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Rare natural colored diamonds: diamonds colored by the 480 nm absorption band

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Introduction

Diamond owes its color to lattice defects related to vacancies or impurities, in a variety of different configurations. Although the color origins of most diamonds have been well documented, a group of diamonds colored by a broad absorption band centered at 480 nm in the visible spectrum is comparatively less constrained, as the structure of the corresponding defect is hitherto unknown. These diamonds are referred to as "480 nm band diamonds" in the gem trade. The 480 nm absorption band most commonly produces yellow body color in diamond. It is also responsible for the rich color of some highly-valued orange diamonds, and is among the color centers in the even rarer suite of "chameleon" diamonds – diamonds that change colors temporarily, typically from green to yellow, when exposed to heat or left in the dark for a period of time (Fig. 1). Diamonds with the 480 nm absorption band only comprise ~5% of natural yellow and orange diamonds submitted to the GIA laboratory for grading, and are not commonly reported from any known diamond localities (Breeding et al., 2020). To date, 480 nm band diamonds have only been reported from the Siberian platform in Russia and the Chidliak kimberlite field in Canada (Titkov et al., 2014; Lai et al., 2020). Currently, the global abundance of these diamonds is unknown, partially due to the unfamiliarity of their physical properties, and thus these diamonds are not readily identified in the mining industry. In this study, we report the gemological properties of these rare diamonds to facilitate their identification. In addition, characteristic surface fluorescence patterns along with FTIR and PL spectra of a set of 100 faceted 480 nm band diamonds are reported, as well as their mineral inclusions identified using Raman spectroscopy.

Results and discussion

Investigating diamond fluorescence during the process of diamond recovery is a quick screening method to identify diamonds colored by the 480 nm absorption band. Generally, 480 nm band diamonds have medium to strong yellow or orange fluorescence when exposed to long-wave UV (365 nm) (Collins and Mohammed, 1982). While this characteristic may not be unique to 480 nm band diamonds, it is strongly associated with this type of diamond and thus many can be rapidly identified by exposure to long-wave UV alone (Fig. 2). Some 480 nm band diamonds (especially chameleon diamonds) also exhibit phosphorescence in response to short-wave UV (254 nm).

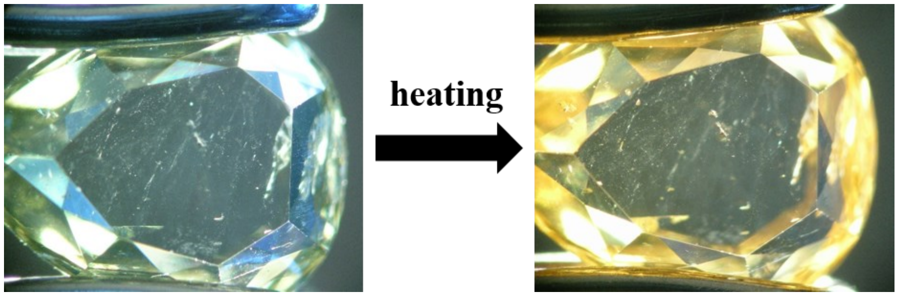

Figure 1: A chameleon diamond changes color from green to yellow upon heating to > 170 °C.

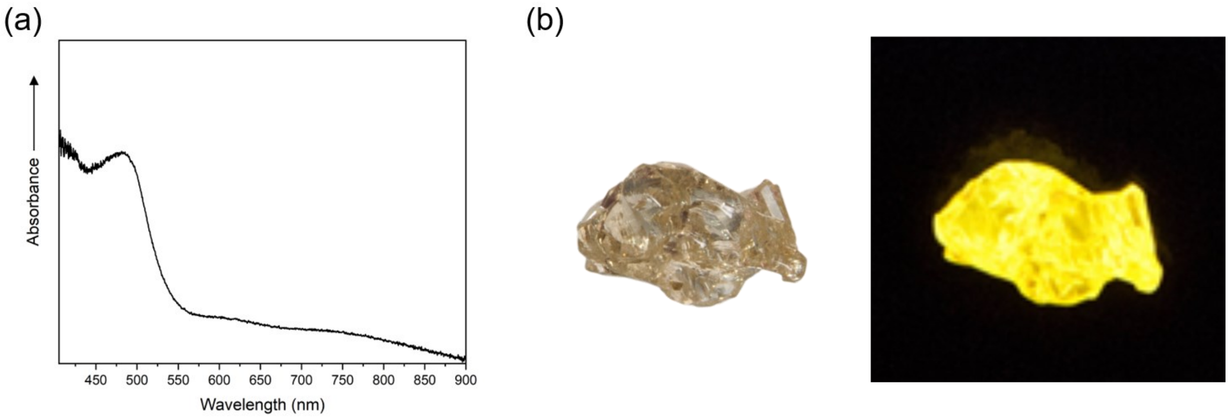

Figure 2: (a) Yellow or orange diamonds caused by a broad absorption band centered at ~480 nm. (b) When exposed to long-wave UV, 480 nm band diamonds show strong yellow or orange fluorescence.

On the microscopic scale, 480 nm band diamonds usually have irregular surface fluorescence patterns excited by deep UV (< 230 nm), due to the highly heterogeneous distribution of lattice defects corresponding to distinct growth zones. Common surface fluorescence colors observed in 480 nm band diamonds include yellow or greenish yellow (caused by defects associated with the 480 nm absorption band), blue (N3 defects) and bright green (H3 defects). Some regions in 480 nm band diamonds are inert to UV excitation and appear black (Fig. 3). Multiple clusters of reflective disks with size < 10 µm are frequently observed in 480 nm band diamonds, which are often oriented in three different directions (Fig. 4). This type of inclusion is unique to 480 nm band diamonds and it is also a key feature for identification.

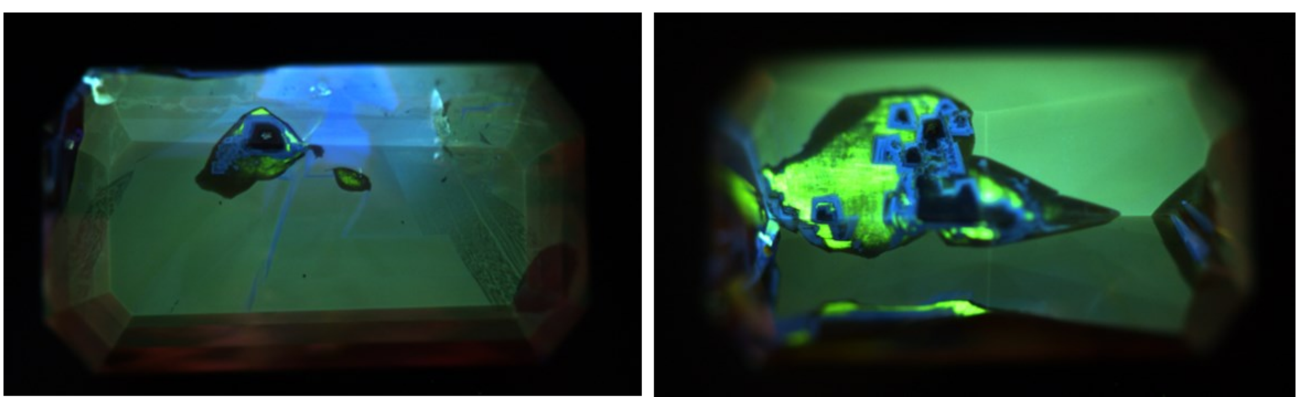

Figure 3: Surface fluorescence images of 480 nm band diamonds collected with DiamondView (excitation wavelength < 230 nm) showing distinct growth zones associated with different lattice defects.

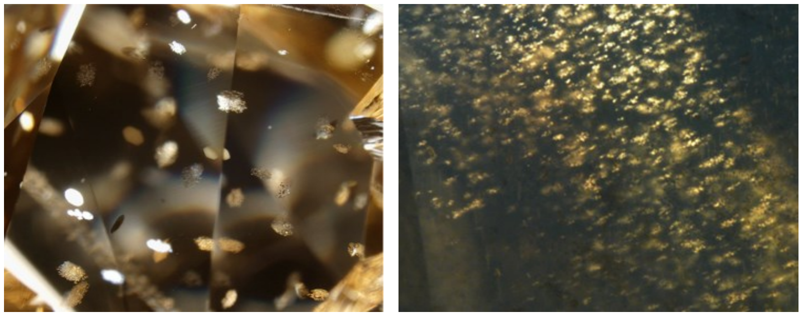

Figure 4: Clusters of micron-sized reflective disk-like inclusions oriented in three different directions in 480 nm band diamonds.

The majority of 480 nm band diamonds have low but detectable nitrogen concentrations using FTIR spectroscopy. The one-phonon infrared region (1332–400 cm^{-1}) of 480 nm band diamonds commonly shows an absorption band in addition to the well-defined C-, A- or B-centers (Fig. 5a). Photoluminescence (PL) spectra of 480 nm band diamonds excited by a blue or green laser (e.g., laser wavelengths of 457, 514 and 532 nm) show a characteristic broad emission band centered at 630–700 nm (Fig. 5b), which is the vibronic emission associated with the 480 nm broad absorption band (Collins and Mohammed, 1982).

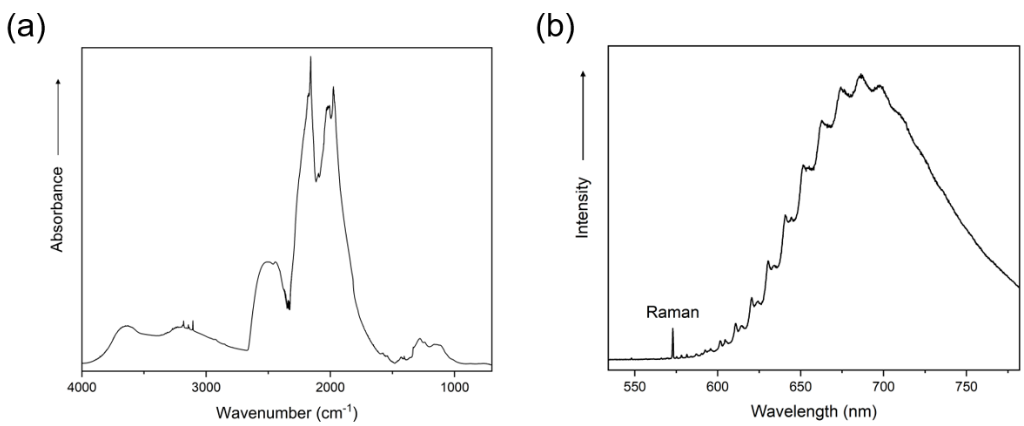

Figure 5: Characteristic FTIR (a) and PL spectra (b) of 480 nm band diamonds.

Mineral inclusions were observed in a subset of 15 diamonds in our study. Raman spectroscopy identified these inclusions as omphacite, rutile, and pyrope-almandine-grossular garnet, which are all associated with eclogitic host rocks. This suggests that these 480 nm band diamonds formed in the lithospheric mantle, and may occur more commonly in diamond mines that produce predominantly eclogitic diamonds.

References

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