Frictional discharges by rock friction and seismo-electromagnetic phenomena

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From rock fracture and hypervelocity impact experiments, the generation of plasmas and charged particles, in addition to the emission of electromagnetic waves and light have been proposed to play a role in seismo-electromagnetic phenomena (e.g., earthquake luminosity and electromagnetic emissions before earthquakes). However, the previously reported phenomena based rock deformation experiments accompanies catastrophic rock failure and therefore do not seem to be applicable to the electromagnetic precursors observed before critical main shocks. Thus, why anomalous electromagnetic signals precede the main shock has been still a major problem to be solved. Generally, earthquakes occur on systems of pre-existing active faults locked by asperities sharing the total tectonic stresses. It is natural to consider that the source of the electromagnetic anomaly can be responsible for the asperity shearing during seismogenic processes. From a pin-on-disk experiment that simulates the motion of an asperity on a fault plane, we report luminous (photon) emissions at frictional contacts between natural rock minerals (Brazilian quartz and natural pyrite) as a source of the seismo-electromagnetic phenomena. From spectroscopic measurements, we show that the photon emissions are caused by dielectric breakdown of ambient gases due to frictional electrification. The generation of plasmas was found to occur under normal stress as low as 4 MPa and at sliding speed one or two orders of magnitude less ($v = 10^{-2}$-10^{-1} m/s) than seismic speed of 1 m/s. This means that the plasma generation does not require high normal stresses needed to fracture rocks and sliding speeds as high as seismic rates. Thus microscopic slips along asperities on fault surfaces at sliding speed one or two orders of magnitude less than seismic rates may produce enough charges to electrify atmospheric air or flowing natural gases, and generate the frictional discharge plasmas before a macroscopic slip at seismic rates (~1m/s), i.e. main shock of earthquake. On the other hand, once a fault slips toward large displacements at seismic speed of the order of m/s, frictional heating prevents electrification of fault surfaces, and suppresses the generation of frictional discharges during the main shocks of earthquakes. Thus, by these mechanisms, the generation of frictional discharges might be hindered at the main shocks of earthquakes.