THERMIONIC EMISSION FROM SURFACE TREATED NANOCRYSTALLINE DIAMOND

Vance S. Robinson and T. S. Fisher
School of Mechanical Engineering and Birck Nanotechnology Center
Purdue University
West Lafayette, IN 47907-2088

Yoshiyuki Show and Greg Swain
Department of Chemistry
Michigan State University
East Lansing, MI 48824

Abstract

Thermionic emission is a well known means of using heat to create a flow of electrons. This technology has been applied to fluorescent bulbs, vacuum gauges, mass spectrometers, and X-ray tubes. Thermionic emission is also a means of direct energy conversion (heat to electricity). Its attraction in this area can be attributed to its relative simplicity, efficiency, scalability and durability. However, taking full advantage of these features requires further investigation. The objective of this study is to determine the effects of temperature on emission performance and on the emitter's surface chemistry.

Three different nanocrystalline film emitters are included in this study. The films are made of boron-doped nanocrystalline diamond with different surface terminations: hydrogen, oxygen, and a nitrophenyl adlayer. A succession of thermionic emission energy distributions (TEEDs) was measured from each sample at 600°C, 780°C, and again at 600°C (see Fig. 1). The TEEDs demonstrate that the surface terminations of the nanocrystalline emitters begin to show signs of instability at 600°C. These results support the work done by Köck et al. (2002) which used thermionic field-emission electron spectroscopy and current voltage measurements to show that the hydrogen surface terminations of nitrogen-doped diamond films became unstable at approximately 725°C. Furthermore, the multiple peaks shown in the TEEDs suggest that the electrons are emitted from surface regions of differing electron affinities, and that as the temperature of the emitting surface changed the area of these regions changed as well. A residual gas analyzer was used to track the presence of various gases in the vacuum chamber as the emitters were heated (see Fig. 2). This information was used with the TEEDs to show that the surface terminations became unstable and eventually desorbed from the emitter at high temperatures. In addition, the TEEDs (see Fig. 3) showed a secondary peak that consistently formed at approximately the same energy (4.6 eV) which could represent emission from the graphitic channels in the diamond film, from the diamond itself, or a combination of both (Abbott, 2001).

By developing a better understanding of the performance of the surface treatments of nanocrystalline diamond, which are often used to lower the potential barrier and create negative electron affinities, we can design and fabricate more efficient thermionic emitters.

References

Abbott, P., Sosa, E.D., and Golden, D.E., 2001, "Effect of Average Grain Size on the Work Function of Diamond Films," *Applied Physics Letters*, **79**(17), pp. 2835-2837.

Köck, F. A. M., Garguilo, J. M., Brown, B., Nemanich, R. J., 2002, "Enhanced low-temperature thermionic field emission from surface treated N-doped diamond films," *Diamond and Related Materials*, **11**, pp. 774-779.

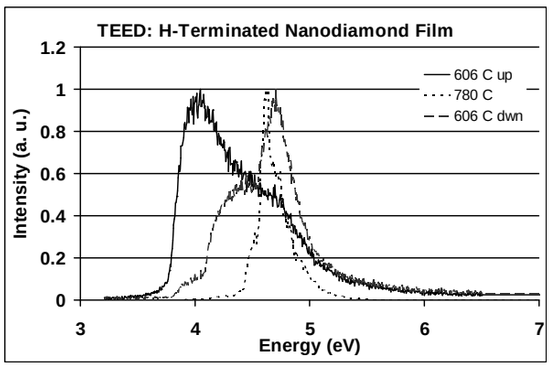

Figure 1: TEEDs of an H-terminated nanocrystalline diamond film at 606 °C, 780 °C and again at 606 °C. Notice that the leading edge of the distribution is not consistent indicating a change in the chemistry of the emitter surface.

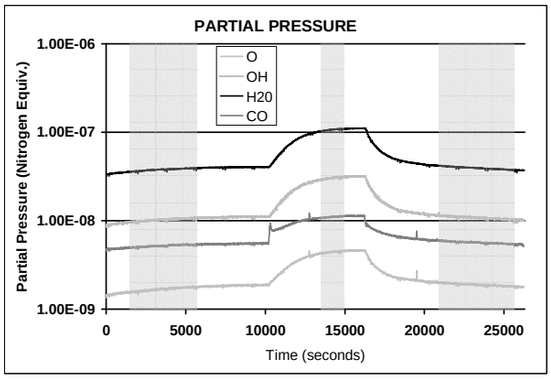

Figure 2: Plot of the change in partial pressure over time of the most prevalent oxygen-containing gases. The shaded regions are the time periods over which the TEEDs were measured.

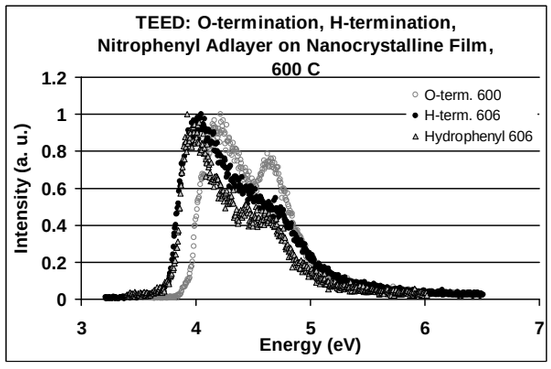

Figure 3: TEED from nanocrystalline diamond. The H-terminated emitter and the emitter with the nitrophenyl adlayer have the same electron affinity which is lower than that of the O-terminated emitter. Both emitters show a secondary increase in intensity at approximately the same energy (~4.6 eV).