The production mechanism of the E_1' center by low-velocity friction based on the particle characteristics

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Electron spin resonance (ESR) dating is a method to determine an age of a fault movement using the unpaired electrons trapped in defects in fault materials. It is based on a premise that the ESR intensity, which means the number of unpaired electrons, accumulates by natural radiation and set to zero by the cataclastic deformation and/or frictional heating of a seismic slip [1]. The premise called as zero-setting, however, has not been demonstrated in the laboratory and its physical mechanism is still obscure. We have performed low-velocity friction experiments for the simulated-quartz gouges with different displacements or normal stresses [2]. The result indicates that the E_1' center (an unpaired electron trapped at oxygen vacancy) increases mainly by cataclastic deformation of low-velocity and low-pressure friction. However, the production mechanism has not been clarified. In this study, we analyze the particle characterization of gouges before and after friction tests. We will discuss the production mechanism of the E_1' centers related to the cataclastic deformation of frictional slip at the shallow depth.
Starting simulated-quartz gouge was commercial natural quartz sand which mainly consists of SiO_2. Low-velocity friction tests were performed for the gouges using a rotary shear apparatus. The inner diameter, outer diameter, and thickness without compaction of gouges were 20 mm, 30 mm and 1.5 mm, respectively. Slip rate and displacement were calculated at a diameter of 25 mm. Friction experiments were performed under two experimental conditions. Experiments to study the effect of displacements on the E_1' center (Experiment 1) were performed with a slip rate of 0.76 mm/s, a normal stress of 1.0 MPa and displacements from 0.28 to 1.4 m. Experiments to study the effect of normal stresses on the E_1' center (Experiment 2) were performed with a slip rate of 0.76 mm/s, normal stresses from 1.0 to 15 MPa and a displacement of 0.57 m. ESR measurements were conducted for gouges (see [2] for detail). Particle characterizations were carried out for gouges using Morphologi G3 (Malvern Instruments Ltd.). We estimated the specific surface area from particle size distribution obtained from the particle characteristics and formula [3].
In experiment 1, ESR intensity increased with displacements and reached about 120 % at a displacement of 0.85 m. The intensity was kept constant about 120 % (average) with further increases in displacements upto 1.4 m. Specific surface area also increased with displacements and reached about 540 % at a displacement of 0.85 m. The surface area was kept constant about 470 % (average) with the further increases in normal stresses from upto 1.4 m. In experiment 2, ESR intensity increased with normal stresses and reached about 140 % at a normal stress of 2.9 MPa. The intensity was kept constant about 120 % (average) with further increases in normal stresses upto 15 MPa. Specific surface area increased with the normal stresses and reached 510 % at a normal stress of 2.9 MPa. The surface area was kept constant about 370 % (average) with the further increases in normal stresses from upt 15 MPa. This clear correlation between specific surface area and the ESR intensity indicate that the E_1' centers are produced on the newly formed surfaces depending on the degree of cataclastic deformation. According to this study, cataclastic deformation of frictional slip at the shallow depth can not cause zero-setting of the ESR intensity of quartz grains. In order to prove the zero-setting of ESR intensity, we should consider the other effects (e.g., frictional heat, deformations without grain reduction) .

Reference

1. Ikeya, et al., 1982. *Science*. **215**, 1392-1393.
2. Tanaka et al., 2019. *Abstract in the conference of the 126th Annual Meeting of the Geological Society of Japan. (Japanese)*
3. Arakawa, 1969. *Journal of the Research Association of Powder Technology*. **6**, 31-38. (Japanese)

Keywords: Electron Spin Resonance (ESR), Low velocity friction, Particle characteristics

