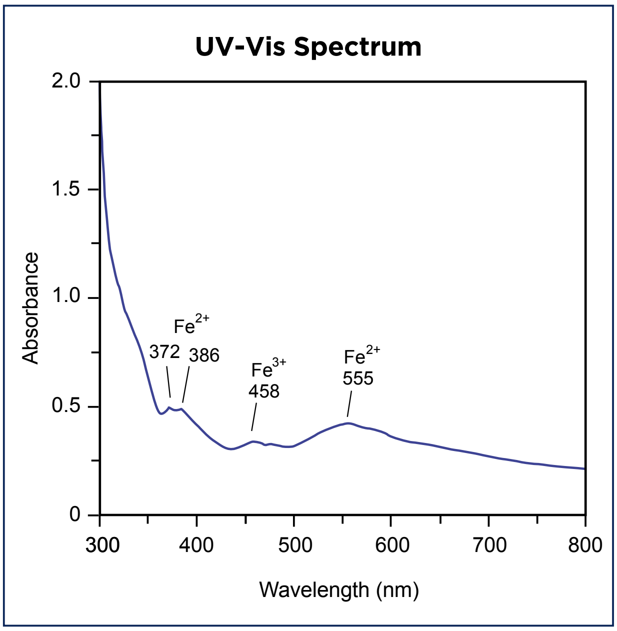

Figure 16: This representative UV-Vis spectrum of a purple spinel from Afghanistan (about 3.0 mm path length) shows absorption peaks related to Fe^{2+} and Fe^{3+}.

Table I: Trace-element concentrations in violet-to-purple spinels from Afghanistan, as determined by LA-ICP-MS.

Element	Average (ppm)	Range (ppm)
Li	23.3	8.60–39.7
Be	26.2	12.7–53.0
Ti	83.5	69.4–99.9
V	28.0	17.3–39.5
Cr	1.04	<0.36–3.60
Mn	243	196–287
Fe	10170	8720–12210
Co	8.91	5.49–15.2
Ni	39.7	18.9–59.3
Cu	0.23	<0.03–4.37
Zn	1160	420–2510
Ga	329	185–526

purplish pink spinel. Both colour varieties are said to originate from mines in the Kuran wa Munjan District. The carrot-shaped crystal form of the rutile inclusions documented here is not commonly encountered in spinels from other deposits and may provide a good indicator for Badakhshan material.

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References

Boehm, E.W. 2017. Gem Notes: Purple spinel from Badakhshan, Afghanistan. *Journal of Gemmology*, **35**(8), 694–697.

D'Ippolito, V., Andreozzi, G.B., Hålenius, U., Skogby, H., Hametner, K. & Günther, D. 2015. Color mechanisms in spinel: Cobalt and iron interplay for the blue color. *Physics and Chemistry of Minerals*, **42**(6), 431–439, https://doi.org/10.1007/s00269-015-0734-0.

Hughes, R.W. 1994. The rubies and spinels of Afghanistan — A brief history. *Journal of Gemmology*, **24**(4), 256–267, https://doi.org/10.15506/JoG.1994.24.4.256.

Peretti, A., Kanpraphai-Peretti, A. & Günther, D. 2015. World of magnificent spinel: Provenance and identification. *Contributions to Gemology*, No. 11, 285–292.

DIAMONDS

Treated Greenish Yellow Diamond with Brown Radiation Stains

The Swiss Gemmological Institute SSEF recently analysed a treated greenish yellow diamond showing evidence of artificial irradiation and annealing (Figure 17). This 1.07 ct cushion-shaped stone exhibited very strong greenish yellow fluorescence under long-wave UV radiation (with slightly less intensity under short-wave UV). The greenish yellow fluorescence was visible even in normal daylight.

Infrared spectroscopy (Figure 18) revealed that it was type IaAB, and contained approximately 64 ppm nitrogen as A centres and 135 ppm nitrogen as B centres (based on absorption coefficients given in Boyd *et al.* 1994, 1995), as well as platelets and hydrogen-related defects. In addition, two clear absorption lines at 5163 and 4934 cm^{-1} indicated the presence of H1c and H1b centres, respectively (Figure 18, inset).

Figure 17: The 1.07 ct greenish yellow diamond described here was identified as having been artificially irradiated and annealed. Photo by Luc Phan, © SSEF.

Low-temperature (–120°C) UV-Vis absorption spectroscopy indicated the presence of N7, N6, N4, N3, H4 and H3 centres (Figure 19). The H3 centre, causing an absorption line at 503.2 nm, also emits light at the same wavelength when excited by UV radiation, which explains the strong greenish yellow fluorescence. According to Collins (2003), when both the H3 and H4 optical centres are dominant in a diamond, they suggest that the stone was artificially irradiated and annealed. In irradiated and annealed type Ia diamonds, the ratio of H3 to H4 is proportional to the ratio of A to B aggregates as observed in the infrared region. However, traces of the H4 defect can occasionally be detected in untreated stones. In that case, the H4 is always much weaker than the H3 centre, even if most of the nitrogen is found in B centres (Collins 2003). Figure 19 shows that the strength of the H4 line in the greenish yellow stone described here is of the same order of magnitude as the H3 line, providing further evidence that the stone was subjected to artificial treatment. This is confirmed by the observation of H1c and H1b features in the infrared spectrum.

A series of naturals along the faceted girdle of the stone could be seen with the gemmological microscope. Interestingly, two brown stains were also visible (Figure 20). The larger of the two stains coincided with a small natural, perhaps resembling in shape the remnants of a stained etch channel after polishing (cf. Moses & Reinitz 1991).

Brown and green radiation stains on natural diamonds have been described by many authors (e.g. Nasdala *et al*. 2013; Eaton-Magaña & Moe 2016) and are often regarded as indicating that the colour of a diamond is of natural origin. Fake green stains introduced deliberately

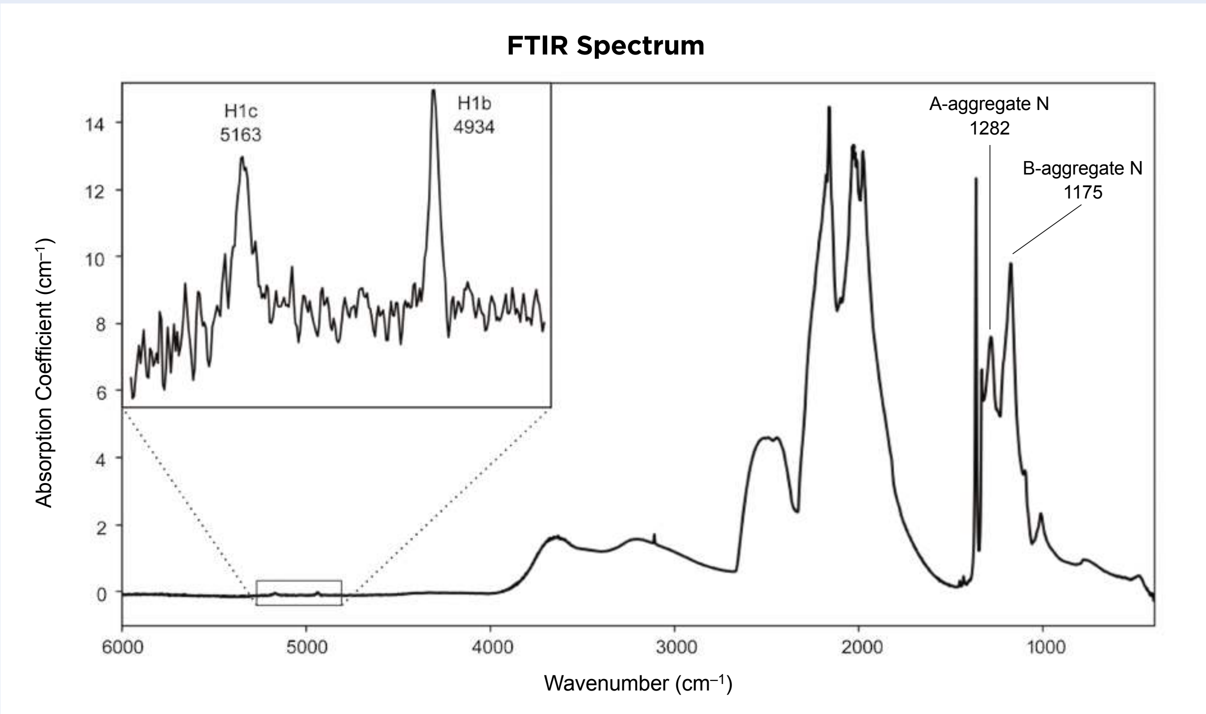

Figure 18: The infrared spectrum of the diamond indicates that it is type IaAB, containing nitrogen in the form of A aggregates (approximately 64 ppm) and B aggregates (about 135 ppm). The inset of the area between 5300 and 4800 cm^{-1} shows that H1b and H1c lines are clearly visible, pointing towards treatment.

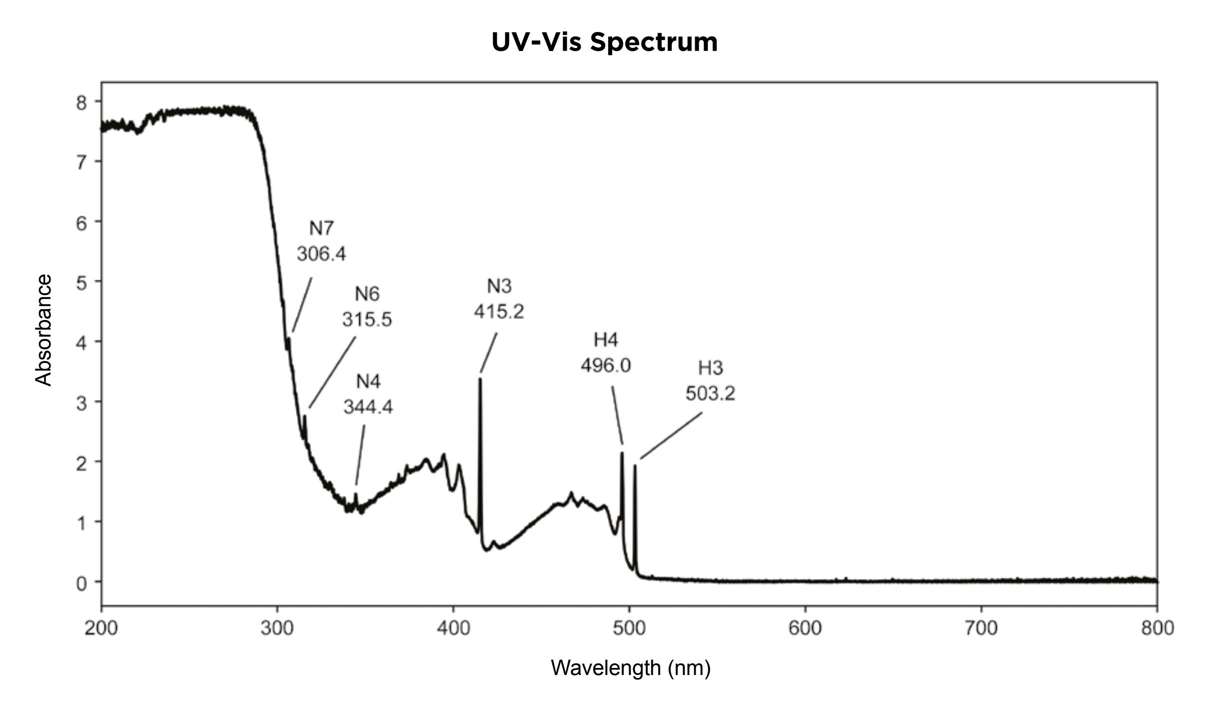

Figure 19: The UV-Vis spectrum of the treated greenish yellow diamond exhibits a large N3 feature, as well as related N4, N6 and N7 lines. The H3 centre in conjunction with a strong H4 line provides strong evidence of treatment.

to mimic natural radiation stains have also been reported (Schwartz & Breeding 2019). The stains seen in Figure 20, however, cannot be confused with fake stains (e.g. such as those consisting of platy green Cr-oxide crystals adhering to the surface that can easily be removed).

The absence of GR1 and 594 nm spectral features and the presence of the H4 centre in the greenish yellow diamond described here imply that is was annealed at a temperature greater than 800°C (Collins 2003). In addition, when subjected to heat treatment, irradiation stains in diamond first change from green to brown, and then become fainter and eventually disappear at temperatures greater than 1400°C (Nasdala *et al*. 2013; Eaton-Magaña & Moe 2016). Thus, the conditions of heating to which this diamond apparently was subjected are consistent with the faint brown stains we observed.

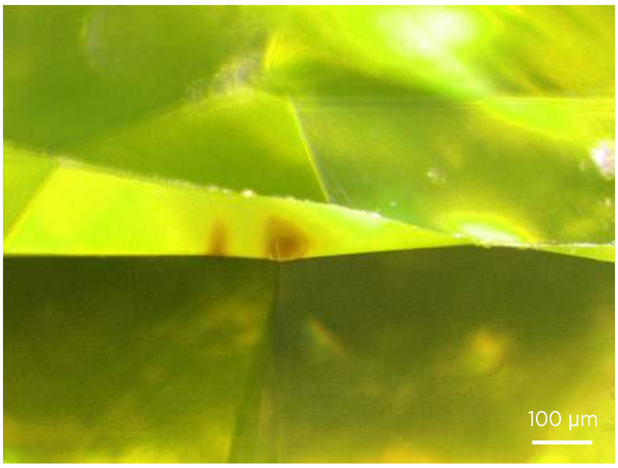

Figure 20: Two brown radiation stains can be seen on the girdle of the treated greenish yellow diamond in Figure 17. The stain to the right coincides with a natural. Photomicrograph by L. Speich, © SSEF.

Determining the colour authenticity of greenish yellow diamonds is challenging since they can be of natural colour (e.g. Chalain *et al*. 2004), HPHT treated (e.g. Collins *et al*. 2000), or irradiated and annealed like the stone described here. Radiation stains are often regarded as a strong indicator of natural colour and, to the best of our knowledge, brown stains occurring on the surface of a treated diamond have not been reported previously. However, our findings show that the presence of brown radiation stains does not preclude artificial modification of a diamond's colour, so further examination by spectroscopy is needed.

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References

Boyd, S.R., Kiflawi, I. & Woods, G.S. 1994. The relationship between infrared absorption and the A defect concentration in diamond. *Philosophical Magazine B*, **69**(6), 1149–1153, https://doi.org/10.1080/01418639408240185.

Boyd, S.R., Kiflawi, I. & Woods, G.S. 1995. Infrared absorption by the B nitrogen aggregate in diamond. *Philosophical Magazine B*, **72**(3), 351–361, https://doi.org/10.1080/13642819508239089.

Chalain, J.-P., Bosshart, G. & Hammer, V. 2004. Spectroscopic properties of an historical greenish yellow diamond. *55th Diamond Conference*, University of Warwick, 3 pp. (unpublished).

Collins, A.T. 2003. The detection of colour-enhanced and synthetic gem diamonds by optical spectroscopy. *Diamond and Related Materials*, **12**(10–11), 1976–1983, https://doi.org/10.1016/s0925-9635(03)00262-0.

Collins, A.T., Kanda, H. & Kitawaki, H. 2000. Colour changes produced in natural brown diamonds by high-pressure, high-temperature treatment. *Diamond and Related Materials*, **9**(2), 113–122, https://doi.org/10.1016/s0925-9635(00)00249-1.

Eaton-Magaña, S.C. & Moe, K.S. 2016. Temperature effects on radiation stains in natural diamonds. *Diamond and Related Materials*, **64**, 130–142, https://doi.org/10.1016/j.diamond.2016.02.009.

Moses, T. & Reinitz, I. 1991. Gem Trade Lab Notes: Diamond—Green, with radiation stains in etch channels. *Gems & Gemology*, **27**(2), 110.

Nasdala, L., Grambole, D., Wildner, M., Gigler, A.M., Hainschwang, T., Zaitsev, A.M., Harris, J.W., Milledge, J. *et al*. 2013. Radio-colouration of diamond: A spectroscopic study. *Contributions to Mineralogy and Petrology*, **165**(5), 843–861, https://doi.org/10.1007/s00410-012-0838-1.

Schwartz, V.A. & Breeding, C.M. 2019. Lab Notes: Rough diamond crystal with an unusual coating of fake green “radiation stains”. *Gems & Gemology*, **55**(2), 247–249.

INSTRUMENTATION

Portable Spectroscopy Using a GoSpectro Device with a Smartphone

GoyaLab, a French start-up company, offers spectroscopy-based tools (www.goyalab.com). Among these is the GoSpectro (Stockton 2017), a handheld diffraction-type spectrometer that can be connected via an adapter to the camera of a compatible smartphone or tablet. Since the adapter does not fit every smartphone, it is important to check the list of compatible devices on GoyaLab’s website. An optional optical fibre with a stand is available separately to make the device easier to handle (Figure 21). The GoSpectro device requires an app, which is freely available for use with either iOS or Android mobile devices.

Figure 21: The set-up used for the experiments described in this report consisted of the GoSpectro device attached to a smartphone (Sony Xperia Z2), with the optional optical fibre and stand. A KL2 fibre-optic lamp (Schneider Gemmologie, Idar-Oberstein) was used as the light source. Photo by Q. Wang, German Gemmological Association.