Abstract

Carbon nanotubes (CNTs) exhibit a unique combination of electronic, thermal, mechanical and chemical properties, which promise a wide range of potential applications in key industrial sectors. An essential step towards the application of nanotubes is a thorough understanding of the effect of process variables on CNT growth and the role of the metal catalyst involved in the synthesis procedure.

In this study, the synthesis of multi-walled carbon nanotubes (MWCNTs) was carried out by chemical vapor deposition (CVD) using propane as the carbon source and Si as the catalyst support. The effect of CVD process variables such as temperature, choice of catalyst, etc on the growth behavior of nanotubes has been examined to understand the catalytic growth of CNTs. The transition metal catalysts, Fe and Ni, were used in both elemental metal form and in a metal complex form. In the case of elemental metal catalysts, the respective metals were deposited over the Si substrate using thermal evaporation following which nanotubes were synthesized by means of CVD. Subsequent studies of the synthesized carbon nanostructures employing elemental metal catalysts revealed a significant influence of the temperature and the catalyst material on the structure of CNTs. The CNTs synthesized using Ni catalyst were bamboo-like whereas the CNTs developed employing Fe catalyst were straight tubes with partial metal filling. Consequently, growth models for the different growth mechanisms have been proposed. Certain limitations of the above process have been overcome by employing spin-coating of a metal complex catalyst material on the Si substrate. The CVD synthesis of nanotubes using metal complex catalysts always resulted in partially catalyst filled CNTs. More importantly, the metal complex catalyst could be easily patterned on the Si substrate using spin-coating and photolithography, which resulted in site selective growth of partially catalyst filled MWCNTs. Since the entire process of site selective growth is suitable for conventional device fabrication, this method is a promising and practical pathway for large-scale fabrication of several magnetic material filled CNT-based devices.

Keywords: Multi-walled carbon nanotubes; Lithography; Site selective growth; Chemical vapor deposition