

have distinct Raman spectra. This supports the interpretation that metamictization is a disorder phenomenon, the end product of which is a glassy state with zircon composition.

The laser-induced fluorescence observed in zircon is attributed to photoluminescence of trivalent REE ions that substitute for Zr^{4+} (e.g., Marfunin 1979). The fine structure of emission lines of the REE depends on the local crystal field around the REE ion and is thus unique to each host mineral. The only detailed study of laser-excited fluorescence of REE ions in a mineral (fluorite) was conducted by Burruss et al. (1992), who established a correlation between the REE concentration and the intensity of the fluorescence emission. All terrestrial and extraterrestrial samples of zircon that contain REE exhibit such laser-induced fluorescence emissions at specific wavelengths; those wavelengths are exactly the same for different zircon samples. A full analysis of these REE emission spectra will be reported in a subsequent paper. In this paper, we mention only that the 488 nm laser-excited fluorescence bands observed in zircon essentially define three groups: (1) from ~539 to ~558 nm, caused by Eu^{3+} , Er^{3+} , and Tb^{3+} , (2) from ~568 to ~582 nm, caused by Dy^{3+} , and (3) several more isolated bands at 604, 616, 650, and 660 nm, caused by Eu^{3+} . In comparison with bands of other samples of lunar and terrestrial zircon (unpublished data from our laboratory), the fluorescence bands in the zoned, single-crystalline zircon of this study are weak (even on the trace element-rich side of the crystal), consistent with the relatively low concentrations of REE in this sample. There is a strong linear correlation between the intensity of the emission line at 546 nm (caused by Er^{3+}) and the Er concentration as determined by ion microprobe analysis. The general applicability and usefulness of this finding needs testing, especially because the presence of crystalline disorder may complicate the quantitative interpretation of REE photoluminescence.

Quantification of the degree of structural disorder using Raman microprobe analysis may lead to a better understanding of the thermal history and the redistribution of radiogenic Pb, Th, U and other intermediate daughter products related to the expansion of the zircon structure owing to metamictization. Further studies of zircon need to address the following questions: (1) Can the observed variations in the Raman spectra of zircon be calibrated against the U concentration or the sum of heavy trace elements present in any given sample? (2) Can the interpretation of Raman spectra provide a general means of quantifying the degree of metamictization? (3) Can the Raman microprobe be used to quantify and evaluate the degree of self-annealing over extended geologic time, as suggested to occur by Weber et al. 1994? (4) Is there a generally applicable correlation between REE concentrations and the intensity of the laser-induced fluorescence emissions? (5) Does the strong correlation between Raman parameters and trace element concentrations in the

lunar zircon also hold for zircon that has been subjected to terrestrial igneous and metamorphic processes?

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