ANTIMONY ON DIAMOND: A COMPARISON TO Sb/Si AND Sb/Ge

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ABSTRACT

Diamond is an important semiconductor which has great potential in high temperature, high power device applications. In the fabrication process of diamond electronic device, doping of diamond and understanding of diamond/metal interfaces are important. As a Column V element, Sb is a possible dopant for diamond. Early work reported that Sb is incorporated into diamond by ion implantaion [1]. In addition, Sb plays an important role in Si and Ge heteroepitaxial growth. On the Si or Ge surface one ordered monolayer of Sb occupies the epitaxial sites and saturates the surface dangling bonds, which leads to uniform epitaxial growth. While diamond has the same crystal structure as both silicon and germanium, it has a drastically smaller lattice and much stronger bond. This makes it very difficult to extrapolate antimony's behavior on diamond from its behavior on either silicon or germanium. In this work, we have studied the electronic and geometric structure of Sb on diamond surfaces using photoelectron spectroscopy and low energy electron diffraction. While the exact adsorption sites could not be determined, we find that antimony strongly bonds to the diamond surface. Further, antimony behaves very differently on the diamond(100) face as compared to the diamond(111) face. We also find that neither Sb/diamond system behaves like antimony on either silicon or germanium. We attribute these results to the drastically smaller diamond lattice and the stronger C-C bond.

INTRODUCTION

Diamond has extremely high thermal conductivity, high electrical resistance, and a wide bandgap. Because of these properties, it has great potential for both technologic applications and scientific research. If doped single-crystal diamond films can be routinely grown,it will be used in semiconductor devices. Since antimony is a column V element, and is one of three elements (boron and lithium are other two.) that is incorporated in diamond by ion implantation [1], it is a possible dopant for diamond. With the development of diamond synthesis in the metastable region, we have known that well-crystallized diamond can be obtained through chemical vapor deposition [2]. However, growth of high quality crystalline doped diamond has been rare, and fundamental mechanisms involved in diamond deposition, diamond doping, and its interfaces with other metals are not yet well understood. On the other hand, extensive research has been done to understand the Sb-Si and Sb-Ge interfaces [3-5]. It is found that high quality epitaxial Si/Ge layers can be grown using Sb as a surfactant. This is mainly due to the unique structure of Sb/Si and Sb/Ge, where one ordered monolayer of Sb occupies the epitaxial sites on the Si or Ge surface and saturates the surface dangling bonds, which leads to uniform epitaxial overlayer. Since C, Si and Ge are all Column IV element, it is interesting to compare the Sb's behaviors on these interfaces. Diamond is also a Column IV element, and has the same crystal structure as silicon and germanium, its lattice is significantly smaller than that of both silicon and germanium, and its C-C bond is much stronger than the Si-Si and Ge-Ge bond. The covalent radius of antimony is 1.45Å, only 0.09Å shorter than the C-C bond in diamond, which is only 1.54 Å. The question arises whether antimony is going to bond to the diamond? If so, what is the overlayer geometry? The objective of this photoemission study is to improve the understanding of Sb's behavior in diamond and diamond/metal interfaces, moreover to investigate the effect of substrate lattice size on overlayer geometric structure.

