Growth and Characterization of Gallium Based III-V Low Dimensional Structures on Silicon

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ABSTRACT

The present work is a comprehensive study of the growth and characterization of gallium based III-V binary as well as ternary low dimensional structures fabricated on silicon substrate by metal oxide chemical vapor deposition (MOCVD). Three types of structures, viz. InGaAs thin film, InGaAs nanowires and GaP quantum dots are grown with an aim to integrate the optoelectronic properties of III-V semiconductors with silicon microelectronics. Group V hydrides such as arsine, phosphine and group III alkyls, viz. tri-methyl gallium, tri-methyl indium were used as precursors. To optimize the growth, parameters like growth temperature, precursors flow rates, V/III ratio and growth duration were varied. The samples were characterized by different microscopy and optical spectroscopic tools. In the present investigation InGaAs thin films were grown onto silicon substrates using a buffer layer of InP having thickness less than one micrometer with sharp interfaces between the grown layers. Gallium nano droplets were deposited on Si substrate by pyrolysis of tri-methyl gallium for the self- assisted growth of InGaAs nanowires via vapor solid liquid technique. It was observed that the size of the droplets increases at high temperature with reduced surface density. The effect of growth temperature and duration on the shape and size of the droplets were demonstrated on the basis of Oswald ripening based coalescence mechanism. It was found that partial coalescence of smaller droplets leads to the formation of valve-shaped nanostructures whereas complete coalescence of droplets gives rise to spherical nanomorphology. Self-catalyzed InGaAs nanowires were grown on Si substrate by a two steps process in atmospheric pressure MOCVD using gallium nano droplets as catalyst. Growth temperature and the V/III ratio were optimized to obtain vertically stranded nanowires. Growth morphology showed that with increasing V/III ratio the diameter of the nanowires decreases. It was also found that the indium and gallium fraction varies along the length of the grown nanowires. The TEM fringe pattern revealed that the nanowires were grown along the (111) direction. Gallium phosphide nanostructures, grown on Si, was found to have height comparable to the Exciton Bohr radius, however, the diameter was larger. The increase in band gap energy of GaP nanostructures was explained with the weak confinement of charge carriers due to size quantization. Finally, a high –k dielectric based metal oxide semiconductor capacitor with structure Si/InP/InGaAs was fabricated using 20 nm titanium oxide layer. Capacitance - voltage and frequency dependent conductance measurements were carried out to find the interface trap density and it is found to have smaller value on annealing in arsine ambient.

Keywords: MOCVD, VLS Growth, Quantum Confinement, Self-catalyzed Growth, III-V Nanowires, Quantum Dots, High-k Dielectric, MOSCAP, Interface Trap Density.