of a standing graphene.

We applied Direct-Current Plasma Enhanced Chemical Vapor Deposition (DC-PECVD) to successfully synthesize diamond films on silicon substrates followed by the synthesis of standing graphene nanowalls on the diamond films without breaking the vacuum. Plasma in different gas mixtures of methane and hydrogen assists in the synthesis of diamond and graphene. For the synthesis of diamond, higher concentration of hydrogen and lower concentration of methane are needed. For the synthesis of graphene, lower concentration of hydrogen and higher concentration of methane are needed. Therefore, by properly controlling the plasma chemistry, graphene can be grown on diamond in a continuous process. This work demonstrated the transition from diamond growth to graphene growth. PECVD microcrystalline diamond films on which graphene nanowalls stand provide excellent durability against chemical reactions and corrosion of electrodes made of the graphene on diamond hybrid substrates by the ambient environments [1].

We further investigated the possibility of heteroepitaxial growth of graphene on single crystalline silicon [2]. According to experimental results we believe that single crystal silicon is etched by ion bombardment assisted atomic hydrogen etching to form silicon {1 1 1} oriented nano-facets during the pre-treatment of the silicon crystal. In this process hydrogen plasma preferentially etches the Si (1 0 0) plane. High resolution transmission electron microscope image shows that AA stacked multi-layer graphene nanowalls nucleate on some silicon {1 1 1} nano-facets. Amorphous carbon and some silicon carbide clusters are deposited in the remaining silicon surface. The lattice mismatch between graphene (0 0 2) plane and silicon (1 1 1) plane is small, therefore, it is energy

favorable for heteroepitaxial growth.

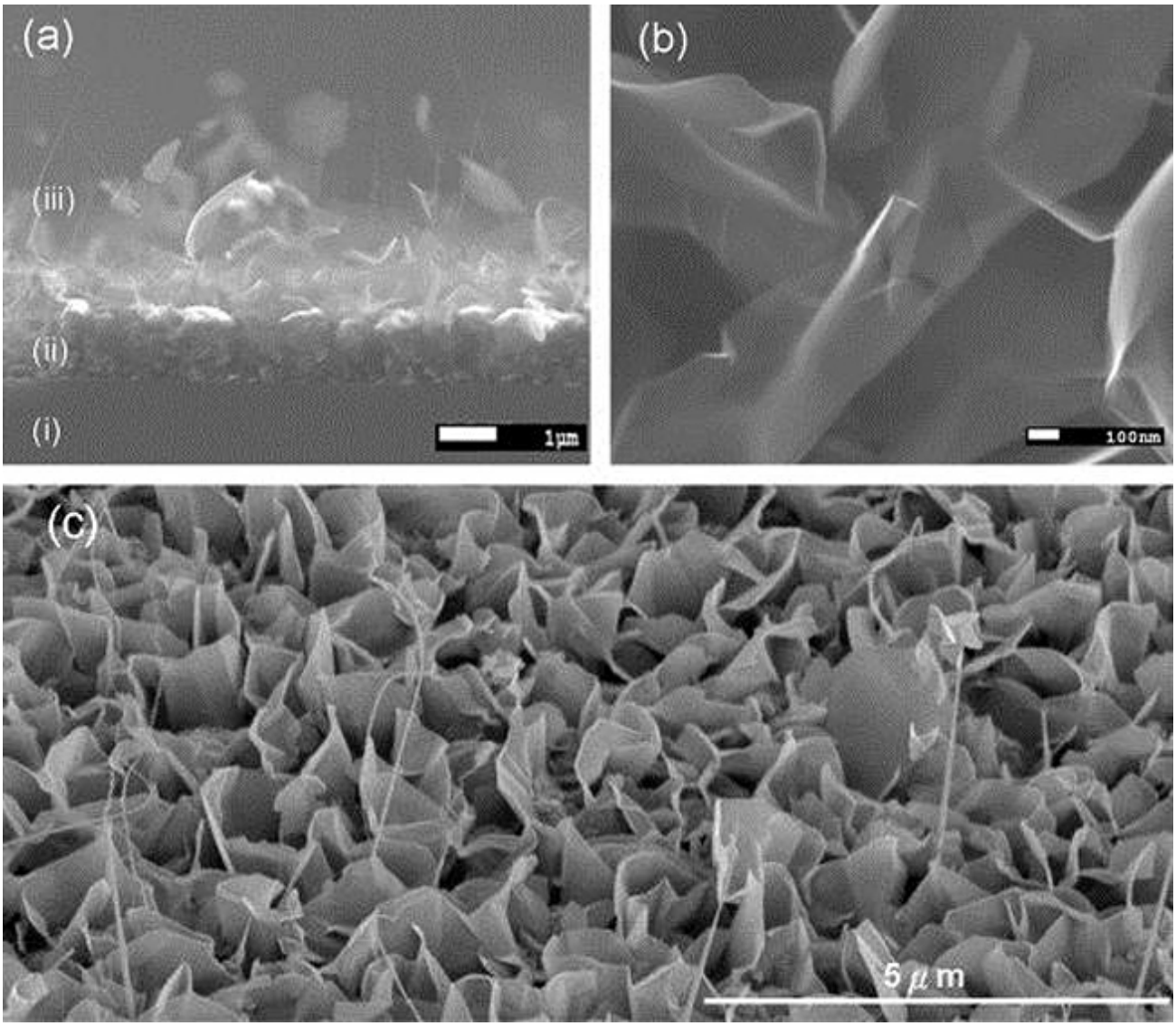

Figure 1. SEM image of standing graphene nanowalls grown on a CVD diamond film.

References:

1. Yonhua Tzeng*, Wai Leong Chen, Chiahao Wu, Jui-Yung Lo, and Chiuan-Yi Li, The synthesis of graphene nanowalls on a diamond film on a silicon substrate by direct-current plasma chemical vapor deposition. Carbon 53, pp. 120-129 (2013). (IF:5.87, Rank: 23/241 in Materials Science)
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