# Fundamentals of Nanoelectronics

ECE495 - Session 34, Nov 18, 2009

**Transmission**

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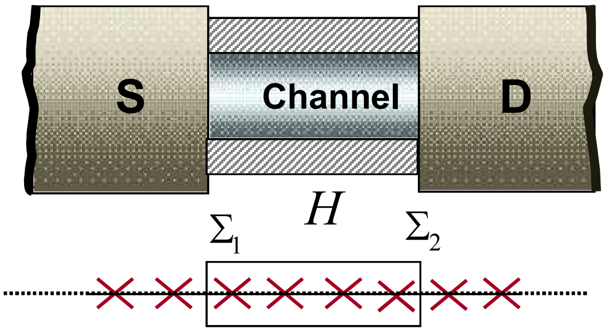
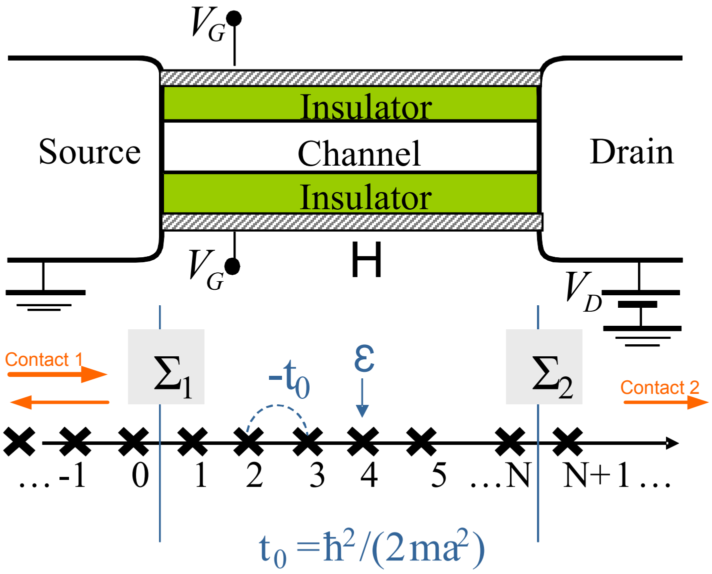



We've learned in this course that we can describe the properties of any device a Hamiltonian H. For current flow however we also need to take into broadening which comes from the self energy functions Σ.

## Example 1-D

For a one dimensional lead:




$$\Sigma_1 = \begin{bmatrix} * & \\ & \end{bmatrix} \quad \text{and} \quad H = \begin{bmatrix} \varepsilon & t \\ t & \varepsilon \end{bmatrix}$$

$$\text{and} \quad \Sigma_2 = \begin{bmatrix} & \\ & * \end{bmatrix} \quad \text{where} \quad * = -i\frac{\gamma_i}{2}$$

The important point to notice is that unlike H, Sigma is complex. The imaginary part indicates a finite lifetime and tells us how easily an electron can escape into the contact.

$$E\Psi_n = \varepsilon\Psi_n - t_0\Psi_{n-1} - t_0\Psi_{n+1}$$

$$\Psi_n = Ae^{ika} + Be^{-ika} \quad \text{and } E = \varepsilon - 2t_0 \cos ka$$

For n=N: $\Psi_n = Ae^{ika}$ there is no reflection then $Be^{-ika} = 0$

$$E\Psi_N = -t_0\Psi_{N-1} + \varepsilon\Psi_N - t_0\Psi_{N+1}$$

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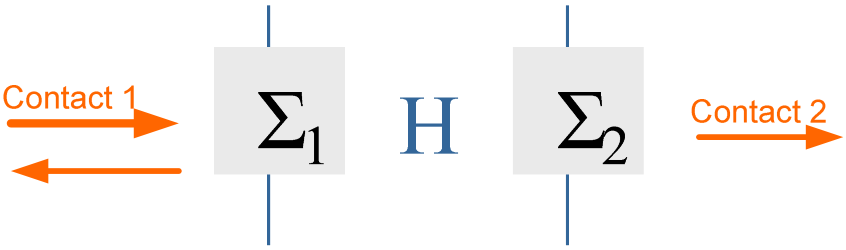
$$\Psi_{N+1} = Ae^{ika(N+1)} \text{ and } \Psi_N = Ae^{ika(N)} \Rightarrow \frac{\Psi_{N+1}}{\Psi_N} = e^{ika}$$

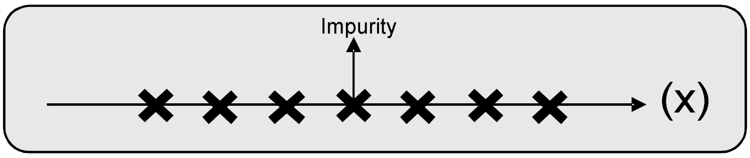
We can do it only on the last point because we don't have any reflection.

$$E\Psi_N = -t_0\Psi_{N-1} + (\varepsilon - t_0e^{ika})\Psi_N$$

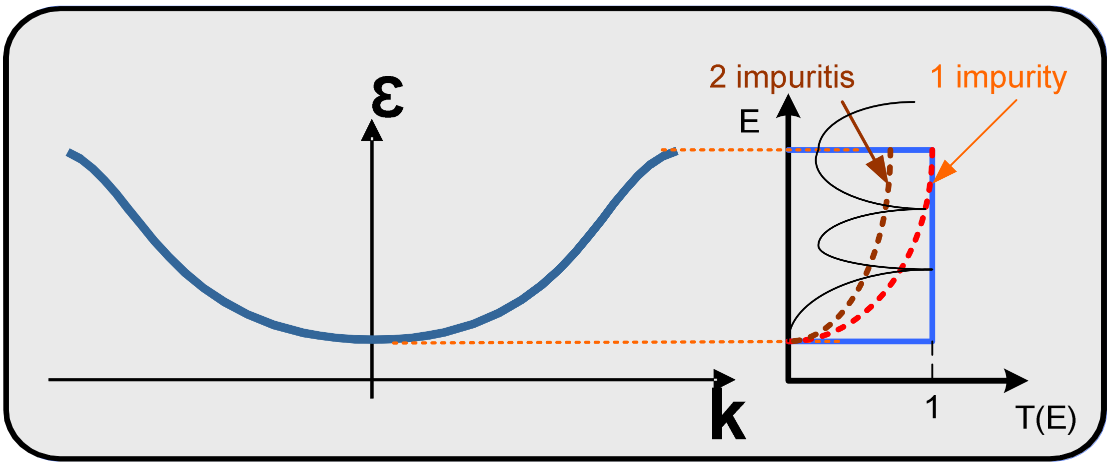



$$H = \begin{bmatrix} \varepsilon & -t_0 & & & \\ -t_0 & \varepsilon & -t_0 & & \\ & -t_0 & \varepsilon & \ddots & \\ & & \ddots & \ddots & \\ & & & & \varepsilon - t_0e^{ika} \end{bmatrix}$$

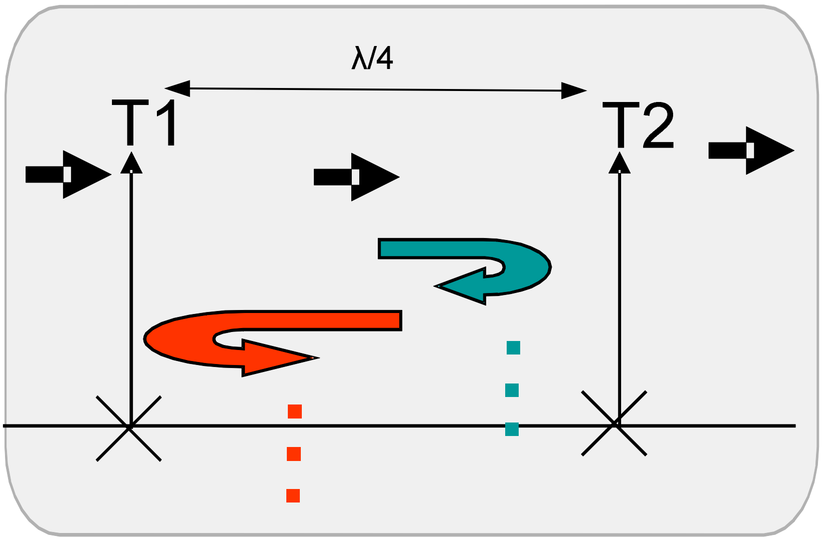
## Adding impurities




$$I = \frac{q}{h}\int dE\, Trace(\Gamma_1 G \Gamma_2 G^+)(f_1 - f_2)$$




In lower energy transmission is less because electron could not pass it – i.e. barrier – easily.




$E\Psi_N = -t_0\Psi_{N-1} + \varepsilon\Psi_N - t_0\Psi_{N+1}$

$\Psi_n = Ae^{ika} + Be^{-ika}$

$\Psi_0 = A + B \text{ and } \Psi_{-1} = Ae^{-ika} + Be^{+ika} = \Psi_0 e^{ika} + \underbrace{A(e^{-ika} - e^{ika})}_{\text{source term}}$

$[EI - H]\{\Psi\} = 0 \Rightarrow [EI - H - \Sigma_1 - \Sigma_2]\{\Psi\} = S_1$