HOT-WIRE PLASMA ENHANCED CHEMICAL VAPOUR DEPOSITION SYSTEM FOR PREPARATION OF SILICON CARBIDE THIN FILMS

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ABSTRACT

This research offers insights on the function of a home-built plasma enhanced chemical vapor deposition (PECVD) system in the preparation of silicon carbide (SiC) thin films. The work started with designing and building a reaction chamber for the PECVD system that would utilize radio frequency (RF), direct current (DC) and hot-wire (HW). The first phase of the work ensured that the PECVD system is capable of producing good quality and reproducible silicon carbide thin films via independent deposition techniques namely RF-PECVD, DC-PECVD and HW-CVD. The effects of methane to silane gas flow rate ratio on the deposition rate, optical energy gap, Si-C and Si-H bonding configurations and formation of any crystalline structures were investigated. Analytical study revolved around the results obtained from Optical transmission spectroscopy, Fourier transform infrared (FTIR) spectroscopy, micro-Raman scattering spectroscopy and X-Ray diffraction spectroscopy. Based on the findings from the first phase of the work, the research was then proceeded to the next phase of the work where a hybrid deposition technique comprising DC-PECVD and HW-CVD was introduced and applied. The study for these films involved the effects of applied DC voltage and the role of hydrogen in the growth and deposition process of silicon carbide thin films. Results of this work demonstrated that the optical energy band gap of the silicon carbide films prepared by all techniques could be increased by increasing the methane to silane gas flow rate ratio. These results were consistent with published results and the variation of the properties of the films was consistent with the deposition kinetics of silicon carbide. The system is tunable to produce silicon carbide films with a wide range of optical energy band gap from 1.63 eV to 3.26 eV. The film deposition rate is affected in contrary manners for different techniques and does not show direct effect on carbon incorporation nor crystallization of the film. However, by the multiple ranges of deposition parameters allowed by the system built in this work, a variety of silicon carbide thin film could be produced. RF-PECVD technique provides silicon rich amorphous silicon carbide films with deliberately high optical energy band gap. DC-PECVD technique displayed low deposition rate as compared to the other techniques but produces silicon carbide films with relatively high optical energy band gap and more ordered structure with traces of silicon nanocrystallites. Silicon carbide films prepared by HW-CVD technique exhibit enhanced properties such as increasing value of optical energy band gap and more amorphous structure with increased methane to silane gas flow rate ratio. The new HW-PECVD technique demonstrated in this system has succeeded in preparing silicon carbide thin films and provided a minimum optical energy band gap of 2.05 eV. The optical energy band gap could be increased by applying lower DC voltage. The new deposition system is also made feasible to hydrogen applications. It was observed that nanocrystallite structures were formed and were embedded in amorphous SiC film matrix with longer hydrogen surface treatment time.

ABSTRAK

Penyelidikan ini menawarkan kefahaman tentang fungsi sebuah sistem pemendapan wap kimia secara peningkatan plasma (PWKPP) dalam penghasilan filem nipis silikon karbaid (SiC). Kajian dimulakan dengan merekabentuk dan membina kebuk tindakbalas untuk sistem PWKPP yang menggunakan kuasa frekuensi radio (FR), arus terus (AT) dan dawai-panas (DP). Fasa pertama kerja memastikan bahawa sistem PWKPP tersebut berupaya menghasilkan filem nipis SiC yang berkualiti tinggi serta bersifat boleh-ulang menggunakan teknik-teknik yang dinamakan FR-PWKPP, AT-PWKPP dan DP-PWKPP secara bersendirian. Kesan nisbah kadar aliran gas metana kepada kadar aliran gas silana terhadap kadar pemendapan, jurang tenaga optik (E_g), konfigurasi ikatan Si-C dan Si-H serta sebarang pembentukan kristal telah diselidiki. Kajian analitikal berkisar tentang hasil yang diperolehi dari spektroskopi pemancar optik (UV-Nir-Vis), spektroskopi Transformasi Fourier Inframerah (FTIR), spektroskopi sinar-X dan spektroskopi mikro-Raman. Berdasarkan dapatan dari fasa pertama, penyelidikan diteruskan ke fasa berikutnya dimana satu kaedah pemendapan hibrid yang merupakan gabungan teknik AT-PWKPP dan DP-PWKPP diperkenal dan digunakan. Kajian tentang filem ini melibatkan kesan voltan DC dan peranan hidrogen dalam pembentukan dan pemendapan filem nipis SiC. Hasil kajian menunjukkan bahawa bagi semua teknik, jurang tenaga optik boleh ditingkatkan dengan meningkatkan nisbah kadar aliran gas metana kepada kadar aliran gas silana. Hasil ini setara dengan hasil yang telah diterbitkan dan variasi sifat-sifat filem adalah setara dengan kinetik pemendapan filem SiC. Hasil kajian ini setara dengan hasil tang telah diterbitkan dan kepelbagaian kepada sifat filem juga konsisten dengan kinetik pemendapan SiC. Sistem HW-PECVD ini boleh diubah untuk menghasilkan filem SiC dengan lingkungan jurang tenaga yang besar di antara 1.63 eV dan 3.26 eV. Kadar pemendapan filem terkesan pada cara yang berbeza di antara teknik yang berbeza dan tidak menunjukkan kesan langsung terhadap penggabungan karbon mahupun pengkristalan filem. Namun dengan kepelbagaian parameter yang tersedia dalam sistem ini, berbagai jenis filem SiC boleh dihasilkan. Teknik FR-PWKPP menghasilkan filem SiC yang amorfus dan kaya dengan silikon serta mempunyai nilai E_g yang sederhana tinggi. Teknik AT-PWKPP menunjukkan kadar pemendapan yang rendah berbanding teknik lain tetapi menghasilkan filem SiC dengan nilai E_g yang tinggi serta mempunyai struktur yang lebih tersusun dengan sedikit silicon kristal bersaiz nano. Filem SiC yang disediakan daripada teknik DP-PWK mempamerkan sifat memberangsangkan seperti nilai E_g yang meningkat dan filem yang lebih amorfus dengan pertambahan nisbah kadar aliran gas metana kepada kadar aliran gas silana. Teknik pemendapan baru DP-PWKPP yang diperkenalkan dalam sistem ini berjaya menghasilkan filem nipis SiC yang memberikan nilai E_g minimanya 2.05 eV. Nilai E_g ini boleh ditingkatkan dengan mengurangkan nilai voltan arus terus. Struktur kristal nano yang tertanam di dalam struktur matrik amorfus silicon juga telah terhasil dengan masa rawatan hidrogen yang lebih lama.

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