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A ferrimagnetic resonance signal produced by fault frictional heating

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Foliated pseudotachylyte was found along the Nojima Fault that moved in the 1995 Kobe Earthquake (Otsuki, 2001). A FMR (ferrimagnetic resonance) signal of gamma-Fe2O3 consisting of bulky trivalent iron ions was detected from the foliated pseudotachylyte by ESR (Electron Spin Resonance) measurement (Fukuchi, 2001). This FMR signal can appear by heating the Nojima fault gouge, so gamma-Fe2O3 in the pseudotachylyte may have been produced by thermal dehydration of gamma-FeOOH [gamma-Fe2O3 H2O] in the Nojima fault gouge at the time of ancient fault movements (Fukuchi et al., 2001).

In this work, we try to reproduce the Nojima pseudotachylyte using a new rotary-shear high-speed frictional testing machine (Shimamoto and Tsutsumi, 1994). Experimental conditions are as follows: the axial stress is 0.61 MPa, the rotational speed is 500-1500 rpm, and the duration of slip is about 5-15 seconds. As for the experimental gouge sample, the Nojima fault gouge screened into 8-20 microns was used. The gouge sample was put between two specimens made of silica glass, so we could visually observe the fault surface after shear tests. The diameter of the silica-glass-specimen is about 25mm. Furthermore we used a teflon ring to prevent fault gouge from leaking out. After the shear test under the rotational speed of 1500rpm and the duration of about 10 seconds, the surface of the fault gouge changes into black pseudotachylyte-like material. On the other hand, the concentric traces of thermal dehydration is observed on the surface of the fixed side of the fault gouge. Since the fault gouge used for the shear test had been dried for 1 day at 60 degree C, the thermal dehydration is probably attributed to crystal water in hydrous minerals such as clay minerals or gamma-FeOOH in the fault gouge. The fault gouge after the shear test was divided into four portions of 0-3mm, 3-6mm, 6-9mm and 9-12.5mm on the basis of the circumference (=0mm) of the circular shearing plane. We measured ESR spectra of each portion. The equivalent slip rates along the four portions are respectively 1.74m/s (0-3mm), 1.27m/s (3-6mm), 0.81m/s (6-9mm) and 0.37m/s (9-12.5mm) (Shimamoto and Tsutsumi, 1994). As a result of ESR measurements, the portion of 0-3mm has the largest FMR signal intensity of gamma-Fe2O3 as well as the fault gouge after heating in an electric furnace for one minute at 500 degree C. The FMR signal intensity decreases with approaching to the center of the circular shearing plane. The black pseudotachylyte-like material and the FMR signal have been detected from the fault gouge just on the Nojima fault plane in the DPRI 500m drill core samples (Fukuchi and Imai, 2001). Since the FMR signal can be produced from muddy fault gouge containing clay minerals such as smectite, we can use it to detect seismic frictional heating for a wide range of faults.

Generally, the ESR signal intensity and magnetic susceptibility of a paramagnetic material are proportional to each other because they are attributable to the spin concentration in the material. There is a linear relationship between the FMR intensities and magnetic susceptibilities obtained from the Nojima pseudotachylyte and the fault gouge heated. Thus, the black pseudotachylyte-like material, FMR signal and magnetic susceptibility are very important as indicators for detection of seismic frictional heating.