Shining light on “480 nm band” diamonds: Gemmological characteristics of an unusual group of diamonds with yellow and red luminescence

Marleen Bouman and Jelena Zarupski
HRD Antwerp-Research, Antwerp, Belgium
marleen.bouman@hrdantwerp.com

Fancy colour diamonds that derive their colour from nitrogen-related defects (such as N3/N2 centers or C-centers) are relatively common and well-studied. An underexplored group derives its colour from a broad absorption band centered around 480 nm, which is hypothesized to be related to oxygen impurities (Hainschwang *et al*. 2008). These diamonds are referred to as “480 nm band diamonds” and their properties have been described in a number of studies (e.g. Breeding *et al*. 2020, Lai *et al*. 2024). A rare subgroup of “480 nm band” diamonds are “chameleon diamonds”, which temporarily change colour upon heating or prolonged storage in the dark. Common features of these diamonds are (De Weerdt & Van Royen, 2001, Fritsch & Delaunay, 2018):

1) A band at 426 nm in UV-Vis-NIR absorption spectroscopy, related to the 480 nm absorption band.
2) A peak at 1241 cm^{-1} in FTIR, which is thought to be linked to the 480 nm band.
3) Yellowish-green fluorescence in DiamondView, often accompanied by irregular zones of blue and bright green fluorescence.
4) Nickel-related defects in Photoluminescence Laser spectroscopy (PL), such as the 883/885 nm doublet, S2 and S3 centers.
5) Hexagonal or rounded plate-like inclusions, identified as graphite platelets by Shiryaev *et al*. (2023)
6) Hydrogen-related absorptions in FTIR spectroscopy.

An often-overlooked feature of “480 nm band” diamonds, however, is their luminescence reaction. When illuminated with long-wave ultraviolet (LWUV) light (365 nm) these diamonds typically show a yellow luminescence, whereas under blue light (450 nm) they display red luminescence (Collins & Mohammed, 1982). The red luminescence is produced by the 480 nm absorption band (2.6 eV), while yellow luminescence is linked to a vibronic system with a zero-phonon line (ZPL) at 456 nm (2.721 eV).

The aim of this study is to provide a detailed gemmological characterization of the relatively unknown “480 nm band” diamonds. Diamonds were screened with a custom-made luminescence tester, containing a LWUV and blue light source (Figure 1). In this way, we could quickly identify whether diamonds have yellow and red luminescence, which implicates that they contain the “480 nm band”.

More than 50 diamonds were selected for detailed spectroscopic and gemmological analysis. All diamonds show yellow and red luminescence under the luminescence tester. The diamonds were studied by FTIR and UV-Vis-NIR spectroscopy, DiamondView imaging, microscopy, long-wave and short-wave UV excitation, and some of them by other techniques such as PL and ED-XRF spectroscopy. Special attention was paid to the presence of Y centers and CO_2 content in FTIR, since a genetic relation with “480 nm band” diamonds has been suggested before (Kupriyanov *et al*., 2020, Hainschwang *et al*. 2008).

Figure 1: Two"480 nm band" diamond under normal light (left), LWUV light (middle) and blue light (right). Both display yellow and red luminescence under LWUV and blue light, respectively.

For the selected diamonds, brown is the dominant colour grade (usually 'reddish brown'), followed by yellow, orange and rarely olive and pink. Weights are in the range of 0.14 ct to 2.27 ct. FTIR results show that two diamonds contain distinct CO_2 bands around 655 and 2370 cm^{-1}, known as the υ2 and υ3 bands (Schrauder & Navon, 1993). The main Y center band at 1145-1150 cm^{-1} is found in 7 diamonds. This is lower than expected, as Kupriyanov *et al*. (2020) concluded that the typical "480 nm" red luminescence is genetically related to Y centers. Therefore, we would expect to find Y centers in all studied diamonds. It is, however, possible that the Y centers are overshadowed by other defects (A, B, C centers), and further analysis using spectral deconvolution is necessary.

Although the "480 nm band" is responsible for red luminescence, only 15 diamonds show a distinguishable 480 nm band in their UV-Vis spectrum (Figure 2, red spectrum). Most of the studied diamonds owe their colour to a broad absorption continuum (Figure 2, black spectrum). For these stones, other properties such as inclusions, DiamondView and PL spectroscopy correspond to those of typical "480 nm band" diamonds. We can conclude that red luminescence is a more sensitive indicator than UV-Vis spectroscopy for the presence of the "480 nm band" defect.

In conclusion, our study shows that screening for luminescence reaction is a useful gemmological tool to quickly identify diamonds with "480 nm band" properties, since the combination of yellow and red luminescence is unique to these diamonds. We identified "480 nm band" diamonds over a range of colours, extending beyond the yellow and orange diamonds that have been typically studied. This allows us to investigate possible genetic links between the "480 nm band", CO_2 diamonds and Y centers.

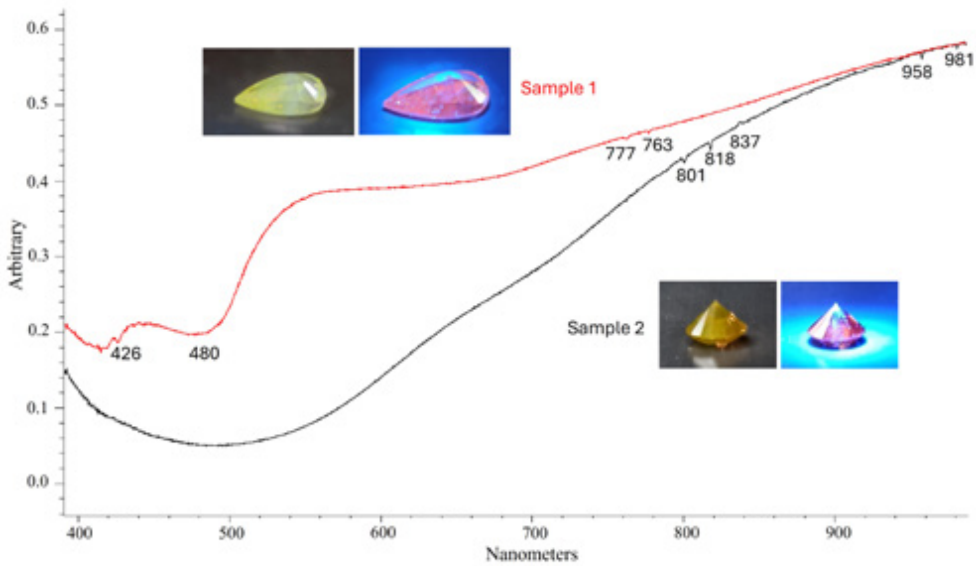

Figure 2: UV-Vis-NIR transmission spectra of two "480 nm band" diamonds. Red spectrum: Diamond with a typical 480 nm absorption band (Sample 1). Black spectrum: Diamond with yellow and red luminescence but no 480 nm band in UV-Vis-NIR (Sample 2). The samples are the same as those shown in Figure 1.

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