SEEDLESS AND CATALYST- FREE GROWTH OF ZINC OXIDE NANOSTRUCTURES ON GRAPHENE BY THERMAL EVAPORATION

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To my beloved late father and mother,

Ahmad Mohd Noor

Bariah Mat Ali

My lovely siblings,

Salwa Ahmad

Busra Ahmad

Nurul Farhana Ahmad

Najiha Ahmad

Suhaidal Ismail

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ABSTRACT

Metal-oxide, namely zinc oxide (ZnO) nanostructures and thin films on graphene is interesting because these structures can offer additional functionality to graphene for realizing advanced electronic and optoelectronic applications. Graphene has a great potential for novel electronic devices because of its extraordinary electrical mobility exceeding 10^4 cm^2/Vs and a thermal conductivity of 10^3 W/mK. Therefore, with the excellent electrical and thermal characteristics of graphene layers, the hybrid ZnO/graphene structure is expected to offer many sophisticated device applications such as sensing devices. In this study, the seed/catalyst-free growth of ZnO on single layer (SL) and multilayer (ML) graphene by thermal evaporation of Zn in the presence of oxygen (O_2) gas was performed. The effects of substrate temperatures, substrate positions and graphene thicknesses on the morphological, structural, and optical properties were found to be very pronounced. The grown ZnO structures exhibit three different structures, i.e., nanoclusters, nanorods, and thin films at 600°C, 800°C, and 1,000°C, respectively. By setting the substrate to be inclined at 90°, the growth of ZnO nanostructures, namely nanoclusters and nanorods, on SL graphene was successfully realized at temperatures of 600°C and 800°C, respectively. However, no growth was achieved at 1,000°C due to the possible severe oxidation of graphene. For the growth on ML graphene at 600°C with an inclination angle of 90°, the grown structures show extremely thick and continuous cluster structures as compared to the growth with substrate's inclination angle of 45°. Moreover, the base of nanorod structures grown at 800°C with an inclination angle of 90° also become thicker as compared to 45°, even though their densities and aspect ratios were almost unchanged. The morphologies of grown structures at 1,000°C with an inclination angle of 90° do not show significant difference with 45°. The intensity ratio of UV emission (I_{UV}) and visible emission (I_{VIS}) was changed, depending on the temperature. The structures grown at a low temperature of 600°C show the highest value of I_{UV}/I_{VIS} of 16.2, which is almost two times higher than the structures grown on SL graphene, indicating fewer structural defects. From the results obtained, the temperature below 800°C, substrate position inclined at 90° towards the gas flow, and ML graphene seems to be preferable parameters for the growth of ZnO structures by thermal evaporation because these factors can overcome the problem of graphene's oxidation that takes place during the growth.

ABSTRAK

Logam-oksida, iaitu zink oksida (ZnO) berstruktur nano dan filem nipis di atas grafin amat menarik kerana ia boleh menawarkan fungsi tambahan kepada grafin untuk merealisasikan aplikasi elektronik dan optoelektronik maju. Grafin mempunyai potensi besar untuk peranti elektronik novel kerana mobiliti elektrik yang luar biasa melebihi 10^4 cm^2/Vs dan kekonduksian terma 10^3 W/mK. Oleh itu, dengan ciri-ciri elektrik dan haba yang sangat baik dari lapisan grafin, struktur hibrid ZnO/grafin dijangka menawarkan banyak aplikasi peranti canggih. Dalam kajian ini, pertumbuhan ZnO bebas pemangkin/benih di atas grafin berlapisan tunggal (SL) dan lapisan berganda (ML) menggunakan penyejatan haba Zn dalam kehadiran oksigen (O_2) gas telah dilakukan. Kesan suhu substrat, kedudukan dan ketebalan substrat grafin pada sifat-sifat morfologi, struktur, dan optik didapati sangat ketara. Pada dasarnya, struktur ZnO yang tumbuh menunjukkan tiga struktur berbeza, iaitu nanokluster, nanorod, dan filem nipis masing-masing pada 600°C, 800°C, dan 1,000°C. Dengan menetapkan substrat condong pada 90°, pertumbuhan struktur-struktur nano ZnO iaitu nanokluster dan nanorod pada SL grafin telah berjaya direalisasikan pada suhu 600°C dan 800°C. Walau bagaimanapun, tiada pertumbuhan dicapai pada 1,000°C berkemungkinan akibat daripada pengoksidaan grafin yang teruk. Untuk pertumbuhan di atas ML grafin pada 600°C dengan sudut kecondongan 90°, pertumbuhan menunjukkan struktur kelompok yang sangat tebal dan berterusan berbanding dengan pertumbuhan pada sudut kecondongan substrat 45°. Selain itu, tapak struktur nanorod yang tumbuh pada 800°C dengan sudut kecondongan 90° juga menjadi lebih tebal berbanding 45°, walaupun kepadatan dan nisbah aspek hampir tidak berubah. Struktur morfologi pada 1,000°C dengan sudut kecondongan 90° tidak menunjukkan perbezaan yang signifikan berbanding 45°. Nisbah keamatan UV (I_{UV}) dan sinar nampak (I_{VIS}) berubah bergantung kepada suhu. Struktur yang tumbuh pada suhu rendah daripada 600°C menunjukkan nilai tertinggi I_{UV} / I_{VIS} iaitu 16.2, yang hampir dua kali lebih tinggi daripada struktur yang tumbuh di atas SL grafin, menunjukkan sedikit kecacatan struktur. Daripada keputusan yang diperolehi, dapat disimpulkan bahawa suhu di bawah 800°C, kedudukan substrat condong pada 90 ° arah aliran gas, dan ML grafin seolah-olah menjadi parameter terbaik untuk pertumbuhan struktur ZnO oleh penyejatan haba kerana faktor-faktor ini boleh digunakan untuk mengatasi masalah pengoksidaan grafin yang berlaku semasa pertumbuhan.