Diamond Surface Conductivity: Effect of pH, Temperature, and Humidity

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Hydrogen-terminated diamond exhibits a p-type surface conductivity that is modulated by the adsorbates from the ambient atmosphere.[1,2,3] It is believed that the conductivity arises by transfer of electrons from the diamond to a redox couple in the water film adsorbed on the surface.[4] In previous work we have studied this effect under different chemical environments and surface terminations.[5] The conductivity increased upon exposure to acidic vapors, which lower the chemical potential of electrons in the water film, and decreased when exposed to basic vapors, which increase the chemical potential of electrons. The effect disappeared with fluorine-terminated diamond and oxidized diamond. Organic liquids that wet the hydrophobic diamond surface displace the water film and quench the surface conductivity.

In this study both ohmic and Schottky contacts on hydrogen-terminated diamond were studied at different pH. The changes occurring using Au/Ti ohmic contacts were far less than observed for Al Schottky contacts (Fig. 1). The barrier height calculated from the I-V data for the Schottky contacts increased with increase in pH, although these changes were significantly less than predicted by the Nernst equation. See Fig. 2.

Transient measurements were performed in order to study the effect of temperature and humidity. The baseline current was first recorded at room temperature; a step change in temperature was then imposed. The conductance first *increased*, reached a maximum, and then *decreased* to a steady state value, which was lower than the baseline current (see Fig. 3). The increase in conductance immediately after the temperature change is attributed to thermal excitation of electrons to form holes. The subsequent decrease arises from decreased solubility of oxygen and desorption of water from the surface, which decrease the number of available acceptors. Figures 4 and 5 show the steady-state current and the peak current as a function of temperature under different humidity conditions.

The results support the electrochemical transfer doping model proposed by Maier *et al.*[4]

References

1. M. I. Landstrass, K. V. Ravi, *Appl. Phys. Lett.* **55** (1989) 975-977.
2. R. S. Gi, T. Mizumasa, Y. Akiba, Y. Hirose, T. Kurosu, M. Iida, *Jap. J. Appl. Phys. Part 1* **34** (1995) 5550-5555.
3. R. S. Gi, T. Ishikawa, S. Tanaka, T. Kimura, Y. Akiba, M. Iida, *Jap. J. Appl. Phys. Part 1* **36** (1997) 2057-2060.
4. F. Maier, M. Riedel, B. Mantel, J. Ristein, L. Ley, *Phys. Rev. Lett.* **85** (2000) 3472-3475.
5. V. Chakrapani, S. C. Eaton, J. C. Angus, Extended abstract, The Electrochemical Society, Paris, 2003.

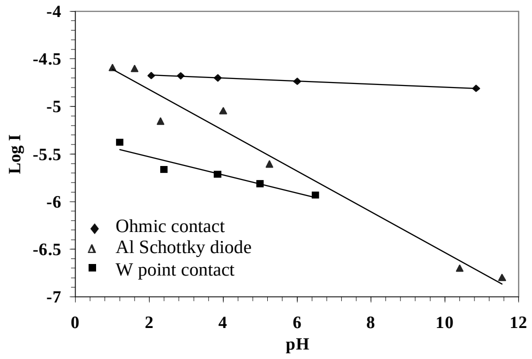

Figure 1. Conductivity change with pH for different contacts.

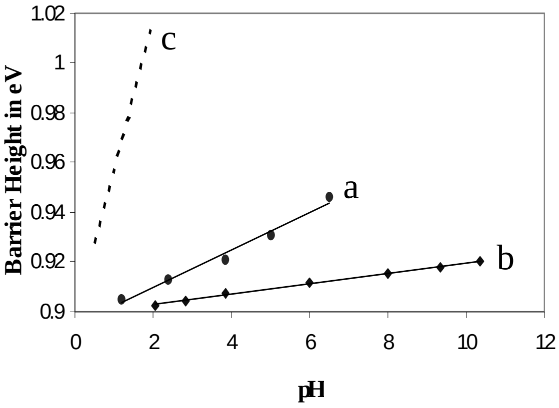

Figure 2. Schottky barrier height as a function of pH for a) polycrystalline diamond; b) single crystal (111) diamond; c) barrier height change predicted by the Nernst equation.

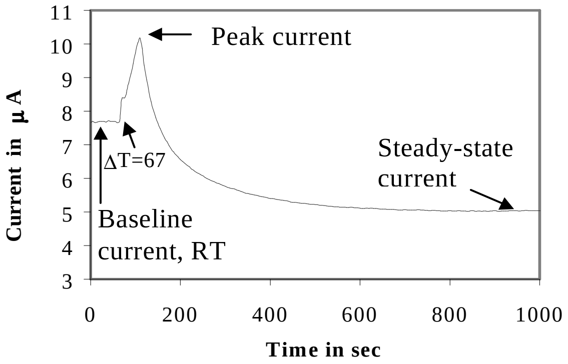

Figure 3. Transient response for imposition of step increase in temperature of 67K for single crystal (111) diamond.

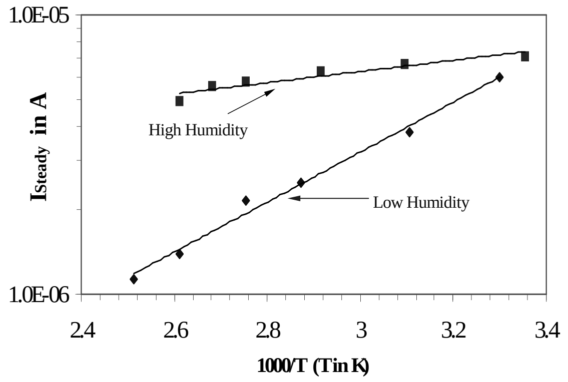

Figure 4. Steady state current as a function of temperature under different humidity conditions for (111) single crystal diamond.

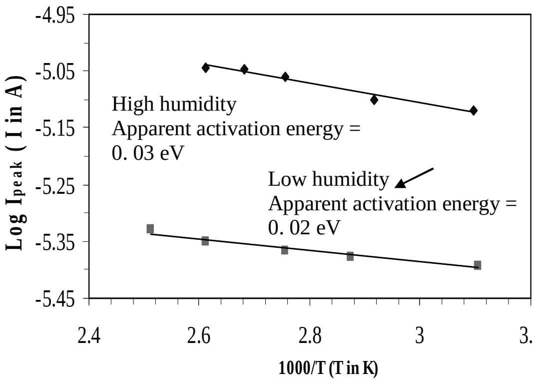

Figure 5. Peak current as a function of temperature under different humidity conditions for single crystal (111) diamond