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Transformation of graphite to diamond via a topotactic mechanism

Laurence A.J. Garvie[1,*], Péter Németh[2,3] and Peter R. Buseck[3,4]

[1]Center for Meteorite Studies, Arizona State University, Tempe, Arizona 85287-6004, U.S.A.
[2]Institute of Materials and Environmental Chemistry, Research Center for Natural Sciences, Hungarian Academy of Sciences, H-1025 Budapest, Pusztaszeriút 59-67, Hungary
[3]School of Earth and Space Exploration, Arizona State University, Tempe, Arizona 85287-6004, U.S.A.
[4]Department of Chemistry and Biochemistry, Arizona State University, Tempe, Arizona 85287-1604, U.S.A.

Abstract

Several mechanisms and intermediate steps have been proposed to explain the transformation of graphite to diamond. However, the mechanism continues to be debated, in part because graphite that is incompletely transformed to diamond has not been reported; although such material could be used to better understand the diamond-forming process. Here we report the discovery of nano-sized grains of interstratified graphite and diamond from Gujba, an extraterrestrially shocked meteorite. We use high-resolution transmission electron microscopy (HRTEM) data from these grains to show that diamond formed via a reconstructive, topotactic rather than martensitic mechanism. Electron diffraction and HRTEM images show the following three-dimensional crystallographic relationships between the interstratified graphite and diamond: $(001)_g||(111)_d$, $(100)_g||(2\bar{1}\bar{1})_d$, and $(1\bar{2}0)_g||(0\bar{1}1)_d$. These relationships yield the transition matrix linking the graphite and diamond unit cells, which become coincident for graphite compressed to 7 GPa. The specific product, whether single-crystal or twinned diamond, is dictated by the initial graphite polytype and transformation route. The derivation of a three-dimensional transition matrix is consistent with a topotactic relationship between graphite and the newly formed diamond.

Keywords: Crystal structure, crystal growth, electron microscopy, meteorite