MNHMT2009-18395 *Technical Publication*

Scattering Process of Gas Molecules on Vertically Aligned Single-Walled Carbon Nanotubes

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Abstract

Scattering process of gas molecules on quartz surfaces covered with vertically aligned single-walled carbon nanotubes (VA-SWNTs) was investigated using the molecular beam technique. Experiments were conducted in a molecular beam apparatus described previously [I. Kinefuchi et al., Proc. of 24th Int. Symp. on Rarefied Gas Dynamcs (2005)]. The samples we used were the films of VA-SWNTs grown on quartz glass substrates by alcohol catalytic CVD method [Y. Murakami et al., Chem. Phys. Lett. (2004)]. Secondary electron microscopy images show that the thicknesses of the samples were approximately 0.1 and 4 um. The thinner sample consists of carbon nanotube (CNT) bundles oriented randomly and does not have well-aligned structure. On the other hand, CNT bundles align vertically in most part of the thicker sample except for the topmost layer, whose structure is similar to that of the thinner sample. These samples have the porosity of more than 95 % [R. Xiang et al., J. Phys. Chem. C (2008)] although the detailed structure is still under debate. The samples were heated at fixed temperatures between 300 and 800 K and were exposed to helium beam with a translational energy of 0.06 eV. We found that the surface modification with VA-SWNT films significantly enhances the energy transfer between gas molecules and surfaces at room temperature and makes the energy accommodation coefficient of helium, which tends to be small even for contaminated surfaces because of the large mass mismatch between helium and surface atom, close to unity. Our results demonstrate a potential application of VA-SWNTs as nanoscale

fin structures to enhance heat transfer between gas phase and solid surfaces. As the surface temperature increases, however, the energy accommodation becomes less efficient. This would be attributed to the small adsorption energy [W. Teizer et al., Phys. Rev. Lett. (2000)], which could reduce the trapping probability of helium on CNT bundles. The weak dependence of the accommodation coefficient on the film thickness suggests that gas molecules penetrate into the films because of their high porosity and suffer more than one collision with CNT bundles.

Session: 6-2 Transport phenomena and chemical reactions in material processing and manufacturing