Figure 14: When exposed to long- or short-wave UV radiation, the glue used to affix the HoP tag in this prototype example fluoresces blue, while the surrounding cultured pearl is inert, enabling the marker to be easily located. The size of the fluorescent spot is approximately 1 mm in diameter. Photomicrograph by O. Segura.

dopants, and a different luminescence colour can be assigned according to the type of mollusc and/or country of origin. Both the fluorescence and the information on the tag can be observed with an inexpensive pocket microscope equipped with 60× magnification and a UV LED (e.g. Figure 15).

All of the usual laboratory techniques that are used to analyse pearls (X-radiography, spectroscopy, etc.) can be accomplished without the results being disturbed by the tag. If necessary, the tag and its UV-fluorescent glue can be removed using nail polish remover (acetone). Thus, the cultured or natural pearl may be returned to its initial state without any remnants of the tagging process; the final consumer may therefore return it to its pristine state without any damage if they wish to do so.

Figure 15: A pocket microscope can be used to read an HoP tag, and also to view the UV luminescence colour of the glue that is used to affix it. Photo by Jean-Pierre Le Pollès.

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SYNTHETICS AND SIMULANTS

Modern Doublets, Manufactured in Germany and India

At the November 2014 Hong Kong Jewellery and Gem Fair, one of the authors (HAH) noticed some attractive faceted stones in colours resembling popular gem materials (e.g. Figure 16). These samples were actually doublets produced by a German lapidary, Viktor Kämmerling of Idar-Oberstein. They were manufactured using colourless gem materials cemented by an artificial resin that had been dyed to create strikingly realistic gems. Both the crown and pavilion consisted of beryl (for emerald substitutes), topaz (for imitations of spessartine, tanzanite, Paraíba tourmaline and rubellite), tourmaline (for another Paraíba tourmaline substitute) and quartz (for imitations of

Figure 16: These doublets display various colours and optical effects. Samples 1–15 weigh 1.71–8.83 ct, and consist of colourless natural gemstone crowns and pavilions that are glued together with a coloured binder to create the illusion of popular gem varieties. The other samples weigh 2.29–13.79 ct, and display iridescence (no. 18) or contain pieces of foil in the cementing layer that produce different optical effects (nos. 16 and 17). Photo by H. A. Hänni.

peridot, aquamarine, topaz, morganite, amethyst, ametrine, bicoloured tourmaline and prehnite). The gems typically weighed between 2 and 10 ct and were available in calibrated sizes.

Additional high-quality doublets were seen by the authors in February 2015 at the Inhorgenta show in Munich, Germany. A small number of these gems were on display at the booth of Gemstones Corp. (Jaipur, India), which revealed additional colours; some were even bicoloured. They were priced inexpensively and sold as quartz doublets, the majority as oval cuts weighing ~8 ct. Also on display were quartz doublets showing interesting visual effects (again, see Figure 16): red needle-like inclusions (similar to rutilated or tourmalinated quartz), flat metallic inclusions with the appearance of gold and samples showing remarkable iridescence.

The results of our investigations of 18 samples are reported in Table I, and preliminary observations of some of these doublets were given by Hänni (2014). The dye that was used to impart such a realistic colour appearance to those manufactured by Viktor Kämmerling was either dissolved in the binder or consisted of tiny pigment grains suspended in the resin (e.g. Figure 17, left). The desired saturation of the colour was achieved by adjusting the concentration of dye in the resin and the thickness of the glue layer (e.g. Figure 17, right). In the examined samples, this layer varied from about 0.1 mm ('morganite' no. 11) to less than 0.05 mm (centre portion of 'bicoloured tourmaline' no. 14). The character of the colourless parts and the thin coloured glue layer was best observed in immersion (Figure 18, left). The cement typically contained various

Figure 17: Left: The glue layer in a tanzanite-coloured topaz doublet (no. 7) contains red and blue pigment particles and some gas bubbles (left, image width ~2 mm). Right: The girdle area of the tanzanite imitation displays a coloured glue layer with a thickness of ~0.025 mm. Photomicrographs by H. A. Hänni.

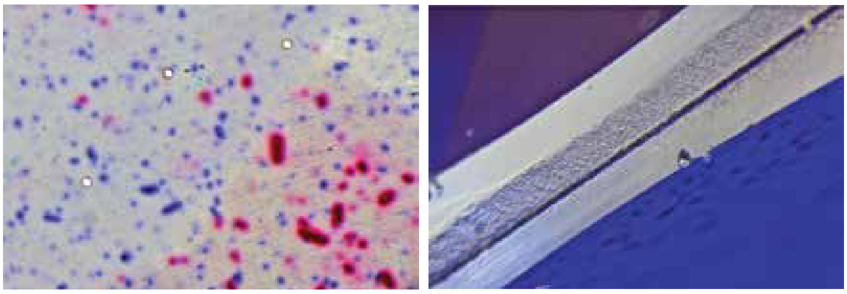


Table I: Properties of some doublets from Viktor Kämmerling and Gemstones Corp.

No.	**Colour**	**Gem imitated**	**Weight (ct)**	**Crown/ pavilion***	**Internal features**	
					In crown and pavilion	**In glue layer**
1	Green	Emerald	5.35	Beryl/beryl	Clouds, fine tubes	Small gas bubbles
2	Green	Emerald	3.86	Beryl/beryl	Partially healed basal fractures, veils	Small gas bubbles
3	Blue-green	Paraíba tourmaline	1.71	Tourmaline/ tourmaline	Open fissures, fluids	Small gas bubbles
4	Blue-green	Paraíba tourmaline	3.36	Topaz/topaz	Partially healed fractures, two-phase inclusions	Very small pigment particles
5	Red	Rubellite	4.45	Topaz/topaz	None	Distinct pigment particles
6	Orange	Spessartine	4.71	Topaz/topaz	None	Some bubbles, small particles
7	Violet	Tanzanite	4.49	Topaz/topaz	Metallic inclusion	Bubbles, red and blue particles
8	Yellow-green	Peridot	8.83	Quartz/quartz	None	Extended bubble fields
9	Light blue	Aquamarine	7.54	Quartz/quartz	Very small fluid(?) blebs	Dust and some bubbles
10	Light blue	Topaz	8.64	Quartz/quartz	None	Dust and some bubbles
11	Orangey pink	Morganite	8.21	Quartz/quartz	Two-phase negative crystals	Bubbles and pigment particles
12	Violet	Amethyst	8.66	Quartz/quartz	None	Bubbles and pigment particles
13	Violet and yellow	Ametrine	8.30	Quartz/quartz	None	Bubbles and pigment particles
14	Red and green	Bicoloured tourmaline	8.37	Quartz/quartz	None	Bubbles and pigment particles
15	Milky green	Prehnite	8.48	Quartz/quartz	Irregular fine fibres	Bubbles and minor pigment particles
16	Colourless with ‘golden’ inclusions	Gold-in-quartz	13.79	Quartz/quartz	None	Metallic foils
17	Colourless with narrow foil strips	Rutilated or tourmalinated quartz	2.29	Quartz/quartz	None	Metallic foils
18	Various iridescent	Girasol	4.28	Quartz/quartz	None	Gelatinous appearance

* Identified by Raman spectroscopy using a B&W Tek MiniRam 785 instrument equipped with a >300 mW 785 nm laser.

amounts of gas bubbles. In some gems, the bubbles were sparse and dispersed sporadically, while in others they were more abundant and concentrated near the girdle of the sample (Figure 18, right).

Natural inclusions in the crown and pavilion components of the doublets were seen in only some samples (see Table I). For the quartz samples from Viktor Kämmerling, Fourier-transform infrared (FTIR) spectroscopy with a PerkinElmer Paragon 1000 spectrometer showed typical bands for natural quartz in the 4000–3000 cm^{-1} range, especially the 3595 cm^{-1} band (Zecchini and Smaali, 1999). Both parts of quartz sample no. 15 contained abundant, randomly oriented, fine fibres. Observation of the stone’s surface with a scanning electron microscope showed only pits corresponding to these inclusions, which were filled with debris from the tin polishing wheel.

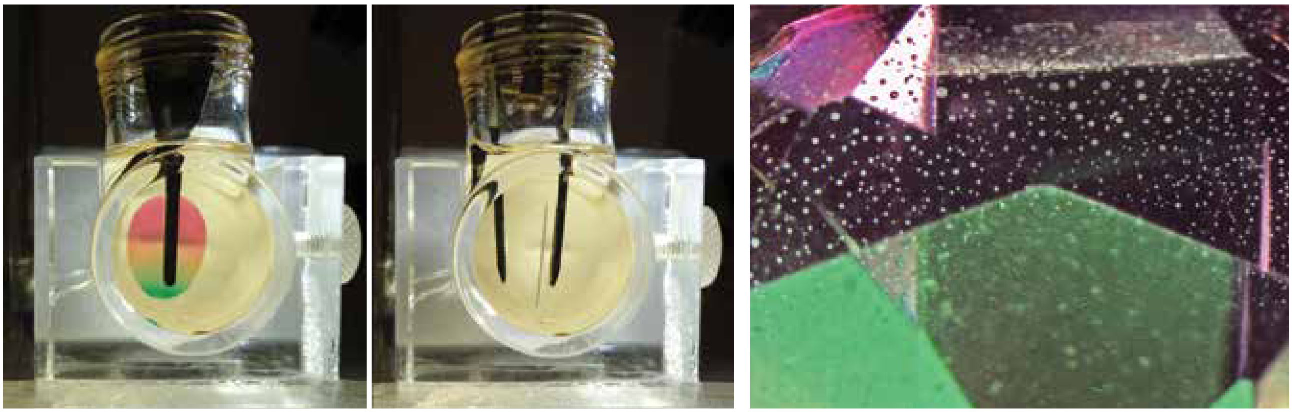
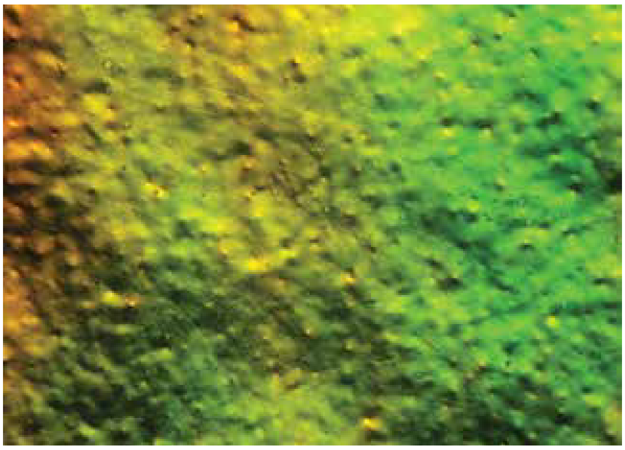


Figure 18: Left: A quartz doublet imitating bicoloured tourmaline (8.37 ct; no. 14) is shown immersed in benzyl benzoate, in views both perpendicular (left side) and parallel (right side) to the girdle plane. Right: The bicoloured tourmaline imitation contains a more concentrated area of gas bubbles near the girdle area (image width ~5 mm). Photos by H. A. Hänni.

Two of the quartz doublets from Gemstones Corp. were found to have thin metallic foils in the cement layer. One of these samples (no. 16) had 'golden'-coloured foil, simulating gold-in-quartz. The other sample (no. 17) revealed narrow foil strips in geometric orientations. The iridescent doublet (no. 18) contained a gelatinous-appearing glue layer that was bright green, yellow or violet depending on the viewing angle when observed in reflected light (e.g. Figure 19). The constituent quartz of these doublets was identified as natural by FTIR spectroscopy, with bands at 3595, 3482 and especially 3379 cm^{-1}. A peak at ~3480 cm^{-1} is typically associated with rock crystal quartz (Choudhary, 2010).

It is not difficult to recognize the composite character of these doublets when they are unmounted and immersed in water or another medium (cf. Henn, 2002). Viewed from the side with a 10× loupe, the girdle plane displays a narrow dark colour band of less than a millimetre. The colourless topaz, beryl or tourmaline used for these doublets may contain inclusions typical for these gem materials, and their conclusive identification as doublets is established by observation of the coloured binder layer. In addition, the doublets will show a peculiar behaviour in the polariscope, with no distinct extinction, which points toward an assembled stone.

Figure 19: The glue layer in the iridescent quartz doublet (no. 18) displays various colours depending on the viewing angle, and contains numerous gas bubbles. Photomicrograph by U. Henn; image width ~10 mm.



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