Seebeck coefficient of olivine: Implausible Mercury's thermoelectric dynamo

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The Mercury's magnetic fields are known to be weaker than that predicted by conventional dynamo models. In order to explain the Mercury's weak magnetic field, several models are proposed (Stanley and Glatzmaier, 2010). One of them is the thermoelectric dynamo, which drive the dynamo via the thermoelectric force (Stevenson, 1987). The field strength is proportional to the relative Seebeck coefficient between the core and the mantle. Because the Seebeck coefficient of insulators is more than one order larger than that of metals, the Seebeck coefficient of Mercury's mantle is the central parameter. Therefore, we investigated the Seebeck coefficient of mantle minerals from the first-principles calculations. The structure relaxation and band structure calculations were conducted by using the Quantum ESPRESSO package. The bandgap energy was calibrated by means of the quasiparticles self-consistent GW (QSGW) approximation adopted in the ecalj package. The Seebeck coefficient was calculated via the Boltzmann equation implemented in the BoltzTraP package. The results indicate that the Seebeck coefficient of forsterite with a small amount of dopant exhibit comparable to that previously thought (|S| ~ 1000 mV/K). This value may constrain the upper limit. The Mercury's mantle may contain ~3wt% FeO (Robinson and Taylor, 2001). The Fe substitution and O vacancy act as donor, which is predicted to reduce the Seebeck coefficient, significantly. The field strength also depends on the electrical conductivity of the mangle. Recent high pressure experiments suggest that the electrical conductivity of the Earth's mantle is ~ 10^{-2} Sm. Considering the both of the Seebeck coefficient and the electrical conductivity of mantle material, the field strength is calculated to be ~ 0.1 nT, which is significantly weaker than the observed value of 300 nT. Therefore, we conclude that the thermoelectric dynamo cannot generate the Mercury's magnetic fields.

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