Non equilibrium thermodynamics of the spin Seebeck and spin Peltier effects.

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The longitudinal spin Seebeck [1] and spin Petier [2] effects are two thermomagnetic effects resulting from passage of a magnetic moment current (spin current) on a ferromagnetic insulator. These effects are well seen in bi-layers composed by a ferromagnetic insulator (like YIG) and a metal with a large spin Hall effect (like Pt). They are reciprocal effect, as a consequence of the Onsager reciprocity relations of non-equilibrium thermodynamics of fluxes and forces [3], however the reciprocity is so evident, as in the case of thermoelectric materials, because the magnetic moment is a non conserved quantity. In the present talk we will review both the experimental details and the physical microscopic origin of the two effects. We will then focus on their thermodynamics by the deriving the effective force for the magnetic moment current. This force turns out to be the gradient of the thermodynamic effective field expressing the distance from equilibrium [4]. Within this framework the constitutive equations for the magnetic moment current and the heat current can be appropriately worked out and the spin Seebeck and spin Peltier effects are both attributed to the coefficient ε_M, the absolute thermomagnetic power coefficient of the ferromagnetic insulator. The coefficient ε_M can be both measured, to verify experimentally the reciprocity, or derived from a microscopic theory [5,6]. Finally, in the talk we will address the possibility to extend this thermodynamic approach to vector quantities with aim to address the thermodynamic reciprocity of spin pumping and spin Hall torque effects [7-9].

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