June 24, 2009

CVD-Grown Pink Diamonds

Wuyi Wang
GIA Laboratory, New York

Natural pink diamonds are very rare. As a result, several treatments have been developed to introduce pink color into both natural and HPHT synthetic diamonds. One technique that is widely used to produce pink color involves the conversion of trace amounts of isolated nitrogen into N-V centers (nitrogen-vacancy pairs) through a combination of irradiation and annealing processes. N-V centers strongly absorb yellow and orange light, thus creating a pink to red color. The trace amounts of isolated nitrogen needed for the treatment to work properly can occur naturally in the starting materials, be incorporated during synthetic growth (Shigley et al., 2004), or be generated by disaggregation of other nitrogen-bearing defects in natural diamonds during high-pressure and high-temperature (HPHT) treatment (Wang et al., 2005). According to Apollo Diamond Inc. in Boston, CVD-grown diamond is unique in that N-V centers, and subsequent pink color, can be created during the synthesis process.

Seven intensely colored CVD synthetic diamonds (graded as Fancy Intense to Fancy Vivid pink or purplish pink; figure 1) were supplied by Apollo Diamond Inc. for this study. The colors were similar to the well-known natural pink diamonds from the Argyle mine in Australia. The faceted CVD synthetic diamonds ranged in size from 0.28 to 0.67 ct, with well-cut proportions. Color distribution was even in all of the samples. In general, the samples were clean, containing only a few pinpoint inclusions. When exposed to both long- and short-wave UV radiation, the synthetic diamonds displayed strong orange to red fluorescence. Infrared spectroscopy revealed very weak absorption peaks at 1344 cm^{-1} caused by the presence of isolated nitrogen impurities. In addition, weak and sharp peaks from local vibrations at 1341, 1355, 1358, 1363, 1375, 1379, 1405 (hydrogen), and 1450 cm^{-1} (H1a) were also consistently detected. An interesting feature observed in the mid-infrared spectra was the coexistence of sharp absorptions at 3107 and 3123 cm^{-1}. Both features are hydrogen-related, but the absorption at 3123 cm^{-1} is specific to CVD synthetic diamonds, whereas the 3107 cm^{-1} peak is very common in natural type Ia diamonds. In all of the tested samples, the intensity of the 3107 cm^{-1} absorption was stronger than that of the 3123 cm^{-1} peak. These infrared absorption features are very different from those previously reported in white, brown, and pink CVD diamonds (Martineau et al., 2004; Wang et al., 2007).

UV-Visible-NIR absorption spectra (figure 2) also showed interesting features, including strong absorptions from GR1 with zero phonon line (ZPL) at 741.1 nm, $[N\text{-}V]^-$ with ZPL at 637.0 nm, $[N\text{-}V]^0$ with ZPL at 574.9 nm, the 595 center at 594.2 nm, and ND1 with ZPL at 393.5 nm, as well as the sidebands of these vibronic centers. In addition to a weak absorption from the H3 defect at 503.1 nm, many other weak peaks of unknown origin in the 400–530 nm region were observed in these samples. Defects of GR1, the 595 center, and ND1 are known to be irradiation-related. The defect combinations created two transmission “windows,” one in the blue region (410–450 nm) and the other in the red region above 637 nm, resulting in an intense purplish pink body color. A remarkable feature observed from UV-Visible-NIR absorption spectroscopy was the consistent occurrence of an absorption doublet at 736.6 and 736.9 nm caused by a Si-related defect. Typically the Si defects, as well as some other well-known CVD-specific emission lines, are more easily observable in photoluminescence spectra; due to the extremely strong fluorescence from N-V centers, that was not the case with these CVD diamonds.

Many gemological and spectroscopic properties of these CVD diamonds were similar to treated natural and synthetic HPHT diamonds with respect to color and spectroscopy. Obviously, these pink CVD-grown diamonds are very impressive gemstones. During gem testing, identifying CVD synthetic diamonds is a challenge. Intense color and strong fluorescence produced by the N-V centers often hides many features that are commonly used to identify CVD diamonds. Despite this difficulty, these CVD-created diamonds can be reliably identified using a series of gemological and spectroscopic features, including growth patterns observed from DiamondView fluorescence images and the occurrence of a 3123 cm^{-1} infrared absorption feature and the Si-related doublet through absorption/photoluminescence spectroscopy.

Figure 1. These 0.28–0.67 ct CVD-grown diamonds displayed intense pink colorations, and were color-graded as Fancy Intense to Fancy Vivid pink or purplish pink. The samples were produced using “standard production techniques” at Apollo for this type of stone.

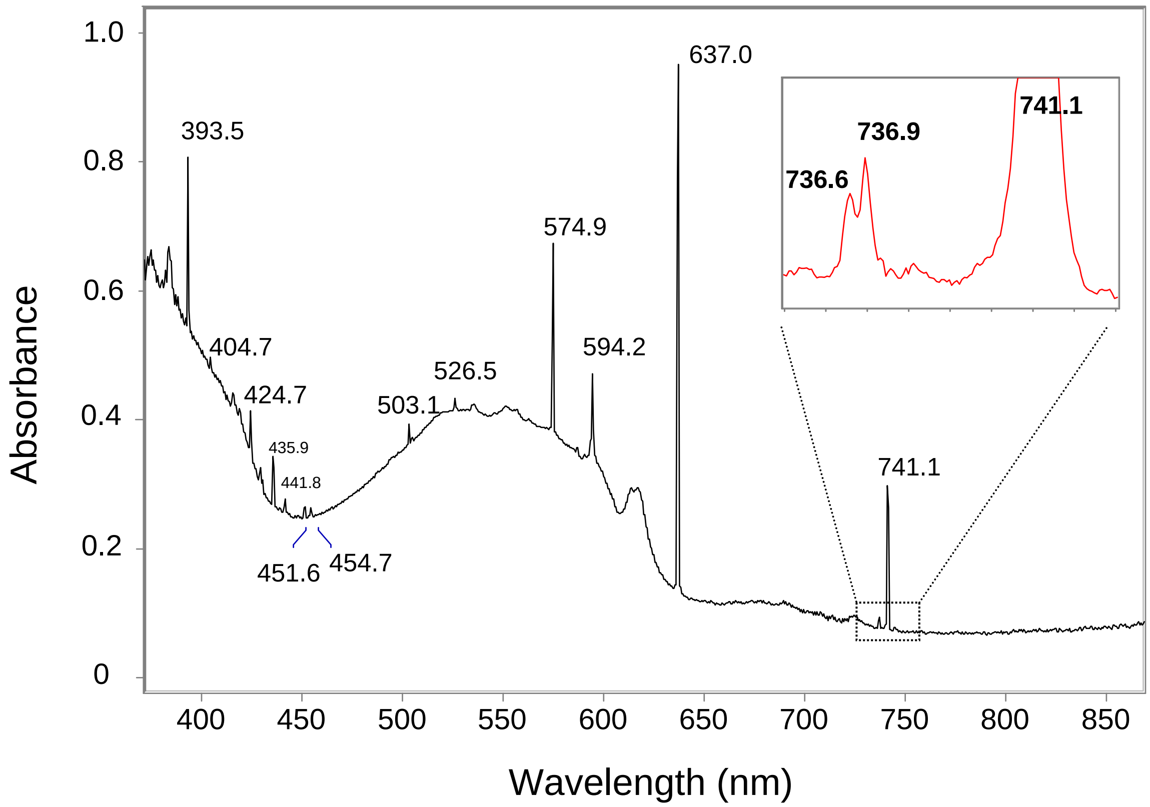

Figure 2. Spectral features observed from UV-Visible-NIR absorption spectroscopy strongly indicated that the pink CVD diamonds were colored mainly by the N-V centers with ZPL at 637.0 and 574.9 nm and their sidebands at the higher-energy side. GR1 (ZPL at 741.1 nm), the 595 center (594.2 nm), and ND1 (ZPL at 393.5 nm), all well-known irradiation-induced defects. The occurrence of Si-related absorptions (736.6/736.9 nm doublet) is a reliable identification feature in CVD synthetic diamonds.

References

Martineau P.M., Lawson S.C., Taylor A.J., Quinn S.J., Evans D.J.F., Crowder M.J. (2004) Identification of synthetic diamond grown using chemical vapor deposition (CVD). *Gems & Gemology*, Vol. 40, No. 1, pp. 2–25.

Shigley J.E., McClure S.F., Breeding C.M., Shen A.H., Muhlmeister S.M. (2004) Lab-grown colored diamonds from Chatham Created Gems. *Gems & Gemology*, Vol. 40, No. 2, pp. 128–145.

Wang W., Smith C.P., Hall M.S., Breeding C.M., Moses T.M. (2005) Treated-color pink-to-red diamonds from Lucent Diamonds Inc. *Gems & Gemology*, Vol. 41, No. 1, pp. 6–19.

Wang W., Hall M.S., Moe K.S., Tower J., Moses T.M. (2007) Latest-generation CVD-grown synthetic diamonds from Apollo Diamond Inc. *Gems & Gemology*, Vol. 43, No. 4, pp. 294–312.