Fundamentals of Nanoelectronics

ECE495 - Session 36, Nov 23, 2009

Spin Valve

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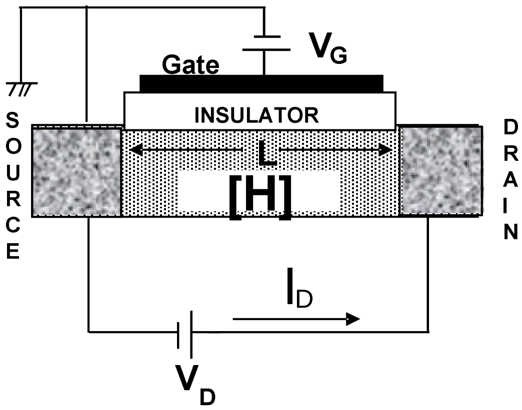
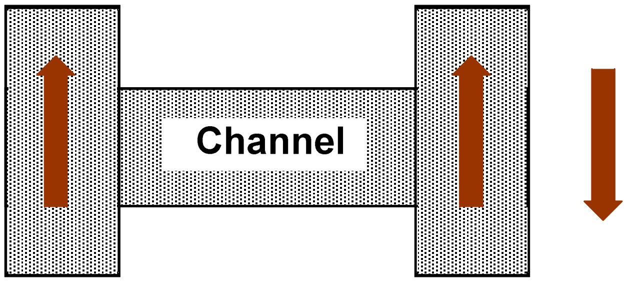
Review

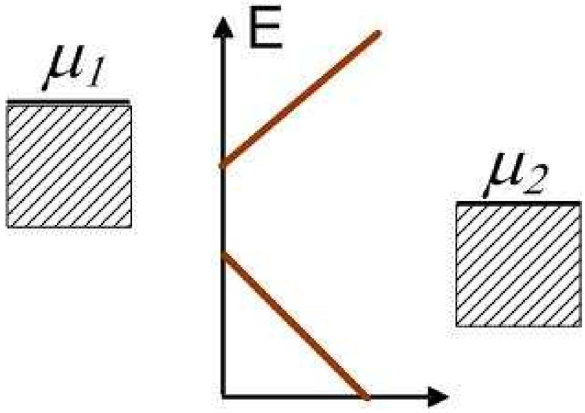
$$I = \frac{q}{h}\int dE \frac{M(E)\lambda}{L+\lambda}(f_1 f_1 - f_2) \quad Semi - classical\, Viev$$

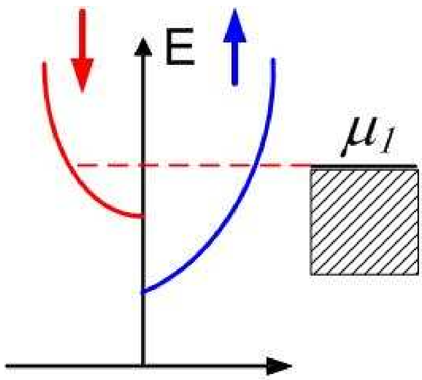
$$I = \frac{q}{h}\int dE Trace[\Gamma_1 G \Gamma_2 G^{+}](f_1 - f_2) \quad Full\;\; Quantum\, View$$

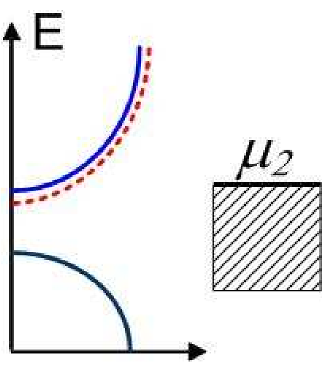


Spin-valve









In magnetic contact one spin moves easier than the other.

If two magnet in two contacts are in the same direction we call it parallel (P) and if they are in opposite direction we call it anti-parallel (AP).

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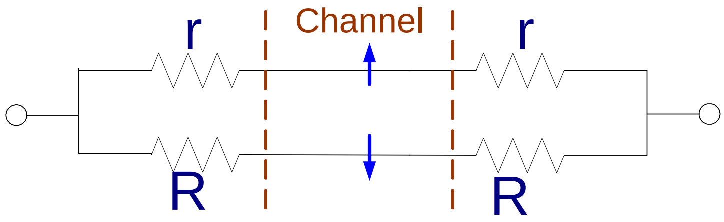


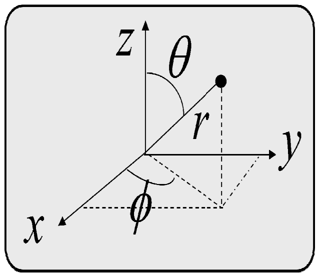
R_P: effective parallel resistance

R_{AP}: effective anti-parallel resistance

$$R_P = \frac{2r.2R}{2r+2R} = \frac{2rR}{r+R}$$

$$R_{AP} = \frac{r+R}{2} \Rightarrow \frac{R_{AP}}{R_P} = \frac{\frac{r+R}{2}}{\frac{2rR}{r+R}} = \frac{(r+R)^2}{4rR} = \frac{(r+R)^2}{(r+R)^2-(r-R)^2} \geq 1$$

Semiconductor is not good for the channel because it has a great resistance in front of contact resistance difference in parallel and anti-parallel modes.

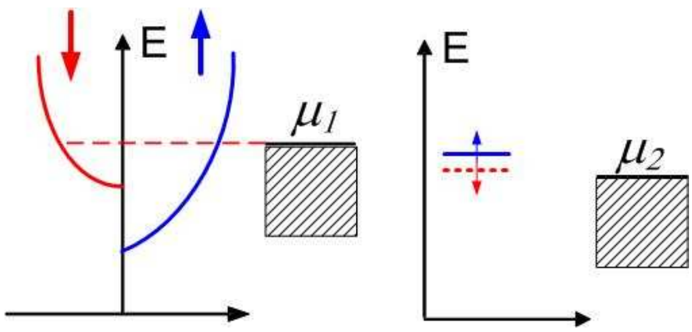


For spin we use ***spinor*** instead of vector.

$$\begin{matrix} Vector \\ \begin{pmatrix} \sin\theta\cos\varphi \\ \sin\theta\sin\varphi \\ \cos\theta \end{pmatrix} \end{matrix} \Leftrightarrow \begin{matrix} Spinor \\ \begin{pmatrix} \cos\frac{\theta}{2} e^{-i\varphi/2} \\ \sin\frac{\theta}{2} e^{+i\varphi/2} \end{pmatrix} \end{matrix}$$

$$Trace\ (\Gamma_1 G \Gamma_2 G^+)$$

$$H = \begin{bmatrix} \varepsilon & 0 \\ 0 & \varepsilon \end{bmatrix} \qquad \begin{matrix} \gamma_\uparrow \equiv \alpha \\ \gamma_\downarrow \equiv \beta \end{matrix}$$



$$[\Sigma_1] = -\frac{i}{2}\begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix} and\ [\Sigma_2] = -\frac{i}{2}\begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix}$$

$$\Gamma_1 = i[\Sigma_1 - \Sigma_1^+] = \begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix} \quad \Gamma_2 = i[\Sigma_2 - \Sigma_2^+] = \begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix}$$

$$\begin{matrix} & +\hat{z} & -\hat{z} \\ +\hat{z} & & \\ -\hat{z} & & \end{matrix} \begin{bmatrix} & \\ & \end{bmatrix} = \begin{matrix} & +\hat{x} & -\hat{x} \\ +\hat{z} & & \\ -\hat{z} & & \end{matrix} \begin{bmatrix} & \\ & \end{bmatrix} \begin{matrix} & +\hat{x} & -\hat{x} \\ +x & & \\ -x & & \end{matrix} \begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix} \begin{matrix} & +\hat{z} & -\hat{z} \\ +\hat{x} & & \\ -\hat{x} & & \end{matrix} \begin{bmatrix} & \\ & \end{bmatrix}$$

To convert our magnet in x direction to z direction we need two other matrices which are each conjugate (U and U^+).

For x direction θ = π/2 and ϕ = 0

$$U = \begin{matrix} & +\hat{x} & -\hat{x} \\ +\hat{z} & & \\ -\hat{z} & & \end{matrix} \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \text{ and } U^+ = \begin{matrix} & +\hat{z} & -\hat{z} \\ +\hat{x} & & \\ -\hat{x} & & \end{matrix} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} \\ -1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix}$$