# SPIN-DEPENDENT TRANSPORT : DIFFUSIVE ASPECTS

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## 1- Generalities

*a- Definition of the characteristic physical parameters (times, lengths)*

In the first part of my course, I will define the characteristic physical parameters occurring in the physics of spin-dependent transport: momentum relaxation time ($\tau_p$), spin relaxation time ($\tau_{sf}$), mean free path ($\lambda$), spin mean free path($\lambda_{sf}$), spin diffusion length ($l_{sf}$). The link between all these quantities will be largely emphasized and a special care will be given by considering scattering by *s-d* interactions in a model of two electron baths.

*b- Cyclotron magnetoresistance, Extraordinary hall effect, Anisotropic Magnetoresistance (AMR)*

I will describe, quite shortly, the classical cyclotron magnetoresistance before describing more in details the effect of anisotropic magnetoresistance, Extraordinary Hall effect (skew scattering and side jump effects) and Planar Hall effect.

## 2- Giant Magnetoresistance in Metallic Multilayers

*a- CIP-GMR (Current in Plane)*

I will then describe the pioneer experiments of CIP Giant Magnetoresistance observed on Fe-Cr multilayers and give some insights of the microscopic origins.

In a second part, I will deeply develop the effect of Giant Magnetoresistance in the geometry perpendicular to the plane (CPP-GMR) by stressing on very important notion of spin accumulations effects. I will show, through a very simple model, how the magnetoresistance is related to the level of spin accumulation then giving rise to the series resistor picture of CPP-GMR. I will comment the importance of bulk effects (ex:Co/Cu) as well as interfacial contributions arising from spin-reflections or spin-dependent tunnelling. Both theoretical and experimental aspects will be developed.

b- *Diffusion Mechanism in CPP geometry (Current perpendicular to the Plane)*

*c- Spin-flip Mechanism in Metals and Ferromagnets (FM)*

*d- Spin accumulation effects*

*e- CPP-GMR (Theory and physical experiments)*

## 3- Spin-dependent transport in Semiconductors

In the last part of my course, I will review the key issues, fundamentals as well as experimental, related to spin injection and detection across semiconductor nanostructures which represents an important challenge at the frontier between spintronics & Quantum Computing. I will discuss the different mechanisms of spin-flips occurring within semiconductors. I will develop the fundamental problem of impedance matching occurring at the interface between a semiconductor (SC) and a ferromagnet (FM) preventing an efficient spin injection into SC and the solution for matching the impedance. I will develop the different experimental methods (time-resolved, optical, transport) employed to study the spin dynamics within semiconductors by emphasizing the Experiments lead in our laboratory on spin injection and detection of spins through p-type GaAs quantum wells.

*a- Spin relaxation Mechanism in Semiconductors (SC)*

*b- Impedance matching at FM/SC interfaces*

*c- Conditions for GMR with semiconductors*

*d- Exemple : Probing the spin lifetime in semiconductors by MR measurements (Experiments and Theory)*