LASER-INDUCED CARBON CVD USING AN OPEN-AIR REACTOR

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Carbon films are deposited on stationary and moving fused quartz substrates by CO_2 laser-induced chemical vapor deposition (LCVD) using an open-air system. This open-air configuration allows for film growth on moving samples, reduced turnaround time, and high spatial control of the heat and deposition zones. The deposition rates of methane, propane and butane gases are observed to have an exponential dependence on temperature. Raman spectra of deposited carbon films indicate that the surface consists of glass-like or nano-crystalline carbon. These findings demonstrate open-air CVD of carbon films with repeatable deposition rate and microstructure.

In this paper, LCVD of carbon films on stationary and moving substrates from methane, propane and butane will be investigated. The resulting carbon films will be characterized for its kinetics and deposition rate. The resulting carbon film morphology and microstructure is also investigated by ESEM and Raman Spectroscopy.

The LCVD system used for the deposition experiment is shown in Fig. 1. A 25-watt continuous wave CO_2 laser (Synrad J48-2W) operating at a wavelength of 10.6 mm is with a closed-loop temperature controller is used to maintain the desire temperature during deposition. The carbon film deposition experiments are performed in a coaxial jet LCVD reactor. This arrangement is an effective way to deliver reactants to the reaction zone in open-air conditions. The outer inert gas jet acts as a curtain to prevent oxygen intrusion. The inner hydrocarbon jet flows over the substrate surface in a cross flow arrangement. Fused quartz rods are used as a substrate. In order to decrease surface contamination, the substrates were clean with methanol and distilled water before deposition. The morphology and microstructure of the carbon coatings are analyzed by Environmental Scanning Electron Microscope (ESEM), optical microscope and Raman Spectroscopy. The Raman spectra of the carbon film are taken using a 514 nm argon ion laser. The laser power used for Raman spectrometry has 5 nm penetration.

Carbon films were deposited by LCVD from propane in the temperature range of 1375K to 1550K. The results in Fig. 2 indicate that significant mass deposition from propane starts at 1375K. The deposition rate shows functional relationship with temperature is close to exponential, therefore an Arrhenius model can be apply to describe this process.

The carbon film surface was examined under ESEM and an optical microscope. The surface was very smooth and shiny (by visual inspection), which are characteristics of a graphitic layer and the surface appears very uniform. Higher magnification reveals no further microstructural information. Raman spectra reveals two peaks at 1584 and 1358 cm^{-1} in the interval of 500-2000 cm^{-1}. The ratio of the two peaks is almost equal to one, which indicates that the surface of the carbon spot consists of nanocrystalline or “glassy” graphite.

When substrate motion is introduced, the carbon film thickness decreases almost linearly with increasing traversing velocity. This is because an increasing velocity reduces the duration in which the substrate stays in the deposition zone, resulting in less film deposition. Raman spectra of carbon films deposited on moving substrates revealed a similar trend. By comparison with a standard disordered graphite spectrum, the carbon film is identified as being disordered graphite. The Raman spectra acquired from all the samples in this study are similar except for the intensity ratio of the two peaks.

In summary, this investigation has shown that open-air deposition of carbon films on stationary and moving fused quartz substrates are possible. Deposition rates are strongly dependent on the deposition surface temperature. This relationship is exponential and can be modeled by Arrhenius’ Law. The carbon films deposited from all three precursors are very shiny and smooth from visual and ESEM inspection. When the substrate was moved at a constant velocity, film thickness was found to decrease with increasing traversing velocity. A knee in the film thickness curve was found to relate to an optimal traverse velocity, where the deposition rate increases until a maximum deposition rate is reached. Microstructural characterization of the carbon film by Raman spectroscopy indicates that carbon films deposited by open-air LCVD consisted of disordered graphite.

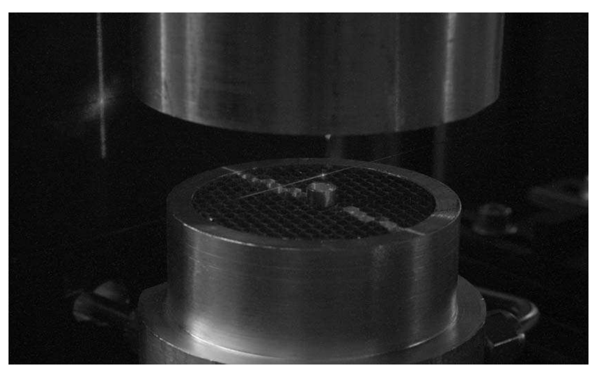

Figure 1. Open-air laser-induced chemical vapor deposition system.

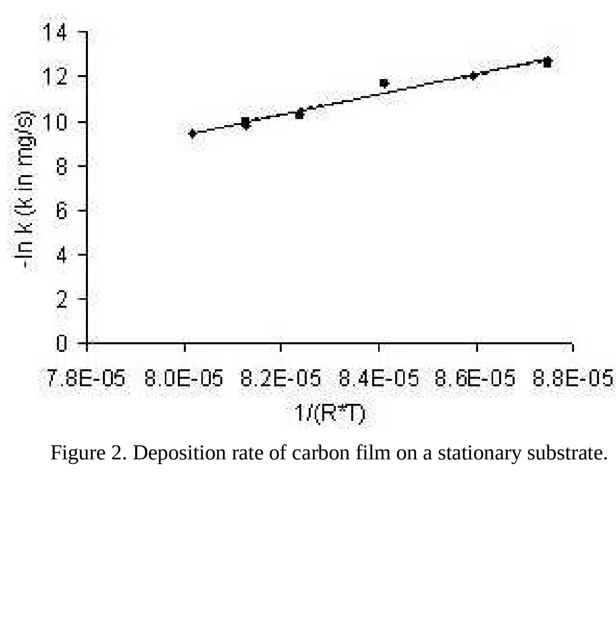

Figure 2. Deposition rate of carbon film on a stationary substrate.

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