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In situ Optical Monitoring of Vertically-Aligned Multiwall Carbon Nanotube Array Growth During Chemical Vapor Deposition

A. A. Puretzky[a] , D. B. Geohegan, J. Y. Howe [b], I. N. Ivanov, S. Jesse, and G. Eres

Condensed Matter Sciences Division and [b] Metals and Ceramics Division Oak Ridge National Laboratory, Oak Ridge, TN 37831
Department of Materials Science and Engineering, University of Tennessee, Knoxville, TN 37996

Abstract

A detailed experimental study of vertically aligned arrays of multi-wall carbon nanotubes (VAA-MWNT) growth by chemical vapor deposition (CVD) based on time-resolved reflectivity (TRR) as a diagnostic to measure and control the length of VAA-MWNTs in situ is performed. Attenuation of a reflected HeNe laser beam and Fabry-Perot fringes are used to measure the length of VAA-MWNT arrays throughout the first 10 microns of growth, providing in situ growth rates and permitting the kinetics and termination of growth to be studied. VAA-MWNT growth was investigated between 530 °C and 900 °C on Si substrates with evaporated Al/Fe/Mo multiplayer catalysts and acetylene feedstock. It was demonstrated that the growth terminates rapidly at a relatively low (535-600 °C) and high (800-900 °C) temperatures, showing a relatively narrow temperature window for optimal growth of long VAA-MWNTs (up to 2-4 mm) around 700 °C, at a growth rate of about 0.2 - 0.3 μm/s. Nanotube lengths were controlled by rapid evacuation of the chamber. The extinction coefficients of the VAA-MWNTs were studied and correlated with nanotube wall structures. It was demonstrated that decreasing the partial pressure of the C_2H_2 gas could increase the growth termination length. A simple kinetic model was considered to explain the observed growth kinetics and to discuss the main processes responsible for the growth of VAA-MWNTs.

Presenting (and contact) author:
Alex Puretzky
MS-6056, Bldg. 3150, ORNL
P.O. Box 2008
Oak Ridge, TN 37831-6056
Phone: 865-574-5497
FAX: 865-576-3676
Email: 1ap@ornl.gov