XRF micro-analysis of gemstone inclusions

Recent developments in X-ray fluorescence (XRF) micro-analysis techniques has seen the traditional wide range of XRF applications expand, benefiting from the combination of single point qualitative analysis with high spatial resolution element imaging.

With the new generation of micro-XRF systems such as the XGT-5000 unique capabilities for micro analysis are possible, including unrivalled 10 µm beam diameters and simultaneous XRF and x ray transmission imaging. The high intensity beams provided via the patented HORIBA x-ray guide tube technology allows limits of detection as low as just a few parts per million.

For gemstone analysis, these features are ideally suited to analysing precise elemental composition, locating and identifying inclusions, and providing key information in quality assurance. Natural or synthetic stones often have their own typical inclusions, as do stones originating from different geographic locations. In this application note, inclusions in diamonds and quartz stones are analysed and identified using micro-XRF, providing useful evidence on the form and origin of the stones.

Diamond inclusions

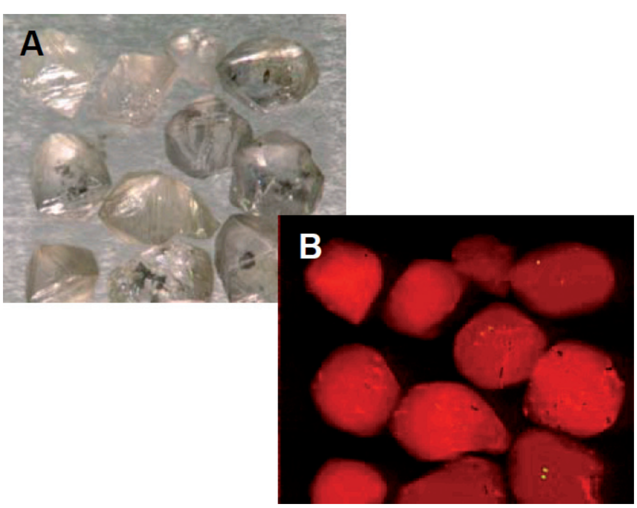

Figure 1: Rough technical diamonds imaged with (A) white light and (B) x-ray analysis (transmitted x-ray and iron)

Figure 1 shows some rough technical diamonds (typically ~2 mm diameter) – the optical image clearly shows the presence of major inclusions within the stones. However, the x-ray image which shows the overlay of transmitted x-rays and XRF signal due to iron, illustrates that only a small number of these inclusions are caused by iron. The remaining are carbon inclusions.

Spot analysis of a diamond with an iron inclusion, located through XRF imaging, identifies the only XRF active element within the inclusion (ie, above Na in the periodic table) as iron. Therefore, the inclusion can be assigned as black magnetite (Fe_3O_4). This material is typically found in Russian Siberian diamonds, and thus provides a very fast indication of the diamond's provenance.

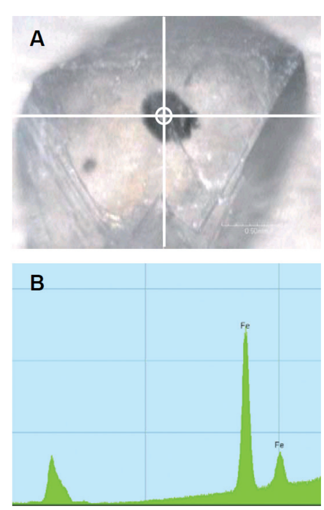

Figure 2: (A) high magnification image of diamond with black inclusion, with XRF analysis zone shown, and (B) resulting spectrum showing presence only of iron.

Needle inclusions in quartz

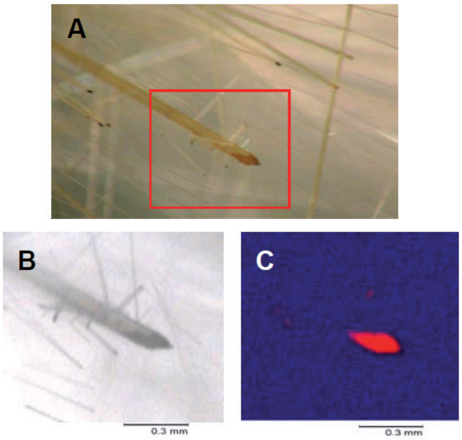

Figure 3: (A) optical image of cut quartz stone, with needle inclusions, (B) high magnification image of mapping region, and (C) XRF composite image showing Si and Ti

Although quartz itself is rarely used in jewellery, variants which show specific colours or features often are (for example, amethyst, citrine and rose quartz). Rutilated quartz is a transparent stone containing fine rutile (TiO_2) needles, resulting in a beautifully structured semi-precious stone. These needles can be formed prior to, or during, the quartz formation. In the latter case, the needles are aligned with the crystal lattice of the host mineral.

Unlike diamond, which is transparent to the x-ray beams used for XRF analysis, the quartz matrix of SiO_2 does absorb the incident x-rays, so it is only possible to analyse inclusions which terminate at the quartz surface. By contrast, as shown above, inclusions in diamonds can be analysed deep within the stone.

Figure 3 shows optical and XRF images of a cut quartz stone with needle inclusions. The titanium signature is clearly visible at the points where the needles reach the quartz surface, providing evidence that these needles are composed of rutile.

Conclusions

X-ray fluorescence micro-analysis provides an ideal technique to quickly characterise inclusions and flaws in gemstones. The optimised beam collimation possible with the XGT-5000 means that even inclusions which are buried deep within a (transparent) gem can be accurately analysed. The options for 10 µm and 100 µm beam diameters are well suited for analysis of inclusions with a range of sizes.

Acknowledgments

The data used herein was kindly provided by Petr Cerný of the Czech Customs Administration, Prague, who is thanked for useful discussion during preparation of this application note.

XGT-5000

info.sci@horiba.com
www.horiba.com/scientific

HORIBA Scientific

USA: +1 732 494 8660 **France:** +33 (0)1 64 54 13 00 **Germany:** +49 (0)89 4623 17-0
UK: +44 (0)20 8204 8142 **Italy:** +39 0 2 5760 3050 **Japan:** +81 (0)3 38618231
Spain: +34 91 490 23 34 **China:** +86 (0)10 8567 9966 **Brazil :** +55 11 5545 1540
Other Countries: +33 (0)1 64 54 13 00