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Pink color in Type I diamonds: Is deformation twinning the cause?

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Abstract

Plastic deformation of diamond has long been associated with the generation of color, specifically brown and pink. Extensive previous optical and spectroscopic characterization of natural pink Type I (nitrogen containing) diamonds has revealed two clear groupings, with distinct geographical origins. Group 1 pinks, which have low concentrations of nitrogen and are relatively highly aggregated (IaA $\leq$ B), have only been found in the Argyle lamproite pipe (Australia) and Santa Elena alluvial deposits (Venezuela). Group 2 pinks, which have much higher nitrogen concentrations and exhibit low levels of aggregation, have been found in deposits from southern Africa, Canada, and Russia. Pink color is intimately associated with deformation lamellae on the {111} crystal planes, and understanding their formation and structure has been a priority with respect to defining the source of this gemologically valuable color center. In group 2 pinks, these {111} lamellae have been characterized as deformation microtwins by both transmission electron microscopy and X-ray diffraction. Subsequently the {111} lamellae in group 1 pinks have been assumed to also be deformation microtwins. In this paper we report electron backscatter diffraction (EBSD) studies of three brown and six pink naturally deformed diamonds with varying nitrogen concentrations and aggregation states. The results show that there are no deformation microtwins in the group 1 pink or brown diamonds. The study also highlights the usefulness of orientation contrast imaging as a simple and rapid method for determining the presence of microtwins. Our results suggest that the color in the group 1 pink diamonds is not directly related to the presence of deformation twins. However, we propose that twins may have been present but subsequently removed by de-twinning, a process that utilizes the same Shockley partial dislocations involved in the original twinning event. Therefore, it may be the process of twinning (and de-twinning) that creates the defect responsible for pink color, as opposed to the actual structure of microtwins themselves. In addition, a large laboratory data set of pink diamond analyses reveals the occurrence of group 1 pink diamonds in the Namibian marine (secondary) deposits. This would appear to suggest an additional source of group 1 pink diamonds in southern Africa, but the antiquity of these diamonds means that a common source on the former Pangaea supercontinent cannot be ruled out.

Keywords: Shockley partial dislocations, plastic deformation, de-twinning, Argyle, electron back-scatter diffraction (EBSD), nitrogen aggregation