Saturday, 3:45 pm, Randle Ballroom A/B

Characterization of Nanofeatures in Gem Materials

George R. Rossman (grr@gps.caltech.edu)
California Institute of Technology, Pasadena

The inclusions in gem minerals that are commonly observed with an optical microscope occur at a scale of a micrometer or larger. In addition to these inclusions, there are also a multitude of inclusions and features that are larger than the individual atoms that cause color in common gems, but are so small that they cannot be clearly resolved with optical methods. These features can be nearly 1,000 times smaller than features seen with optical microscopes, and are measured in nanometers. Such features can cause iridescence, opalescence, asterism, and turbidity in gem materials. High-resolution scanning electron microscopy allows us to image features on the nano-scale. When images are combined with chemical analysis and electron diffraction patterns, a whole world of previously inaccessible mineralogy becomes available for investigation.

Opals are a classic example of a gem that contains nano-scale features that are the origin of color. A microscopic journey into opals will demonstrate the spectacular differences that occur when the nanofeatures (silica spheres) are arranged either in ordered or disordered patterns. Iridescence in garnets, feldspars, and several ornamental stones is also due to sub-micrometer-sized features. Star phenomena in stones occur because of oriented inclusions. Both the bodycolor and asterism in rose quartz arise from inclusions of an aluminoborosilicate phase related to dumortierite that are a few hundred nanometers in width. Stars, and particularly turbidity, in sapphire and ruby have been long attributed to myriad minute rutile inclusions. Rarely have these inclusions been identified by direct analysis. High-resolution imaging of the submicroscopic inclusions often fails to find rutile, but instead finds an aluminum oxide phase with a stoichiometry that is consistent with diaspore.

An additional observation frequently made during high-resolution imaging is that the surface quality of stones varies widely. Sub-micrometer-scale surface features from the polishing process are often observed at high magnification and illustrate that there is a wide range of variation in the quality of surface finish.