Specular Reflectance Data for Quartz and Some Epoxy Resins – Implications for Digital Image Analysis Based on Reflected Light Optical Microscopy

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ABSTRACT

Reflected light optical microscopy, or epimicroscopy, is one of the oldest techniques of modern mineralogy. At a relatively low capital cost, it is also very resourceful, and the analytical choice for the identification of most ore minerals.

In ore mineralogy, reflected light optical images have the potential to overcome the main limitation of backscattered electron images from scanning electron microscopes, namely contrast of mean atomic number (Z) below the spectral resolution of the backscattered electrons detector. This is the case for relevant ores, like iron (haematite-magnetite) and copper-zinc ores (sphalerite-bornite), but for both cases the pairs of minerals are easily discriminated in reflected light.

The improvements in optics and electronics also made microscopy a powerful source of digital images, suitable for automated analysis for minerals processing, as the determination of liberation spectra. The drawback, however, has always been the impossibility to recognise the transparent minerals, which account for most of the gangue phases in ores, from the embedding resin, usually epoxy.

In order to determine if there was any possibility to separate quartz from epoxy resins, reflectance spectra have been acquired for quartz and some commercial epoxy resins (Araldite, Buehler’s Epothin and Epocolor, Araldite spiked with fluorochrome from Struers), from 380 to 720 nm in 5 nm intervals. Reflectance of quartz and epoxy is very similar over the whole visible light range, and varies from 4.5 to five per cent. Epocolor, a red-dyed epoxy, reflects slightly more above 560 nm, as does Araldite spiked with the fluorochrome from 460 to 570, but for both the reflectance is still very close to that of quartz, under 5.1 per cent.

This data set is final, and precludes the application of reflectance in light optical image analysis for assessment of liberation, phase quantification, or any other signal that requires separation of resin from transparent minerals.

INTRODUCTION

Proper mineral liberation is a fundamental requirement for concentrate quality and the recovery of the phase of interest. The liberation process is controlled by the texture of the phases involved, among other factors. The liberation size can be assessed by measuring the grade distribution of the phase of interest on a size by size basis. Although relevant improvements in microtomography are promising for the direct, 3D assessment of the texture (Paktunc et al, 2004; Videla, Lin and Miller, 2007), it will take some time for it to be a widespread available technique, due to high capital costs and operational limitations. Image analysis techniques are, therefore, the only alternative for the assessment of the liberation properties of a given phase in an ore. For image analysis, liberation is measured from cross-sections of close-range sized particle populations, carefully embedded in epoxy, sectioned and polished.

Potential sources of images for liberation analysis are reflected light microscopes and backscattered electrons. Reflected light microscopy, or epimicroscopy, is one of the oldest techniques of modern mineralogy (Kile, 2003; Criddle, 1998). At a relatively low capital cost, it is also very resourceful, and the analytical choice for the identification of most ore minerals.

Recent improvements in optics and electronics also made microscopy a powerful source of digital images, suitable for automated analysis. In ore mineralogy, reflected light optical images have the potential to overcome the main limitation of backscattered electron images from scanning electron microscopes or microprobes, namely contrast of mean atomic number (Z) below the spectral resolution of the backscattered electrons detector. This is the case for relevant ores, like iron (haematite-magnetite) and copper-zinc ores (sphalerite-bornite), easily discriminated in reflected light.

Most liberation analyses, however, are based on backscattered electron images, in scanning electron microscopes (eg Neumann, Schneider and Valarelli, 2000; Fandrich et al, 2007) or electron microprobes (eg Lastra, 2007). A rare example of liberation calculated from optical images is Donskoi et al, 2007. The drawback of optical images is the impossibility to recognise the transparent minerals, which account for most of the gangue phases in ores, from the embedding resin, usually epoxy. Although it probably has always been the reason for not using optical images, this problem is seldom mentioned in publications, and possibly Donskoi et al, 2007 address this in part, while concluding that significant labour is required for correct identification of minerals by manual editing.

This paper aims at providing a fundamental explanation for the lack of contrast between silicates and cold mounting resins, based on the physical properties of quartz and some common resins, and also to establish a scientifically sound technique to test suitability of new embedding materials.

MATERIALS AND METHODS

A clear hexagonal prismatic quartz crystal from a pegmatite in Minas Gerais, Brazil, was cut both parallel and orthogonal to its crystallographic axis c. Although oriented by the faces of the hexagon, the orientation to the optical axis was checked under the petrographic microscope (as c // x). The two chips were cold mounted in epoxy resin, ground using metal-bond 70, 40, 15, 9 and 6 μm diamond, and polished with 3 μm, 1 μm and 0.25 μm diamond suspension on hard cloth.

Commercial resins were tested: regular Araldite (GY251, hardener HY951), Araldite spiked with Struer’s Epodye fluorochrome (5 g/L), Epothin® and bright red Epocolor™, the latter two from Buehler. The coloured resins were analysed to check if their colour showed up in the reflected light images.

Measurements were performed with a Zeiss Axiphot microscope, Zeiss Epiplan Neofluar 20x objective, using an unfiltered quartz halogen lamp light source with a correlated colour temperature of 3100 K. Reflected light was passed through a Zeiss UV grating monochromator, with a grating constant of 12 208 lines/mm, and collected at 5 nm intervals, from 380 to 720 nm, using a Zeiss LambdaScan photomultiplier. Measurements were performed in air, five scans averaged, and against a cubic zirconia P5733 standard.

Quartz reflectance was measured on the 001 section, and on both Rα and Rν (ordinary and extraordinary) vibration planes on the section parallel to the c axis.
RESULTS

Reflectance spectra for all the measurements of quartz are very similar over the whole range, and vary from 4.5 to five per cent (Figure 1).

The reflectance data for the epoxy resins (Figure 2) is basically the same, but the coloured resins reflect slightly more for the wavelengths they were dyed for. Epocolor’s reflectance increases slightly above 560 nm until the upper analysed limit, and Araldite spiked with the fluorochrome displays a slight positive reflectance bump from 460 to 570 nm. The difference, however, is only from a baseline at 4.6 per cent, coincident with the quartz reflectance, to a peak value at 5.05 per cent.

CONCLUSIONS

The close coincidence of specular reflectance for quartz and epoxy resins ensures that there is no relevant reflectance contrast between them, even when spiked with dyes.

This data set is final, and precludes the application of reflectance in light optical image analysis for assessment of liberation, phase quantification, or any other signal that requires separation of resin from transparent minerals.

Although Epodye is yellow, it is a fluorochrome, designed to emit light (mostly above 520 nm) if excited with blue light (400 to 440 nm). Exploratory tests with iron ore (haematite + quartz) mounted in Epodye-spiked Araldite using a suitable light source, in reflected light and in laser scanning confocal microscopy, did not result in useful resin-to-quartz contrast either, as the fluorescence is very strong, and shines through the transparent quartz. It might be assumed that other transparent minerals will behave alike. Less transparent gangue minerals may partially block the fluorescence, but there will still be a severe problem with the particle outline, due to high depth of field. If less transparent minerals are able to provide a contrast to the fluorescing resin, a laser scanning confocal microscope, analysing exclusively the reflectance from the surface of the polished section, could overcome the particle outline limitation.
Measuring the reflectance spectrum is also a fast and scientifically sound way of testing any new material for mounting mineral samples, if developed to ensure good contrast with the transparent gangue phases.

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**REFERENCES**


