Spin relaxation in metals: Anisotropy and scattering resonance effects

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We study the relaxation of spin-polarized conduction electrons in metals and ultrathin metallic films on a theoretical and ab-initio basis. We discuss two mechanisms that can affect the ratio of spin-flip to spin-conserving scattering rate by orders of magnitude [1,2]. These mechanisms are included in the general framework of the Elliott-Yafet theory [3] that is based on the concept of spin-mixing of degenerate Bloch states accompanied by scattering events.

The first mechanism [1] is related to the form of the scattering potential and occurs in the presence of resonant impurity scattering where an incident electron spends a long delay time on the impurity site before decaying back into the Bloch-state continuum. During this delay time the incident spin suffers a precession due to the impurity spin-orbit coupling so that a spin flip can occur even for weak spin-orbit coupling. We establish this intuitive picture by ab-initio calculations of the spin-flip scattering rate and delay time of impurities in Cu and Au.

The second mechanism [2] is related to the anisotropy of the matrix elements of the spin-orbit operator with respect to the choice of spin quantization axis (SQA) for the Bloch states in combination with degeneracies or near-degeneracies on the Fermi surface. These degeneracies can lead to spin-flip hot spots [4] or even extended hot areas [2] on the Fermi surface where the value of spin-mixing of the Bloch states is close to the maximal 1/2. This value, however, strongly depends on the orientation of the initial spin polarization defining the SQA, yielding for several materials a gigantic anisotropy with respect to the SQA with a so-far calculated record value of 830% for hcp Hf. A special role is played by Rashba-type of states in thin films that give a strong contribution to the anisotropy [5] due to their intrinsic spin polarization.

Our ab-initio calculations are based on the Korringa-Kohn-Rostoker Green function method.

References

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