Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SMP44-12 Room:102A Time:May 20 12:15-12:30

Three dimensional visualization of residual pressure around inclusions in sapphire

Hiroyuki Kagi[1]*, Nanako Kamegata[1], Jocelyn Fuetes[1], Naoki Noguchi[1], Ahmadjan Abduriyim[2]

[1]Graduate School of Science, University of Tokyo, [2]Gemological Institute of America

Mantle derived minerals can tell us much information about processes within the deep Earth. It is important to determine the original depth of these mineral samples. Kagi et al. 2009 showed that three-dimensional Raman mapping observations can be used to visualize the distribution of residual pressure around inclusions in diamond, which has provided information about the depth of diamond formation. Corundum is the second hardest mineral after diamond and is expected to also show substantial residual pressure around inclusions.

Samples were collected from New South Wales, Australia as well as Chanaburi, Thailand and are associated with alkali basalts. It is possible to distinguish between corundum crystals formed from various settings, such as metamorphic versus igneous settings, based on trace element analyses. However, distinguishing between crystals of different geographic locality and similar geologic settings is not yet possible using nondestructive methods. Based on current geochemical observations, there are two models for the formation of igneous corundum crystals. Guo et al. 1996 proposed that these crystals formed in the middle crust by a hybrid reaction between carbonatite melt and silicic magma. Alternatively, Sutherland et al. 1998 suggested that they may form directly from volatile-rich felsic melts generated at lower crustal conditions. By using 3D mapping techniques, it may be possible to evaluate the P-T history of the host rock as well as differentiate between gems from different localities.

The fluorescence spectrum of corundum has two peaks associated with the excitation of Cr^{3+} impurities in its structure, R1 and R2. Because the R2 line is insensitive to differential stress, the residual pressure can be calculated based on the peak shift of the R2 line using a pressure calibration curve.

The samples were excited using 514.5 nm emission of Ar-ion laser with a diameter of 2 micron. Measurements were taken every 5 to 10 micrometers around albite, zircon, and rutile inclusions using a point-by-point mapping illumination system. The R2 and R1 lines of the fluorescence spectra were fitted by Lorentzian functions after subtraction of background. In order to account for peak oscillations caused by changes in room temperature, real-time calibration of the fluorescence spectra energy axes were performed by neon emission lines as discussed in Odake et al. 2008.

Over 25 two- and three-dimensional maps of various inclusions have been created so far. The maximum residual pressure for each map ranges from 0.1 GPa to 0.51 GPa. In many of these samples, stress distribution can be explained by differences in elastic constants between the host and inclusion. For example, our results show one slice of a 3D map around a zircon inclusion. In this case, the c-axis of the corundum and the c-axis of the zircon are nearly parallel. With decreasing temperature and pressure, the c-axis is expected to have higher residual pressure due to differences in linear thermal expansion coefficients and bulk moduli between the host and inclusion. It is clear that the c- axis has the highest residual pressure, as expected. Another notable observation is that the maximum residual pressure surrounding zircons correlates with length of the crystal along the c-axis. Two distinct trends between residual pressure and length are observed. This may be due to many factors including the relative orientation of the host and inclusion or the presence of cracks surrounding the inclusion. It could also be due to the different geographic localities. However, more measurements need to be taken to confirm.

Previous methods to determine original depth, such as those used by Barron 2005 and Izraeli et al. 1999, which assume isotropic elastic properties in inclusion and diamond, cannot be used in these corundum-inclusion pairs. Our results show that relative orientation of corundum and inclusions must be accounted for in future calculations of P-T history.

Keywords: residual pressure, fluorescence spectra, ruby, sapphire, inclusions