Epitaxial Diamond Growth on Ir(100) Surfaces

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Motivation—The growth of large-area high-quality diamond thin films is limited by the ability to nucleate diamond on non-diamond substrates. Typically, diamond nucleates only sparsely on non-diamond substrates, and it is difficult to obtain aligned grains, limiting the quality of subsequently grown films. Recently, it has been found that the Ir(100) surface is particularly suited to nucleating oriented diamond crystallites. Unfortunately, Iridium is one of the rarest metals on earth, and large area crystals are not available. Silicon, on the other hand, is abundant, and large area wafers are routinely produced, suggesting that thin-film Ir layers on Si might be feasible for producing large area diamond films. Ir forms an undesirable silicide at typical diamond growth temperatures. One solution is to provide a nonreactive buffer layer between the two materials.

Accomplishment—We have used pulsed-laser deposition to produce thin (~25 nm) Yttria Stabilized Zirconia (YSZ) layers on 4" Si substrates. The Ir thin film (200 nm) is sputter deposited immediately following the YSZ deposition without breaking vacuum. X-ray diffraction results (Figure 1) show that we have achieved highly oriented films that are epitaxially aligned with the Si(001) substrate. The small fraction of (111) oriented Ir material present should have no significant effect on the subsequent diamond growth. For the YSZ material, it is important to perform the initial deposition in high vacuum (~10^{-7} Torr) to establish epitaxy with the silicon. Subsequent YSZ deposition is done in an oxygen background gas to maintain stoichiometry. For the Ir layer, the two most important deposition parameters for producing the favored (100) orientation are the substrate temperature (~775 °C) and the Ar gas pressure (2 mTorr) during sputtering. At lower temperatures and higher pressures, films with mostly (111) orientation are produced.

For the diamond nucleation and deposition, we commissioned a new microwave CVD system that enabled us to nucleate and grow epitaxial diamond layers upon the oriented Ir layers. An example of a (100) oriented epitaxial diamond layer is shown in Figure 2. Control of the diamond nucleation step is critical for growing oriented films, and we have found that a high negative DC bias (-350V) gives the best results. These diamond layers can be patterned using procedures developed in previous projects, and are suitable for creating device structures.

Significance—The problem of growing high-quality diamond thin films reduces to one of producing large area Ir(100) surfaces and uniformly nucleating diamond on this surface. Our progress towards this goal means that diamond thermal management, electronics, and MEMS applications are one step closer to fruition.

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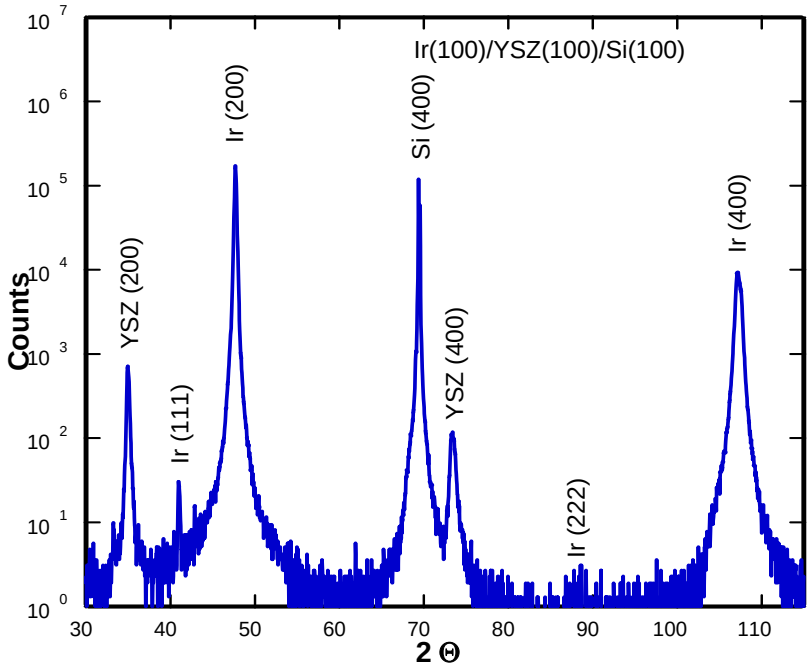

Figure 1. X-ray diffraction scan of Ir/YSZ layers on Si with a high degree of (100) orientation.

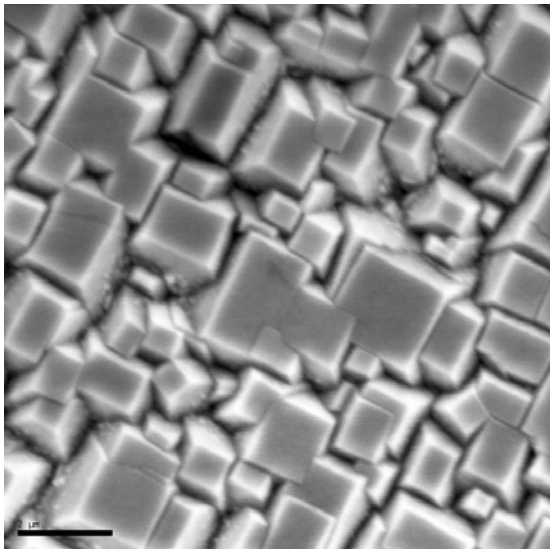

Figure 2. Epitaxial diamond layer nucleated on Ir. Subsequent textured growth produces continuous, flat surfaces.