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Converting glassy carbon into amorphous diamond

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Diamond owes its unique mechanical, thermal, optical, electrical, chemical, and biocompatible materials properties to its complete sp3-carbon network bonding. Crystallinity is another major controlling factor for materials properties. Although other Group-14 elements silicon and germanium have complementary crystalline and amorphous forms consisting of purely sp3 bonds, purely sp3-bonded tetrahedral amorphous carbon has not yet been obtained. In 2011, Lin et al found that glassy carbon was converted into a new carbon allotrope with a fully sp3-bonded amorphous structure under high pressure of about 45 gpa. However, the transition was reversible upon releasing pressure. In this study, by using a diamond anvil cell coupled with in situ laser heating, we explore a P-T range rarely studied before for the carbon system. Using glassy carbon as a starting material, we synthesize an sp3-bonded tetrahedral amorphous carbon which can be recovered to ambient conditions, i.e. Quenchable amorphous diamond. With the aberration-corrected TEM, some fragmented curved graphene can be observed in the amorphous carbon (Fig. 1a). The EELS of glassy carbon shows a sharp pre-peak at ~285 ev that corresponds to π bonding, as a result of its nearly 100% sp2 bonds. This pre-peak is not present in the EELS of the nanocrystalline diamond due to its purely sp3 bonds. Similarly, the EELS pattern of the recovered carbon sample has no pre-peak, implying its atoms should be fully sp3-bonded like those in crystalline diamond. This amorphous carbon form converted from glassy carbon is fully sp3-bonded, optically transparent, dense, and is named quenchable "amorphous diamond". The structure, bonding, and properties of quenchable amorphous diamond are investigated using XRD, high-resolution transmission electron microscopy, electron energy loss spectroscopy, and ab initio molecular dynamics simulation. Amorphous diamond is optically transparent, dense, and shows ultrahigh incompressibility (bulk modulus) comparable to crystalline diamond.

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