The formation process of oxygen vacancies in quartz of uranium ore and of granites revealed by pulsed ESR measurements

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ESR (electron spin resonance) dating method is based on the fact that unpaired electrons are created by natural radiation and accumulated in minerals in geologic time scale. ESR detects unpaired electrons; therefore, the signal intensity corresponds to the age of the minerals. The applicable age range of this dating method has been thought to be limited to Quaternary era because of the thermal stability of the paramagnetic centers which hold unpaired electrons. However, as for the E1' center in quartz, which is an oxygen vacancy with an unpaired electron, its signal intensities were found to be correlated with the ages of host granites (Odom and Rink, 1989).

The authors proposed a method to evaluate the relative amount of oxygen vacancies in quartz (Toyoda and Ikeya, 1991). They showed that this amount of oxygen vacancies is correlated with the age of host granite as well as discussed the processes which create oxygen vacancies in natural quartz. Rink and Odom (1991) proposed that alpha recoil nuclei from uranium and thorium series elements contained in quartz matrix at a very low level while Toyoda et al. (1996) showed that oxygen vacancies can be created by gamma ray irradiation, implying that natural beta and gamma rays from outside of the quartz grains create oxygen vacancies.

Spin-spin relaxation times were measured in the present study by pulsed ESR measurements for irradiated quartz samples and for natural quartz samples from a uranium ore and from granite. The spin-spin relaxation time is closely related with the distance between spins, hence, that of paramagnetic defects. Defects created by radiation with high LET such as alpha or alpha recoil nuclei should be locally dense, therefore should have shorter relaxation time, while those by radiation with low LET should be uniformly distributed at lower concentration, therefore should have longer relaxation time.

Hydrothermal quartz piece was sliced and the slices were irradiated by He ions of 4MeV from a tandem accelerator and by electrons of 500keV from an electron accelerator at Takasaki branch of Japan Atomic Energy Research Institute. Natural quartz grains were extracted from Kanyamba uranium ore of Zimbabwe and from Mannari granite of Okayama Prefecture.

Pulsed ESR measurements were performed at Okayama University of Science with JEOL PX-2300 ESR spectrometer. We used the Hahn pulse sequence to obtain spin-spin relaxation times (T2) with the first pulse width of 40 ns. T2 were calculated from decay of the area of pulse echoes according to increasing the pulse interval. T2 of E1' center of He ion irradiated samples ranged from 980 to 1900 ns while that of electron irradiated samples from 7100 to 16000 ns, both with decreasing with increasing irradiation dose. Gamma ray irradiated sample has T2 of 15000 ns. T2 of quartz of uranium ore ranged from 3500 to 7100 while that of granitic quartz was 6200 ns.

The T2 of quartz of uranium ore and granite are closer to samples irradiated by electrons and by gamma rays rather than to that by He ions. Precise analysis with consideration of averaged spin density will be presented.

References

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