Regenerative Homoepitaxy of Diamond

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InterScience, Inc. is a company founded in 1980 to pursue development of technology related to controlled fusion research for near term applications. During the first decade of the company’s existence, the strategic focus was the transfer of technology and know-how from the fusion program supported by DOE to other federal programs. The company’s activities extend over a broad spectrum of fusion and plasma technologies that include lasers, particle beams, microwave and pulsed power systems, high vacuum and cryogenic systems, materials, diagnostic instrumentation, and control and data acquisition systems. Aspects of these technologies have been developed for incorporation into programs supported by the three services of the Department of Defense (Army, Navy and the Air Force) and the interservice agencies that include the Advanced Research Project Agency, Defense Nuclear Agency, and the Ballistic Defense Initiative Organization, as well as organizations such as the National Aeronautics and Space Agency and the National Institute of Health. The company is now in its second decade of operation and is shifting its focus toward further transfer of its technologies to commercial applications.

Among the technologies with origin from the fusion research being developed with significant potential for large scale commercial applications is a process for the growth of single crystal diamond as substrate for electronic devices. Diamond is an attractive electronic material because of the wide bandgap, high electron mobility, high thermal conductivity and high temperature tolerance. Although it has been shown that diamond can be synthesized from the gas phase by plasma assisted chemical vapor deposition (PACVD), the resulting films are polycrystalline due to lack of control on the nucleation process, and such thin films of randomly oriented diamond crystals are used mostly as coatings for their thermal, mechanical and chemical properties but are not suitable for electronic device applications. The regenerative homoepitaxy process we have developed for synthesis of single crystal diamond films was derive from the knowledge and capabilities in fusion research in three ways. First, the PACVD reactor was built from knowledge of using microwave to generate plasmas. Second, the experience to synthesis diamond by the PACVD process was gained from work supported by the fusion program in attempt to develop a polycrystalline diamond window for high power microwave tubes. Finally, the

Fig. 1. Calculated (a) Trajectory, and (b) induced vacancies of 3.7 Me V O⁺ in a diamond substrate.
Fig. 2. Normaski phase contrast photograph of homoepitaxy diamond grown on Type IIA natural diamond with [100] orientation.

Fig. 3. Normaski phase contrast photograph of homoepitaxy diamond grown on synthetic diamond with [111] orientation.

inspiration for using the PACVD process to obtain single crystal diamond films came from insight gained in studying material damage associated with the first wall of a fusion reactor.

The process is based on homoepitaxy to avoid random nucleation, on a diamond substrate that has been implanted with high energy oxygen ions to cause localized damage deep inside the substrate to facilitate separation. After separation, the substrate can be restored to its original thickness again by homoepitaxy. Therefore the process is regenerative. It is well known from material damage studies that when energetic ions impinge