Chromism in pink diamonds

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Pink diamonds from Argyle have been known by polishers, laboratories and traders to exhibit a phenomenon of photochromism whereby their colour can be influenced by illumination of different lights and intensities. These influences are relatively short-lived and most conspicuous after illumination by short wavelength light of high intensity. This effect is particularly noticeable when using instruments to observe fluorescence, such as a *DiamondView*, which after use with Argyle pink diamonds results in a distinctively bleached or pale colouration. Intensification of the colour can be achieved by subjecting a pink diamond to elevated temperature – thermo-chromism, while the colour can also change unpredictably during polishing – a phenomenon known as tribo-chromism. All these possible changes are temporary and the colour can be readily returned to an 'ambient resting colour'.

Reference to pink diamonds in this article applies primarily to Argyle pink diamonds (Figure 1) rather than Golconda-style Type II pinks or type I purplish colours from Siberia or Canada.

Figure 1. An intensely saturated pink diamond from the Argyle mine in Western Australia. Photo courtesy Rio Tinto Diamonds.

Photo-chromism

While anecdotal reports have been made about colour changes in Argyle pink diamonds, the results of studies by Noble, Byrne, and Fisher (Noble 2011, Byrne 2012, Fisher 2009) have provided a much better understanding of the phenomenon, in which electrons are transferred between defects, one of which is responsible for the pink colouration. Bleaching and restoration of colour are the better characterised phenomena relating to pink colour changes. Generally speaking, UV illumination tends to bleach a pink diamond's colour whereas visible light will restore the colour. The shorter the UV wavelength (down to near 300 nm) the greater the extent of bleaching, whereas the intensity of the bleaching or restoration light affects the rate of colour change. Even prolonged periods of time of days or more in darkness have been found not to result in any colour recovery.

Raising a pink diamond's temperature to above about 800°C intensifies the colour and makes it appear more purplish. As with the bleached form, exposure to white light restores the colour. It has been found that blue light is most effective at restoring the colour, particularly near 460 nm. The images in Figure 2. show the extent of colour changes that can be achieved.

Figure 2. The colour of pink diamonds can be deepened (left) or lightened (right) and returned to their original 'daylight' colour (centre) after illumination with white or blue light. The brown diamonds are for colour reference.

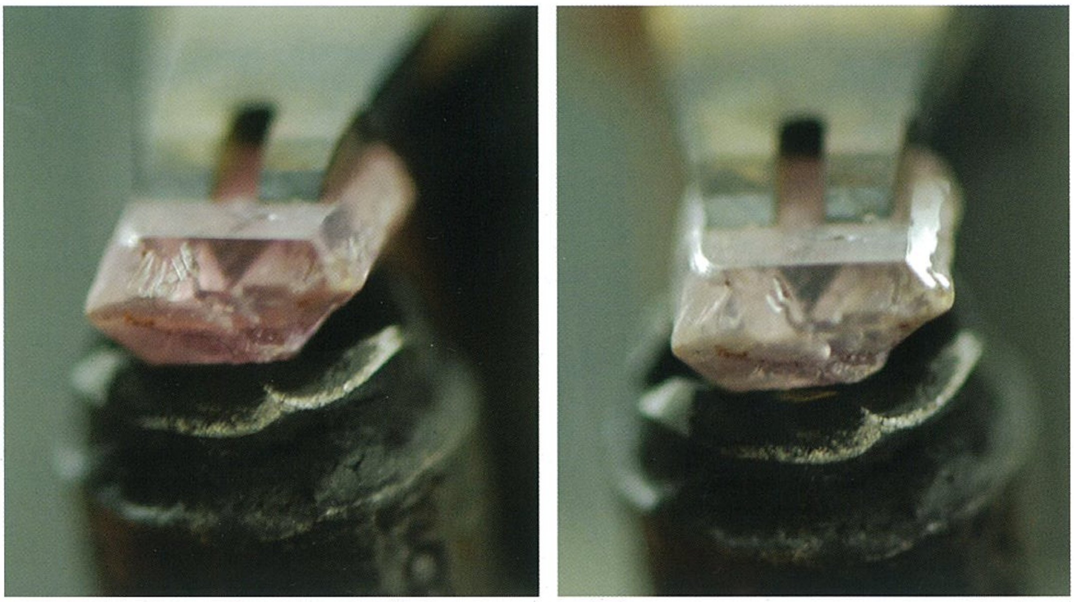
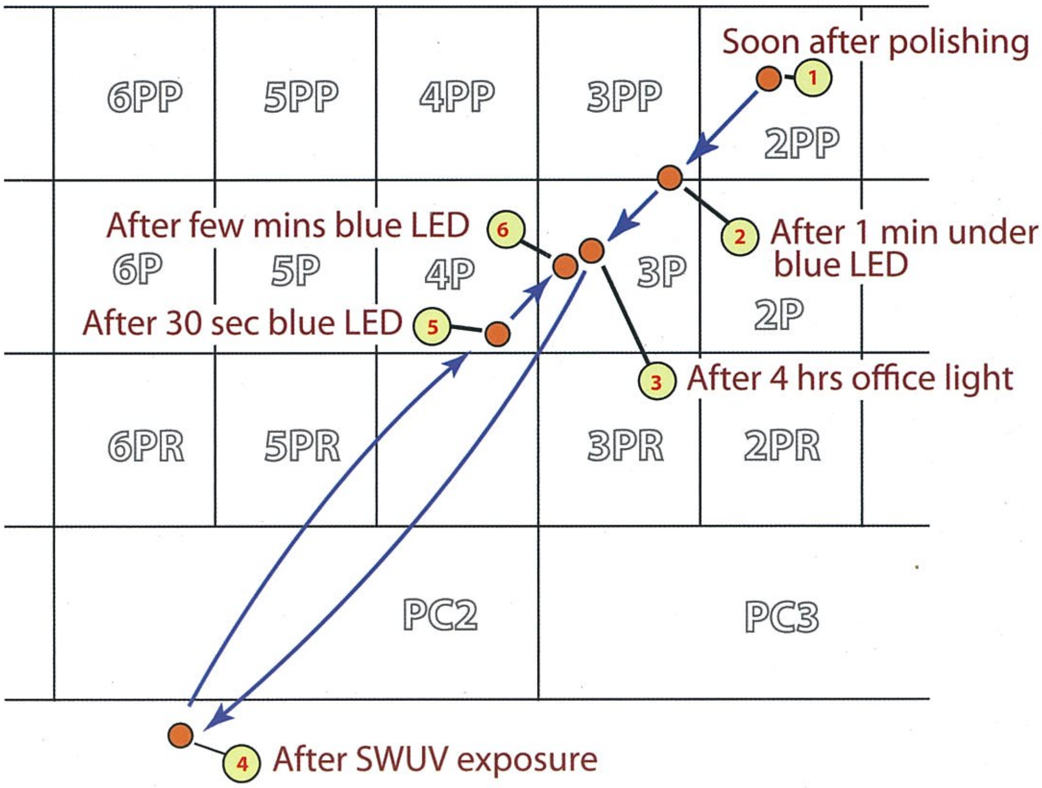


Figure 3. A pink diamond bleaches during polishing, though the effect is short lived and recovery is unaffected by darkness.

Tribo-chromism

During polishing, a diamond can experience temperatures that result in the gem glowing, depending on the force applied to the gem on a polishing wheel and the crystallographic orientation of the face being polished. However colour changes are commonly observed immediately after polishing (Figure 3). These tribo-chromism changes include very short-lived bleaching that only lasts several seconds, but strangely this change is followed by a longer lived colour deepening. It is perhaps for this reason several polishers have claimed that laboratories have somehow altered the colour of their pinks submitted for grading.

To illustrate the effect of colour change after polishing, exposure to UV light and to blue light, a pink diamond fresh off a polishing wheel was presented to a (proprietary) objective colour grading system, after which it was illuminated with blue light and again presented to the colour grader. The stone was then illuminated with SWUV and finally blue light with colour grade measurements made at each stage. Figure 4. shows how the colour varied from the 2PP to 'champagne' (light brown). The slight disparity between stages 3 and 6 reflects either instrumental error or insufficient exposure to blue light at stage 6.



AFTER POLISHING

AMBIENT 'STABLE'

AFTER UV

Figure 4. The movement of an Argyle pink across the Argyle colour palette in a sequence that comprises polishing, bleaching with SWUV and exposure to blue light.

Significantly, pre-conditioning with blue light served to provide a stable condition from which to grade the colour irrespective of whether the colour has been deepened or bleached.

Colour Grading

As wavelengths below about 460 nm can influence the colour, the spectrum of a grading light can induce subtle changes to the colour and hence its grade depending on the reference and method used for grading.

Colour grading of diamonds is normally undertaken under a controlled lighting condition and with reference to either a master set of stones or 'colour chip' such as a Munsell card. From the previous discussion it will be apparent that the spectral characteristics of the lighting, especially in the blue and UV regions, can affect the colour of either or both the gem being graded or a master set if assembled from Argyle-type pinks. If both the graded gem and the master set are exposed equally under the grading light, then colour changes are not critical as matching stones will be equally affected. However if either a master set or a pink diamond to be graded is presented to a grading light for a prolonged time then colour changes may be sufficient for the subject stone to cross a grading border.

The spectra from two commonly used grading lights are shown in Figure 5. Both are rated as having a daylight temperature of 6500 K. It will be seen that one of the sources shows a much higher UV component than the other. A test with a 2PP pink placed in the lighting environment of each of the lamps resulted in a change of measured colour by one-quarter of an Argyle colour grade, sufficient to hop across a colour boundary.

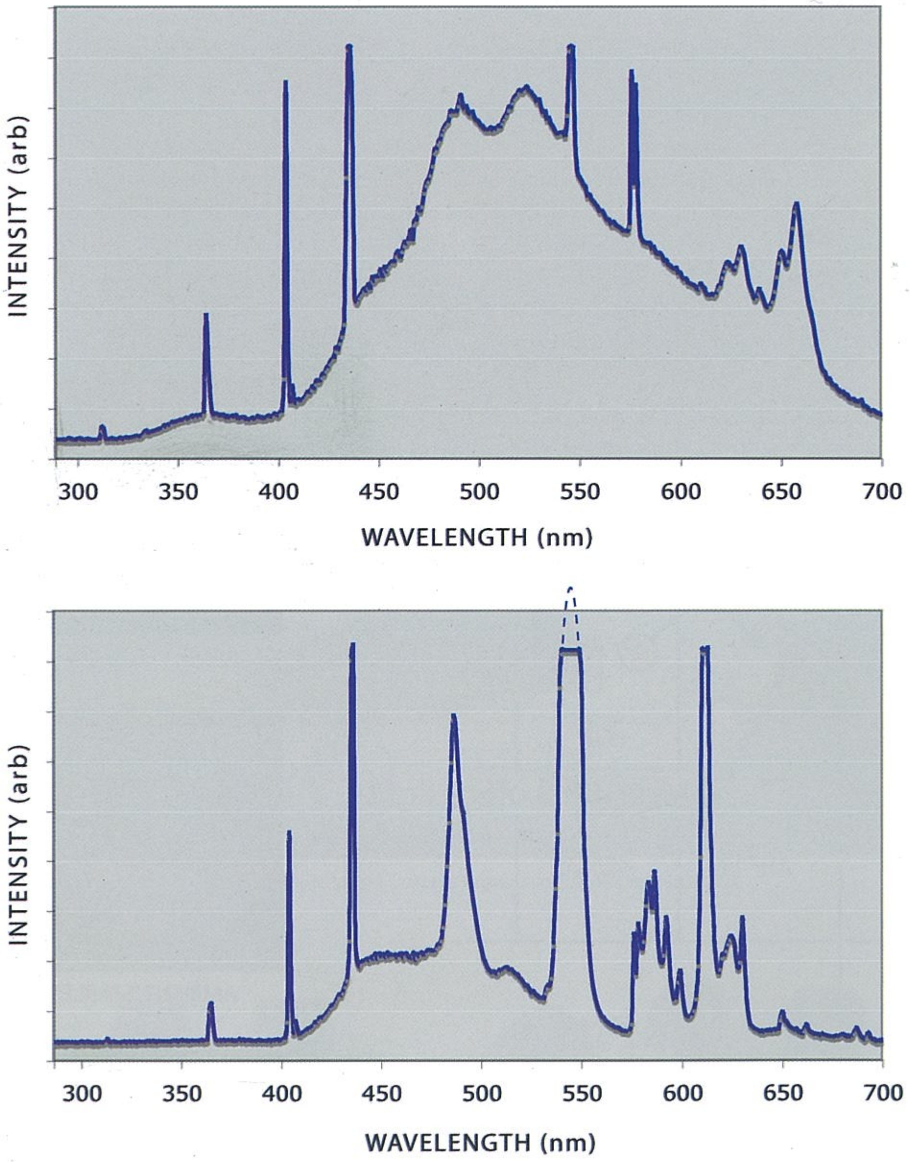


Figure 5. The spectra of two 6500K daylight fluorescent tubes showing different levels of short wavelength light.

Daylight outside shows a much larger UV component than the grading lamps, however window glass is very effective at absorbing wavelengths below 400 nm, so outdoor wearers of pink diamonds may notice an improvement of colour after coming indoors!

If a pink diamond is left in darkness the colour will not change regardless of its colour state (except in instances of a diamond recovering from tribo-chromic bleaching) and curiously the colour of a pink that has been bleached cannot be restored by subjecting it to elevated temperature alone. Restoration with visible light is required in these instances. The processes taking place at the electronic level are not sufficiently understood to explain these phenomena and studies of them may shed further insight into the structure of the colour centre responsible for pink, the details of which still remain a mystery.

Conclusion

The extremely high value placed on Argyle pink diamonds by virtue of their colour demands a good understanding of those factors that can influence the colour, especially when colour grading is being performed. The colour of pink diamonds from Argyle and some other deposits is affected by the balance of bleaching wavelengths below about 450 nm and by colour restoration wavelengths above 450 nm. The colour is particularly prone to bleaching from UV wavelengths. Additionally, the initial colour state of the diamonds can be darkened by the process of polishing. Consequently caution must be applied when colour grading a pink diamond depending on its prior history and the lighting conditions. Freshly polished stones and ones that have been examined for fluorescence are common instances for which laboratories must be vigilant.

Restoration of pink colour to an 'ambient daylight' state can be achieved by exposure to white light or accelerated by illumination from a high intensity blue LED of wavelength near 460 nm.

References

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Noble C. J. 2011. *Applications of Magnetic Resonance in Materials Science and Solid State Physics*. PhD thesis, Monash University.

Fisher D et al., 2009. *Brown Colour in Natural Diamond and Interaction between the Brown Related and other Colour-inducing Defects*. J. Phys: Condensed Matter, 21:364213, 2009.

The Argyle Pink Diamond grading system

The prominence of Argyle Diamonds in marketing pink diamonds led to the development of a colour grading scale particularly suited to the product. It assigns a colour grade which refers to hue and saturation. Three hues are recognised comprising purplish-pink (PP), pink (P) and pink-rose (PR), the latter having a brownish secondary colour. A numerical prefix is added to the hues representing the degree of saturation, where 1 relates to the highest while 9 – the palest. For saturations higher than 1 the grade may transcend into red or purplish red.

All images courtesy of Rio Tinto Diamonds.