THE CAUSE OF LUMINESCENCE IN LUNAR MATERIALS

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Luminescence emission spectra have now been obtained for a range of lunar materials; we have investigated materials from Apollos 11, 12, 14 and 15, and Apollo 16 data may be included in our full paper. Our aim now is to elucidate the causes of the characteristic spectrum of plagioclase, the main luminescent component of lunar material, as a way of obtaining information about the conditions under which the lunar surface was formed.

Last year we approached this by doping terrestrial calcic plagioclase (e.g. labradorite) with likely activators: we showed that the characteristic green peak at about 5600 Å was probably caused by Mn$^{2+}$ in Ca sites, and we assembled circumstantial evidence for assigning the IR peak at about 7800 Å to Fe$^{3+}$. Attempts to test this by doping labradorite with iron produced marginal results, probably because of the complexity of the terrestrial material. We are now carrying out a program of synthesising plagioclase, in as pure a form as possible, in order to have better control over the doping experiments. Results so far have confirmed that Mn$^{2+}$ produces the green emission peak, and we have now also produced a pronounced IR peak by iron doping, under conditions intended to ensure that most of the iron went in as Fe$^{3+}$.

Synthetic calcic plagioclases (anorthites) have been produced from gels at subsolidus temperatures (about 800 °C) using a hydrothermal technique. A sample with 1% Fe$^{3+}$ added in the form of ferric nitrate gave an IR emission band peaking at about 7200 Å; this is shorter in wavelength than the peak found for terrestrial plagioclases, but if the sample were not well crystallised, i.e. if it were partially vitrified, then a shift in this direction would be expected if the Fe$^{3+}$ were in an Al site. We now have other evidence, from our work on oxides, that Fe$^{3+}$ may prefer an Al rather than a Ca site as was previously thought: we have found that Fe$^{3+}$ produces an IR emission band in $\alpha$-$\text{Al}_2\text{O}_3$ (in agreement with Pott and McNicol [1]), whereas the doping of CaO with Fe$^{3+}$ produced no IR emission band. Further evidence that the shorter wavelength of the Fe$^{3+}$ peak is indeed due to vitrification is obtained when the same material is doped with Mn$^{2+}$; similar reasoning predicts that in this case the green peak should be shifted to longer wavelengths, and this we indeed observe, as the peak appears at about 5600 Å.

A problem that occurs with our present method of synthesising anorthite is the presence of chromium (Cr$^{3+}$) contamination, probably from containers used during the heating process. This gives rise to another emission band in the near IR which may mask that due to the deliberately added iron. However, the Cr$^{3+}$ band is unlikely to be confused with the
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Fe$^{3+}$ band as it shows fine structure and is quite different in appearance. In order to overcome this contamination problem other preparation techniques are being tried, including crystallisation from the melt at atmospheric pressure.

Our main interest in the cause of the IR peak is, oddly enough, because of its absence or relative weakness in lunar plagioclase as compared with similar terrestrial materials. It therefore constitutes a major difference between them, and gives a clue as to the different conditions under which lunar and terrestrial surface materials were formed. Our evidence is that the difference lies in whether the iron present is mainly in the form of Fe$^{2+}$ or Fe$^{3+}$: Fe$^{2+}$ is known to quench luminescence, whereas Fe$^{3+}$ has been found to cause it, in the IR. The suggestion is that the iron known to be present in the lunar plagioclase is mostly in the Fe$^{2+}$ form, whereas Fe$^{3+}$ is dominant in the terrestrial plagioclase. If so, this is evidence of oxygen scarcity when the lunar surface material was formed, which supports quite different geological evidence.

Our attempts to identify luminescent components other than plagioclase in lunar samples continue. In addition to the characteristic plagioclase emission, which appears bluish-white, one breccia chip (10059,36) was reported by us last year as showing a variety of other colours, including orange. Electron microprobe analysis has now shown that this orange emission is also caused by plagioclase, but in a highly vitrified form which produces a large shift of the green peak to longer wavelengths, as discussed above.

Reference