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Transformation of graphite to lonsdaleite and diamond in the Goalpara ureilite directly observed by TEM

Yoshihiro Nakamuta[1,*] and Shoichi Toh[2]

[1]University Museum, Kyushu University, Hakozaki, Fukuoka 812-8581, Japan
[2]HVEM Laboratory, Kyushu University, Motooka, Fukuoka 819-0395, Japan

Abstract

This study reports on the structural relationship between graphite, lonsdaleite, and diamond extracted from the Goalpara ureilite and propose a model for the formation of lonsdaleite and diamond in these stony meteorites. The study is based on data from reflected-light microscopy and laser Raman spectroscopy of a polished thin section (PTS) of the Goalpara ureilite and X-ray powder diffraction (XRPD) analyses of the grains taken out of it. Selected-area electron diffraction (SAED) analyses and high-resolution TEM (HRTEM) observations were carried out in the three unique directions of pristine graphite with two thin slices prepared from a carbon grain directly taken out of a PTS. SAED patterns reveal the relative crystal-axes orientations between graphite (Gr), lonsdaleite (Lo), and diamond (Di) as $(001)_{Gr}//(100)_{Lo}//(111)_{Di}$, $[210]_{Gr}//[001]_{Lo}//[2\bar{1}\,\bar{1}]_{Di}$, and $(1\bar{2}0)_{Gr}//(\bar{1}20)_{Lo}//(0\bar{2}2)_{Di}$. The shapes of diffraction spots in the SAED patterns reveal that the transformation of graphite to lonsdaleite and diamond is initiated by sliding of hexagonal carbon planes of graphite along the [210] of the graphite structure. These results suggest that lonsdaleite and diamond in ureilites formed directly from graphite through boat-type buckling and chair-type puckering of hexagonal carbon planes of graphite, respectively. The results of this study confirm the shock origin of diamond in ureilites.

Keywords: Ureilite, graphite, lonsdaleite, diamond, transformation mechanism, TEM