GALLIUM NITRIDE NANOWIRE BY NITRIDATION OF ELECTROCHEMICALLY GROWN GALLIUM OXIDE ON SILICON

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ABSTRACT

GaN is a wide bandgap semiconductor with superb thermal, chemical, mechanical and electrical properties which makes it suitable for high power electronic and optoelectronic devices. Si substrate is preferable for the heterostructure growth of GaN due to its availability in large wafer size, low price and maturity. The co-integration of GaN-based devices on Si is very attractive towards the realization of advanced heterogeneous integration . A transformation of the grown Ga_2O_3 structures on Si to GaN by a so-called nitridation process is considered as a simple method to create a GaN/Si heterostructure. In the first stage, a synthesis of β-Ga_2O_3 nanostructures on Si substrate by electrochemical deposition using a mixture of Ga_2O_3, HCl, NH_4OH, and H_2O was performed. The morphologies strongly depended on the molarity of Ga_2O_3 and pH level of electrolyte. β-Ga_2O_3 nanodot-like structures were grown at low molarity of Ga_2O_3. However, Ga_2O_3 nanodot structures covered with nanorods on top of their surfaces were obtained at higher molarity, and the densities of nanorods seem to increase with the decrease of pH level. In the next stage, the nitridation of the electrodeposited Ga_2O_3 was performed. The complete nitridation was achieved at temperature of 900°C. Here, several prominent diffraction peaks correspond to hexagonal GaN (h-GaN) planes were detected with no diffraction peak of Ga_2O_3 structure. Temperature is a key parameter in a nitridation process where the deoxidization rate of Ga_2O_3 to generate gaseous Ga_2O increase with temperature. It was found that a complete transformation cannot be realized without a complete deoxidization of Ga_2O_3. A significant change of morphological structures takes place after a complete transformation of Ga_2O_3 to GaN where the original nanorod structures of Ga_2O_3 diminish, and a new nanowire-like GaN structures appear. The studied method seems to be promising in producing high-quality h-GaN nanostructures on Si.

ABSTRAK

GaN adalah bahan semikonduktor yang mempunyai sela jalur yang luas serta ciri-ciri yang luar biasa seperti ciri-ciri haba, kimia, mekanikal dan elektrik yang menjadikan ia sesuai untuk dijadikan sebagai peranti elektronik berkuasa tinggi dan peranti optoelektronik. Silikon (Si) substrat adalah lebih sesuai digunakan untuk pertumbuhan strukturhetero GaN kerana adanya saiz wafer Si yang lebih besar, harga yang murah dan kematangan teknologi berasaskan Si. Di samping itu, fabrikasi peranti berasaskan-GaN pada platform Si sangat menarik ke arah merealisasikan integrasi heterogen termaju. Pada peringkat pertama, strukturnano β-Ga_2O_3 telah disintesis pada substrat Si melalui proses pemendapan elektrokimia menggunakan campuran Ga_2O_3, HCl, NH_4OH, dan H_2O. Morfologi Ga_2O_3 yang dideposit sangat bergantung kepada molariti Ga_2O_3 dan tahap pH elektrolit. Struktur berupa nanodot Ga_2O_3 telah tumbuh diatas substrat Si pada keadaan molariti Ga_2O_3 yang rendah. Walaubagaimanapun, struktur nanodot Ga_2O_3 dilitupi dengan nanorods di atas permukaannya diperoleh pada molariti yang lebih tinggi, dan ketumpatan nanorod kelihatan meningkat dengan penurunan tahap pH. Pada peringkat seterusnya, proses penitridaan Ga_2O_3 telah dilakukan selepas melalui proses electrokimia. Pada suhu 900°C penitridaan yang lengkap telah dicapai. Pada suhu ini, beberapa puncak pembelauan utama diperolehi berpadanan dengan satah hexagon GaN (h-GaN) dikesan tanpa puncak pembelauan struktur Ga_2O_3. Suhu adalah parameter utama dalam proses peniridaan, dimana kadar penyahoksidaan bagi Ga_2O_3 untuk menjana gas Ga_2O adalah meningkat dengan suhu. Transformasi lengkap Ga_2O_3 kepada GaN tidak dapat direalisasikan tanpa penyahoksidaan Ga_2O_3 yang lengkap. Perubahan ketara morfologi berlaku selepas transformasi lengkap Ga_2O_3 kepada GaN dimana struktur asal nanorod Ga_2O_3 telah mengecil dan nanowayar GaN yang baru telah muncul. Keputusan ini menunjukkan bahawa kaedah yang dibentangkan sangat berpontensi dalam menghasilkan struktur-struktur h-GaN yang berkualiti tinggi.