Chemical Mechanical Polishing Rate and Surface Smoothness for Single-Crystalline Diamond Substrates

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Diamond is one of the promising materials in modern engineering and it has been recognized due to its excellent mechanical, thermal, and optical properties. Among various types of diamond materials, Single-Crystalline Diamonds (SCD) developed by Chemical Vapor Deposition (CVD) have attracted attention in various applications including next-generation electronics, quantum sensors, optical windows, precision machining tools, and diamond bonding to other semiconductors. However, the surface quality and flatness of diamond materials often plays a crucial role in determining their effectiveness for such applications. In this regard, Chemical Mechanical Polishing (CMP) is a promising approach to achieving low surface roughness and high surface quality for diamond materials. This paper presents a study of the CMP process for CVD diamond films grown on High-Pressure, High-Temperature (HPHT) substrates. The objective of this study is to investigate the CMP rate and polishing uniformity across diamond materials. The study utilized HPHT diamond samples of various dimensions.

The CMP process is performed using a oxidative chemical, potassium permanganate ($KMnO_4$), and boron carbide (B_4C), which is a promising approach to achieving low surface roughness and high surface quality for diamond materials. The material removal rate and uniformity of CMP are determined by plasma etching patterns into the diamond surface and monitoring them using an Atomic Force Microscope (AFM) and surface profilometry tools. The CMP process is performed at fixed time intervals to calculate the CMP rate and the polishing uniformity across the diamond materials. The results of this study show that the CMP process with the $KMnO_4$ and B_4C mixture is an effective approach to achieving low surface roughness of <0.3 nm and high surface quality for CVD diamond films. The study found that the CMP rate (typically ~ 100nm/hr) and polishing uniformity across the diamond materials depend on various parameters, such as the diamond surface orientation, the CMP slurry composition, the rotational speed of the polishing wheel, and the imposed load pressure. The findings of this study can be used to optimize the CMP process parameters and improve the cost-effectiveness and quality of diamond material processing, particularly for electronic applications involving epi-layers of diamonds created by the CVD approach.

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