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Supporting the surface charging mechanism of seismic-electromagnetic phenomena by the direct measurements of the electron and hole trapping centers

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The mechanisms of the seismic-electromagnetic phenomena (SEP) attracted as precursors of short-term earthquake forecast have been suggested, however, it is still incompletely understood. Among the possible mechanisms of the SEP is the surface charging mechanism related to the electron and hole trapping centers in quartz. Previous studies evaluated the plausibility of the mechanism from the surface charge density by the measurement of current or potential changes. On the other hand, only a few studies have evaluated the plausibility from the direct measurements of the trapping centers' concentration.

We have performed low-velocity friction experiments mimicking the fracture with low-frictional heating for simulated fault gouges (commercial natural quartz sands) at a normal stress of 1.0 MPa with displacements up to 1.4 m. In order to measure the concentration of the trapping centers in the simulated-fault gouges, we conducted electron spin resonance for the standard sample, TEMPOL (4-hydroxy-2,2,6,6-tetramethyl-piperidine-1-oxyl), and the gouges before and after friction. In recent decades, researchers also have obtained the concentrations of the trapping centers in the quartz damaged in the rock fracture experiments using ESR and a radical scavenger. From those concentrations with the measured or assumed surface areas, we calculated the surface charge density of the quartz and discussed the plausibility of the surface charging mechanism of the SEP.

In our friction experiments, the E' type centers were detected at g_2 = 2.001 (e.g., E_1' center; □Si□, E_S' center; □Si□, E_α' center; =Si:, where − is an electron pair, : is a lone pair, and □ is an unpaired electron) in the ESR spectra of the simulated-quartz gouges and the trapping center increased by the fracture of low-velocity friction. Assuming that the trapping centers were produced on the grain surfaces by the fracture, the range of the increase in the surface charge density was (0.21–8.0) $\times 10^{-4}$ C/m^2. The rock fracture experiments found the E_1' center, non-bridging oxygen hole center (NBOHC; □Si−O□), and peroxy center (□Si−O−O□) in quartz. On the same assumption, the total surface charge density of those trapping centers and the density of the E_1' center or NBOHC were estimated as 2.7×10^{-1} and 5.0×10^{-2}–3.94 C/m^2, respectively.

The surface charge density required for a corona discharge that can cause the SEP in the air over a flat plane is reported over 5.0×10^{-5} C/m^2. The quantities calculated above are almost enough to induce a corona discharge. The surface charges can form the electric dipoles on the fault plane, inducing the electric and magnetic fields. Our experiment showed that the fracture by fault motions could produce the surface charges on the fault. It proves that the electromagnetic abnormalities by the fault motions may also be observed through the surface charging mechanism. Therefore, our study supports that the surface charging mechanism is plausible.