Hope Diamond's phosphorescence key to fingerprinting

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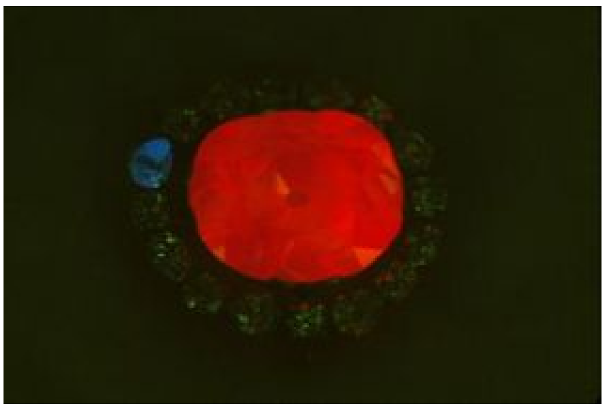

The Hope Diamond phosphoresces a fiery red color when exposed to ultraviolet light. Credit: John Nels Hatelberg

Shine a white light on the Hope Diamond and it will dazzle you with the brilliance of an amazing blue diamond. Shine an ultraviolet light on the Hope Diamond and the gem will glow red-orange for about five minutes. This phosphorescent property of blue diamonds can distinguish synthetic and altered diamonds from the real thing, and it may also provide a way to fingerprint individual blue diamonds for identification purposes, according to a team of researchers from the Naval Research Laboratory, the Smithsonian Institution and Penn State.

Other colors of diamonds do not phosphoresce, but fluoresce, emitting visible light only as long as they are stimulated with ultraviolet radiation.

Blue diamonds that phosphoresce emit light even after the ultraviolet lamp is turned off. Unlike the Hope, however, most blue diamonds produce a bluish light rather than reddish light.

The red phosphorescence is rare enough that researchers thought that those blue diamonds that did glow red must have come from the parent of the Hope – an original 112-carat blue diamond mined in India in the mid-1600s. That diamond was cut down to 67 carats to become the French Blue owned by French kings and, after being lost during the French Revolution, appeared 20 years later in 1812 as the 45-carat stone known today as the Hope Diamond.

The research, reported in the current issue of *Geology*, confirms that all blue diamonds have a red phosphorescent component and that, through spectroscopic analysis, each blue diamond can be individually identified.

"The Hope Diamond is the most popular museum object in the world," says Peter J. Heaney, professor of geosciences at Penn State. "Even so, the Smithsonian considers the specimens in the museum objects of scientific value. They have an enormous number of gemstones in their collection and they encourage scientific research to figure out how the stones formed, and what gives them their special properties."

As popular as the Hope Diamond is, it is always on display at the Smithsonian. Heaney and the other researchers worked on the gems in the morning and after the museum closed.

"If you want to study the Hope diamond using spectroscopy, you need to bring the machine to the Hope diamond," says Heaney. "You cannot bring the Hope to the machine."

The researchers, who included Heaney; first author Sally Eaton-Magana, Gemological Institute of America, formerly of the Naval Research

Laboratory; Jaime Freitas, Paul Klein and James E. Butler, NRL; Roy Walters, Ocean Optics, Inc.; and Jeffery E. Post, curator of gems and minerals, Smithsonian Institution, used a portable spectrometer manufactured by Ocean Optics that could be set up at the museum. They tested a variety of blue stones known to be natural including the Hope Diamond, the Blue Heart – the second largest blue diamond known, the Portuguese Diamond – another large stone, and 64 other blue diamonds, many of which came from the Aurora Butterfly – a collection of 240 stones temporarily on display at the museum.

Of these, only five did not phosphoresce. Those five turned out to be a different type of diamond than the blue Hope and the other 62 diamonds tested.

Spectroscopic analysis is a noninvasive process that shines light on an object and then measures the wavelength of the light emitted by the object. The researchers used two different wavelengths of ultraviolet light – short and long. Exposed to short ultraviolet, the researchers saw bands at 500 nanometers, corresponding to blue-green and 660 nanometers, corresponding to red. Under short ultraviolet, only the red wavelength occurred.

"Even though many blue diamonds appear pink or bluish when exposed to ultraviolet light, we found that all blue diamonds do have red phosphorescence," says Heaney. "Unlike the Hope Diamond, some blue diamonds' red light is overpowered by the blue green."

Impurities in the carbon that makes up a diamond create the color. For blue diamonds, boron impurities make the diamond blue in natural light. For yellow diamonds, nitrogen in the diamond creates the yellow hue. The spectrometer captures the properties of the impurities. Natural blue diamonds have high levels of boron and low levels of nitrogen impurities, and the interaction of these two elements probably causes the red phosphorescence.

When the researchers compared the peak intensities of the 500 and 660 nanometer bands against half the time it took for 660-nanometer light to dissipate, they realized that each diamond had an individual signature. They used the 660 band because the 500 band always disappears faster than the 660. That simple mathematical ratio produces a unique value for every natural blue diamond.

The researchers then tested three artificial diamonds – artificially created diamonds doped with boron. According to Heaney, companies can manufacture synthetic blue diamonds or heat treat other diamonds to create blue ones that are difficult to discern as artificial or altered with the naked eye, but using spectroscopy, these blue diamonds are not the same as the natural ones. All three of the synthetic diamonds lacked a peak at 660 nanometers.

The researchers from the Naval Research Laboratory have a long interest in diamonds because while white diamonds are insulators, colored diamonds, which have minute quantities of elements other than carbon, are semiconductors similar to the silicon currently used in most of today's electronics.

"Diamond's properties are superior to silicon because diamonds are one of the best conductors of heat, and smaller electronics need large capacities to dissipate heat," says Heaney.

The Penn State scientist is interested in methods to non-invasively fingerprint diamonds because of the problems with conflict diamonds – diamonds sold to support military action against legitimate governments – that have been a focus of Heaney's work for some time. Understanding the phosphorescence of blue diamonds may make it possible to physically identify individual blue diamonds to add to the current

Kimberly Protocols, a paper trail method that ensures diamonds come from legitimate sources.

Source: Penn State