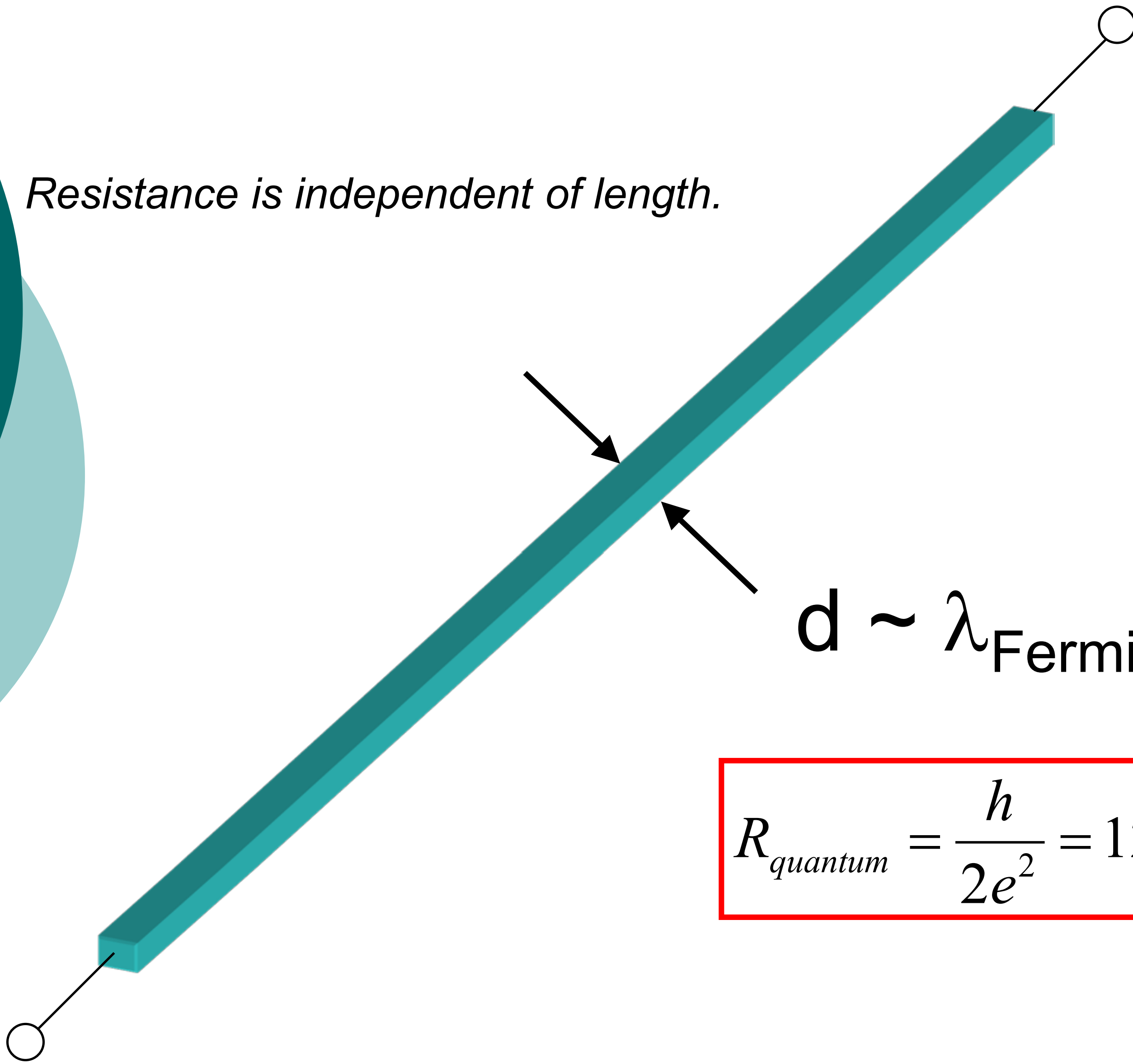
Lecture 11: Quantum point contact

Resistance is independent of length.

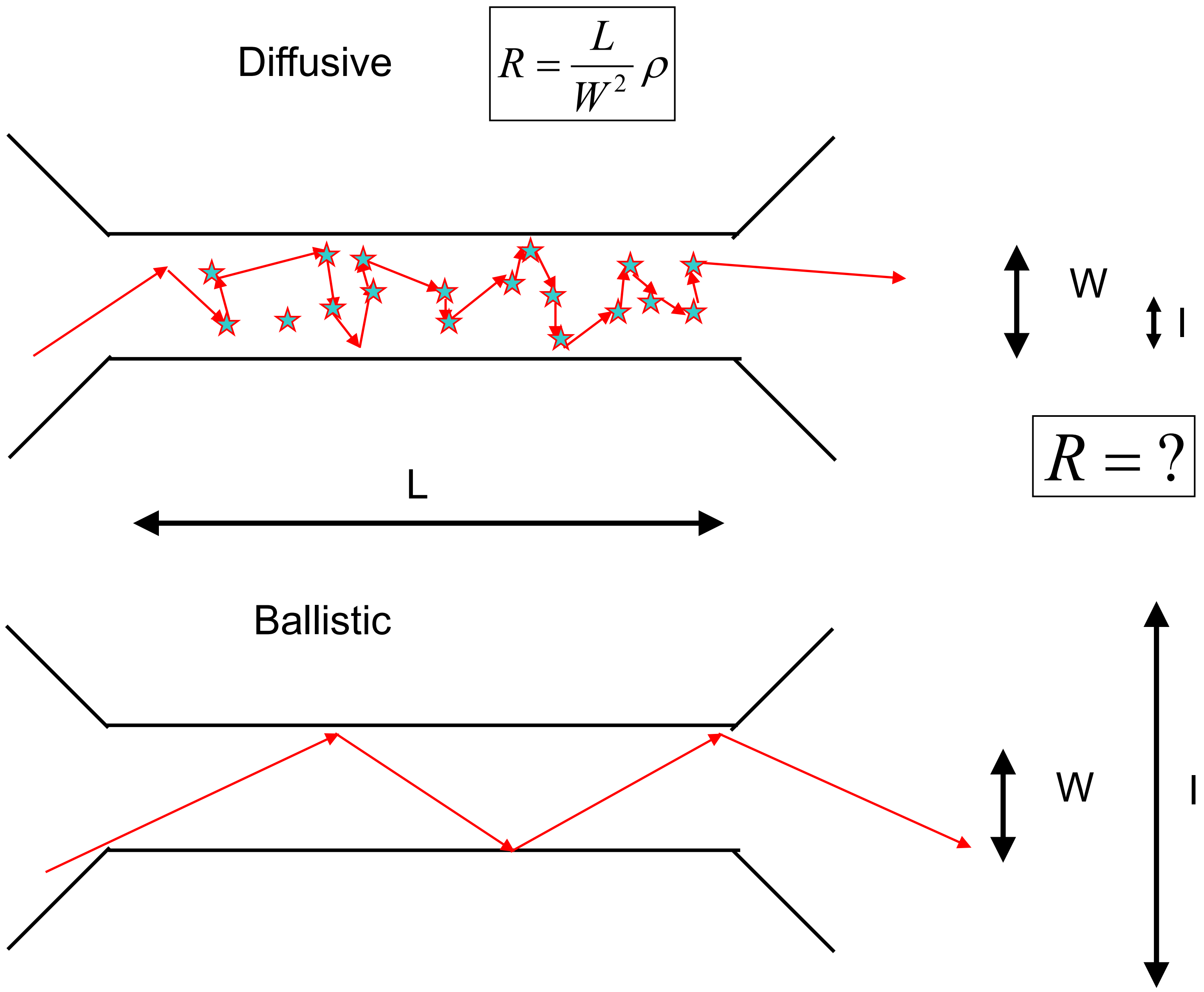


$$R_{quantum} = \frac{h}{2e^2} = 12.5\ k\Omega$$

Readings this lecture covers

- Ferry pp. 124-139
- Van Wees PRL (reading packet)
- Marcus APL (reading packet)
- Zhou APL (reading packet)

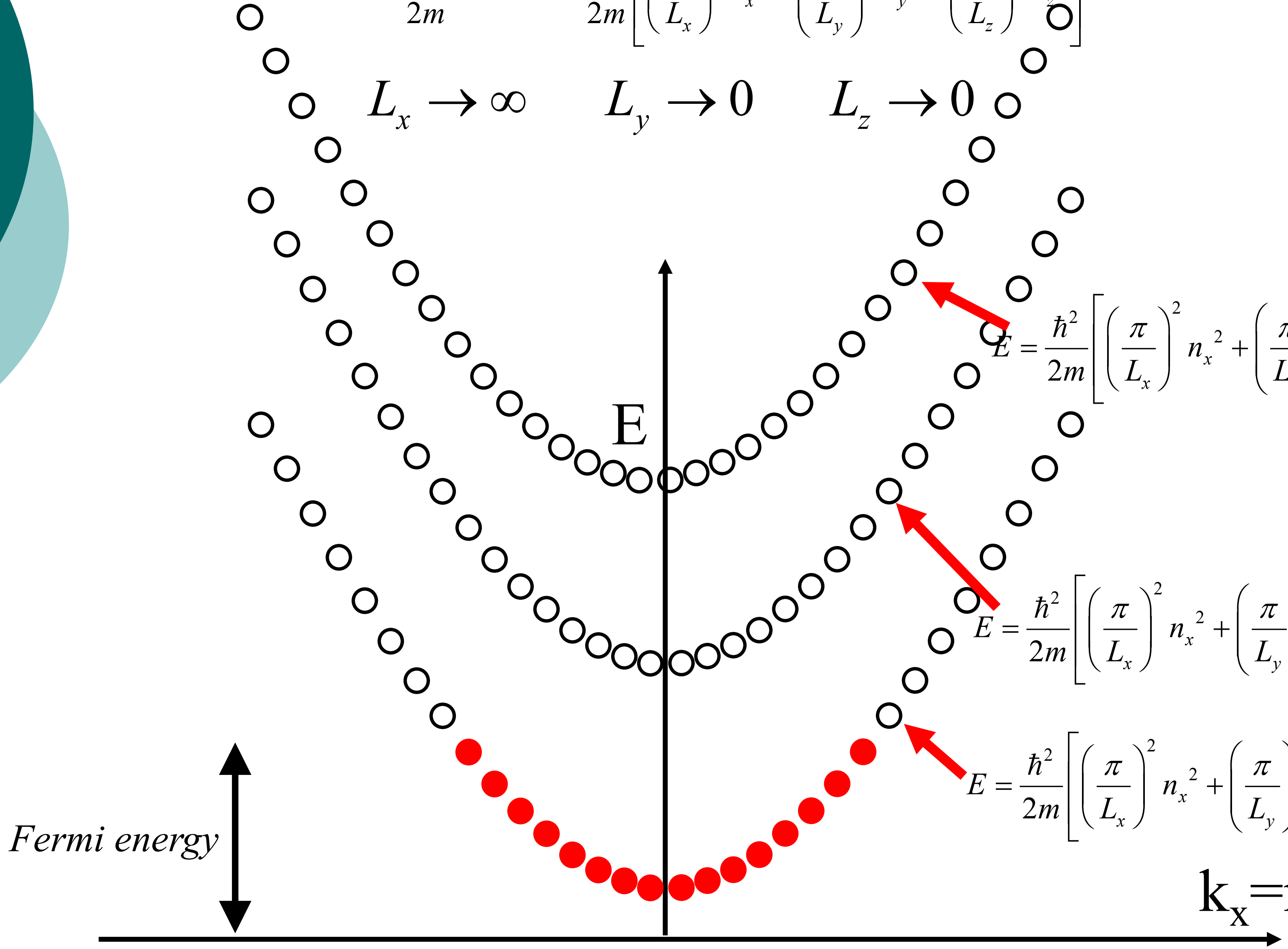
Ballistic vs. diffusive transport



1d system:

$$E = \frac{\hbar^2 (k_{n_x}{}^2 + k_{n_y}{}^2 + k_{n_z}{}^2)}{2m} = \frac{\hbar^2}{2m}\left[\left(\frac{\pi}{L_x}\right)^2 n_x{}^2 + \left(\frac{\pi}{L_y}\right)^2 n_y{}^2 + \left(\frac{\pi}{L_z}\right)^2 n_z{}^2\right]$$

$$L_x \to \infty \qquad L_y \to 0 \qquad L_z \to 0$$



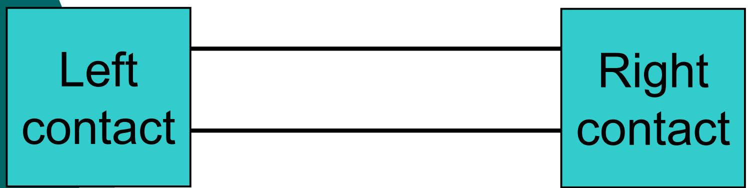
$$E = \frac{\hbar^2}{2m}\left[\left(\frac{\pi}{L_x}\right)^2 n_x{}^2 + \left(\frac{\pi}{L_y}\right)^2 3^2 + \left(\frac{\pi}{L_z}\right)^2\right]$$

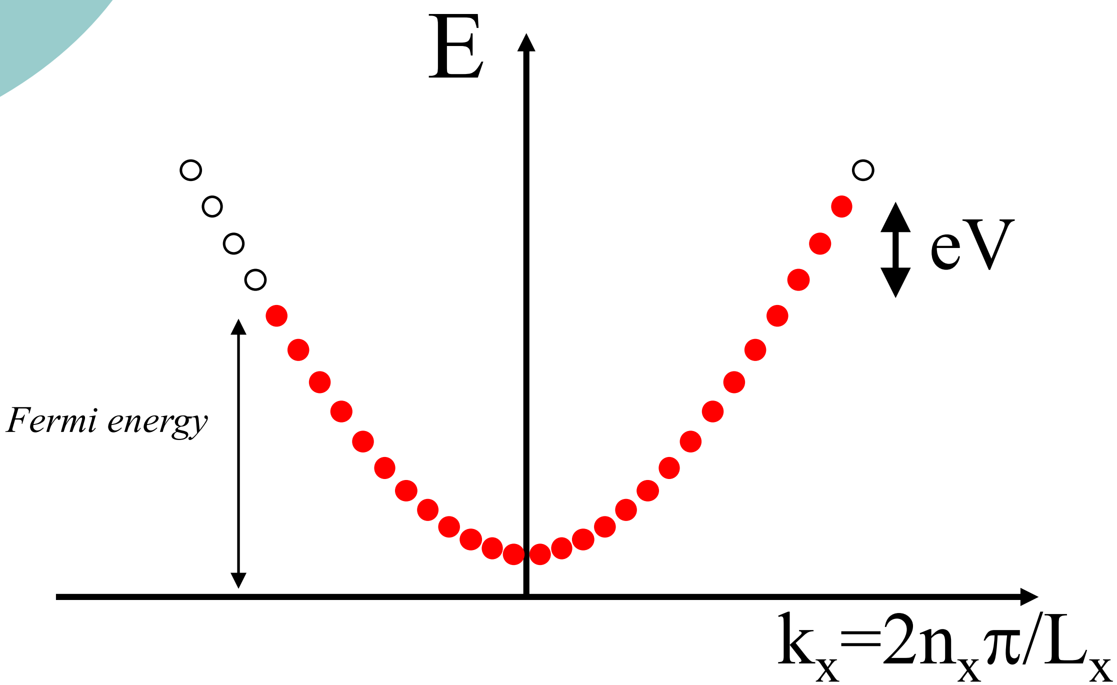
$$E = \frac{\hbar^2}{2m}\left[\left(\frac{\pi}{L_x}\right)^2 n_x{}^2 + \left(\frac{\pi}{L_y}\right)^2 2^2 + \left(\frac{\pi}{L_z}\right)^2\right]$$

$$E = \frac{\hbar^2}{2m}\left[\left(\frac{\pi}{L_x}\right)^2 n_x{}^2 + \left(\frac{\pi}{L_y}\right)^2 + \left(\frac{\pi}{L_z}\right)^2\right]$$

Resistance quantum

Ballistic conductor





$$R_{quantum} = \frac{h}{e^2} = 25\ k\Omega$$

With spin:

$$R_{quantum} = \frac{h}{2e^2} = 12.5\ k\Omega$$

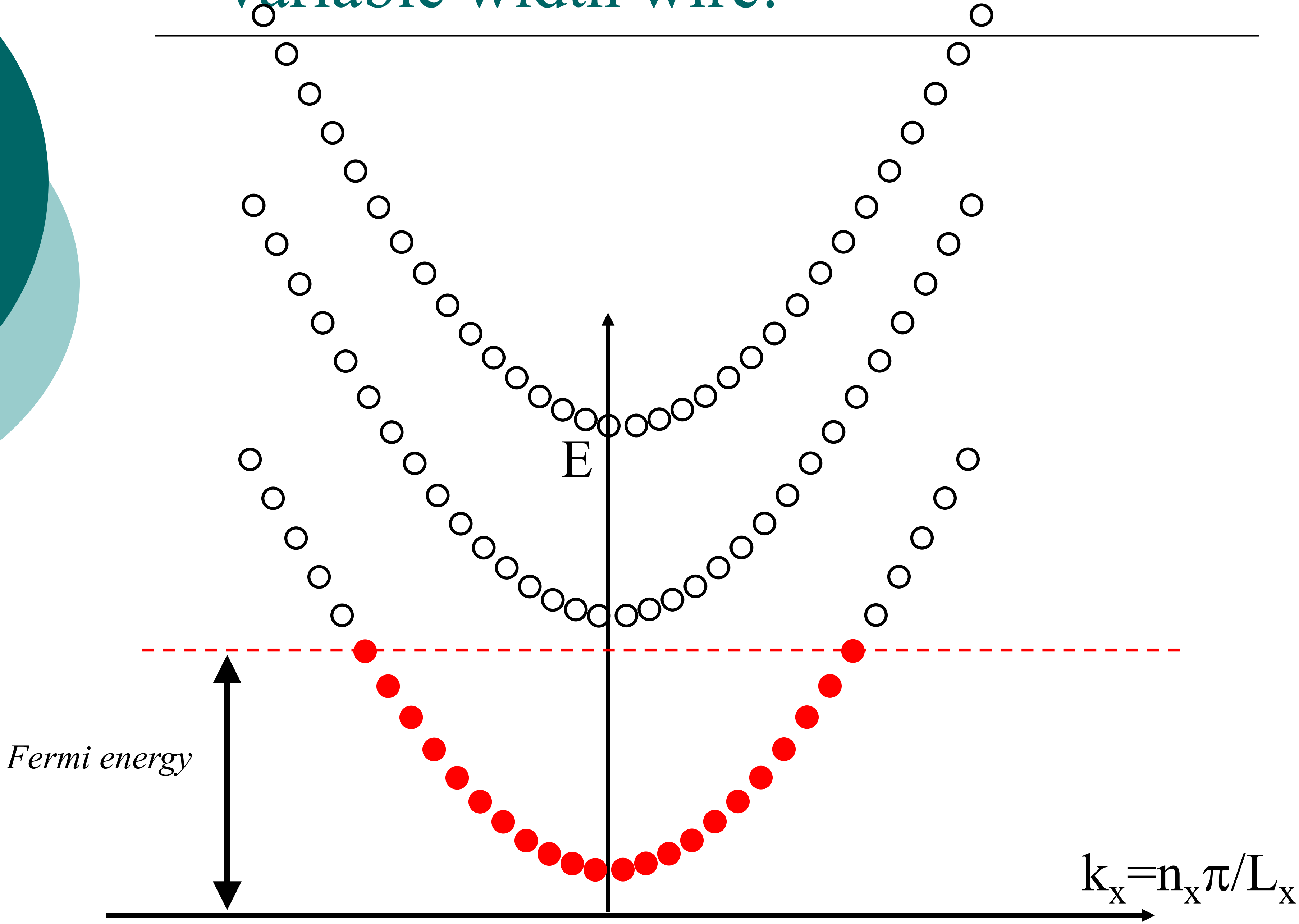
$$G_{quantum} = \frac{2e^2}{h}$$

If injection from leads is not perfect:

$$G = T\,\frac{2e^2}{h}$$

T is the transmission probability.

Variable width wire:



Landauer formula:

$$G = n\frac{2e^2}{h}$$

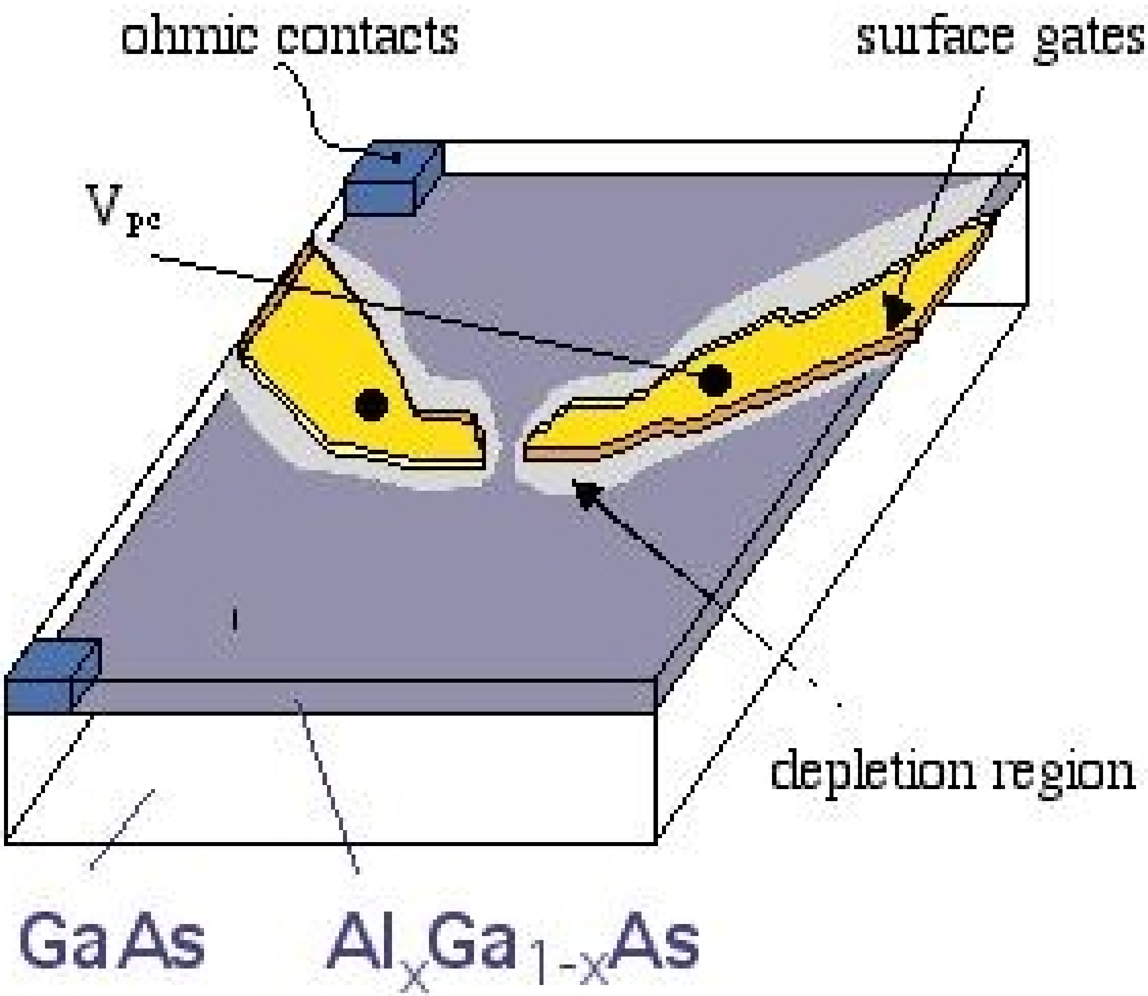
If the leads are not perfect injectors into each "channel" then:

$$G = \frac{2e^2}{h}\sum T_n$$

Experimental realizations:

- Pinch-off gate in semiconductor 2DEG (QPC)
- Break junction
- Electrochemical addition of atoms
- Scanning tunneling microscope

Quantum point contact



Quantum point contact

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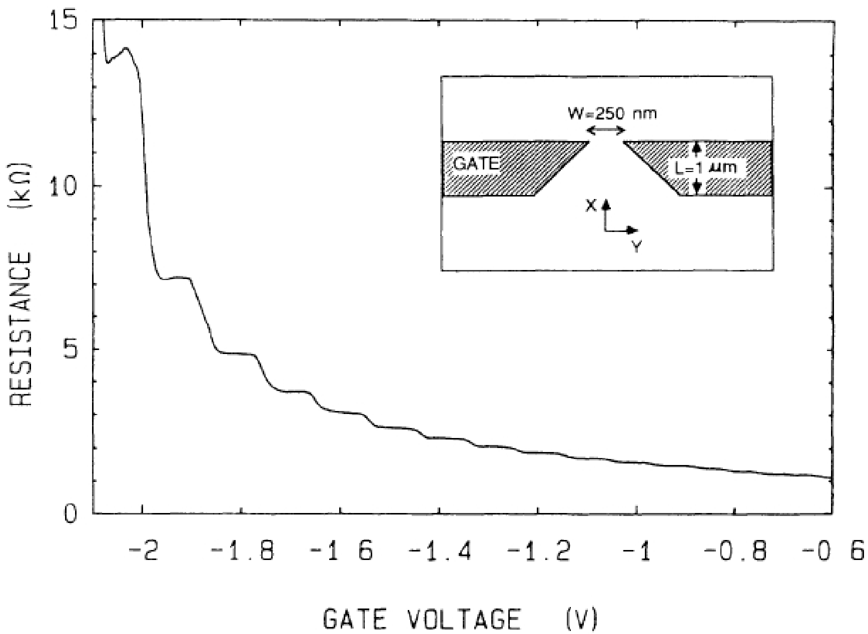


FIG. 1. Point-contact resistance as a function of gate voltage at 0.6 K. Inset: Point-contact layout.

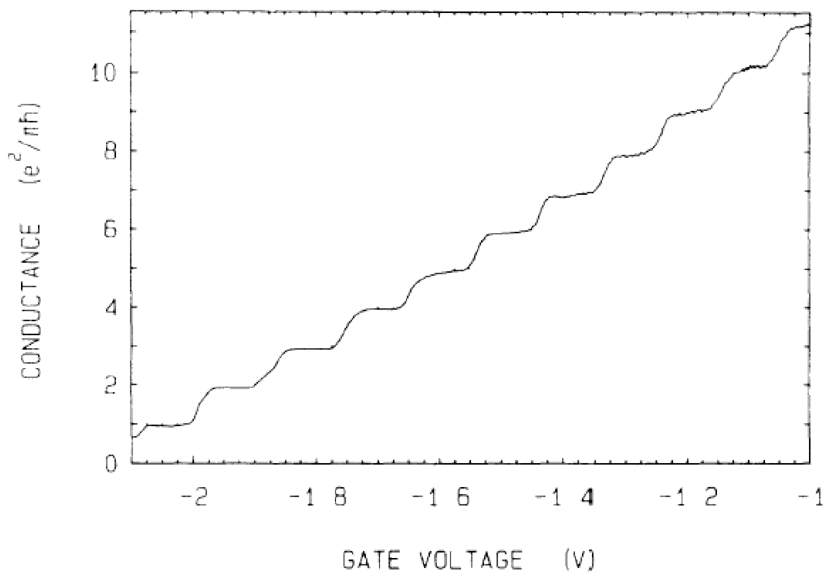


FIG. 2. Point-contact conductance as a function of gate voltage, obtained from the data of Fig. 1 after subtraction of the lead resistance. The conductance shows plateaus at multiples of $e^2/\pi\hbar$.

B.J. van Wees et al. (1988), Phys. Rev. Lett., **60**, 848.

0.7 anomaly

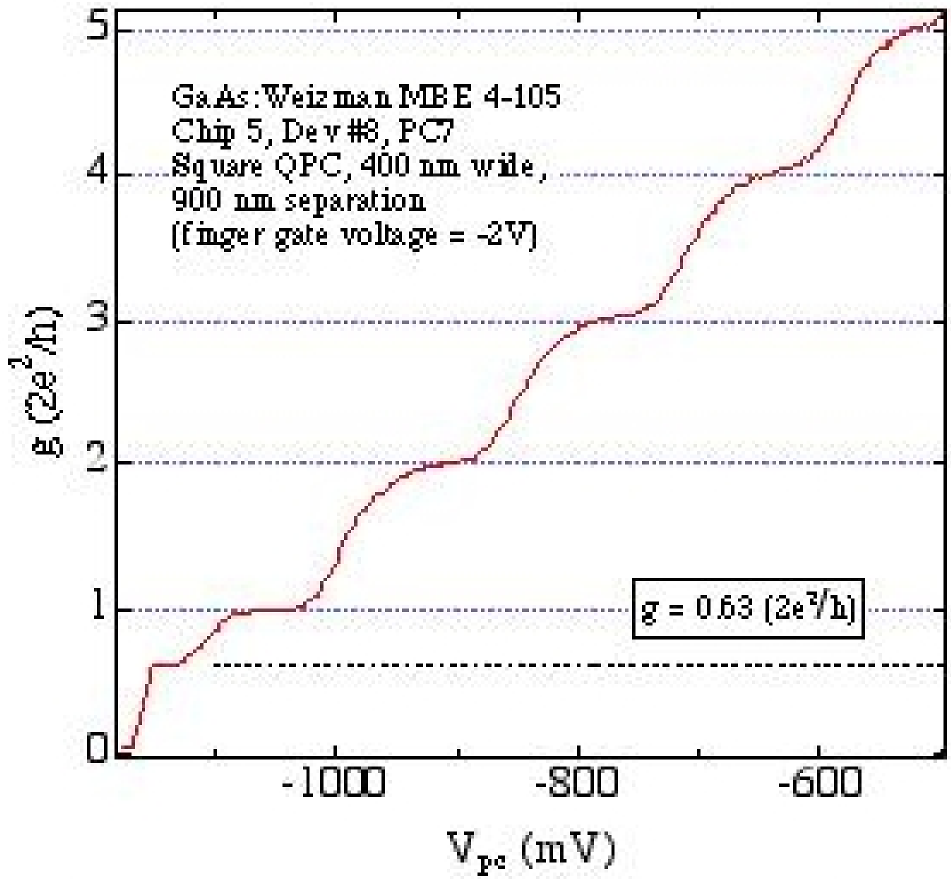
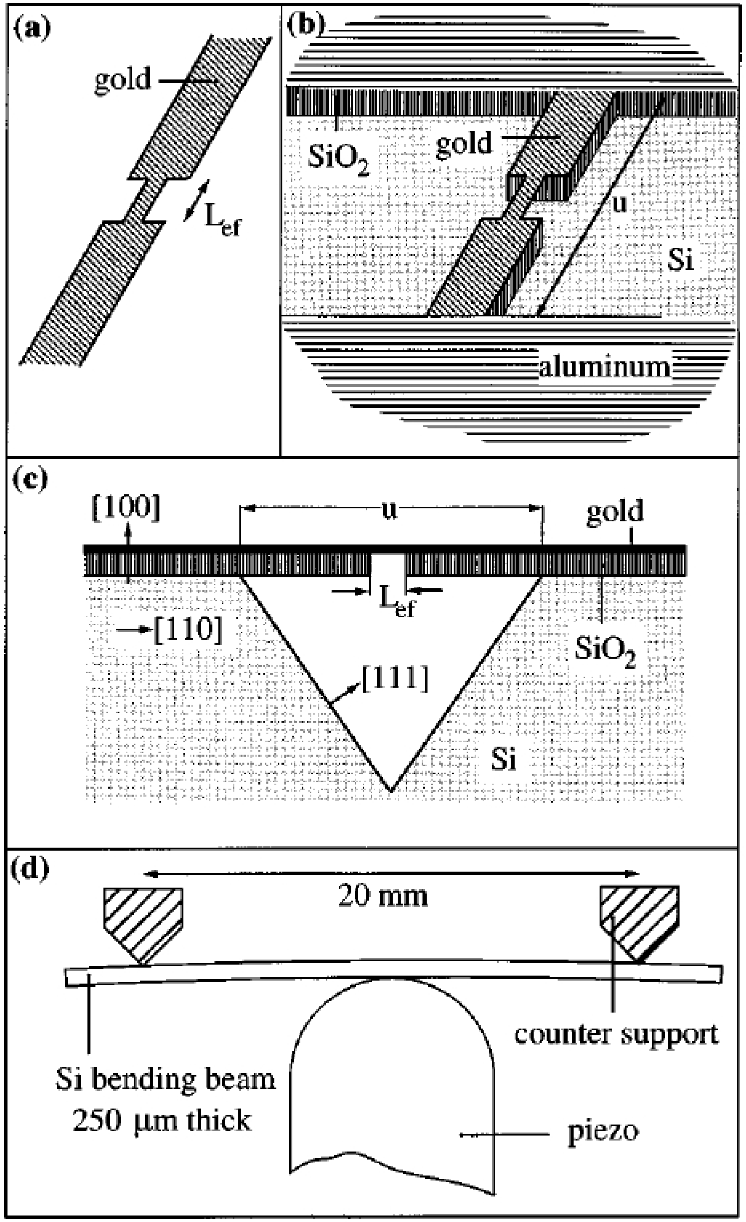
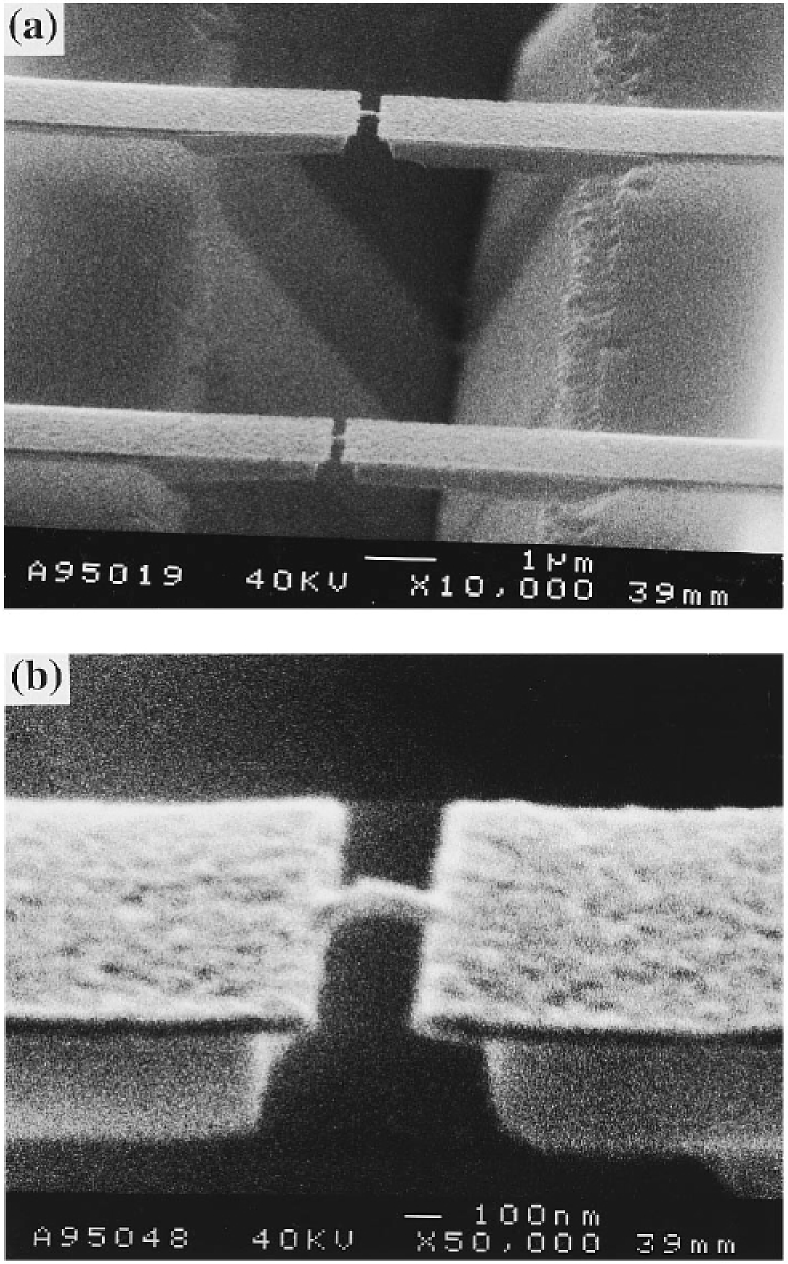


Figure 2: The conductance g through a point contact shows quantized plateaus at integer values of $2e^2/h$ with applied gate voltage, V_{pc}. This QPC shows a very prominent structure at ~0.6 ($2e^2/h$). The gates of this QPC are 400 nm wide and 900 nm apart.

Break junction





Microfabrication of a mechanically controllable break junction in silicon

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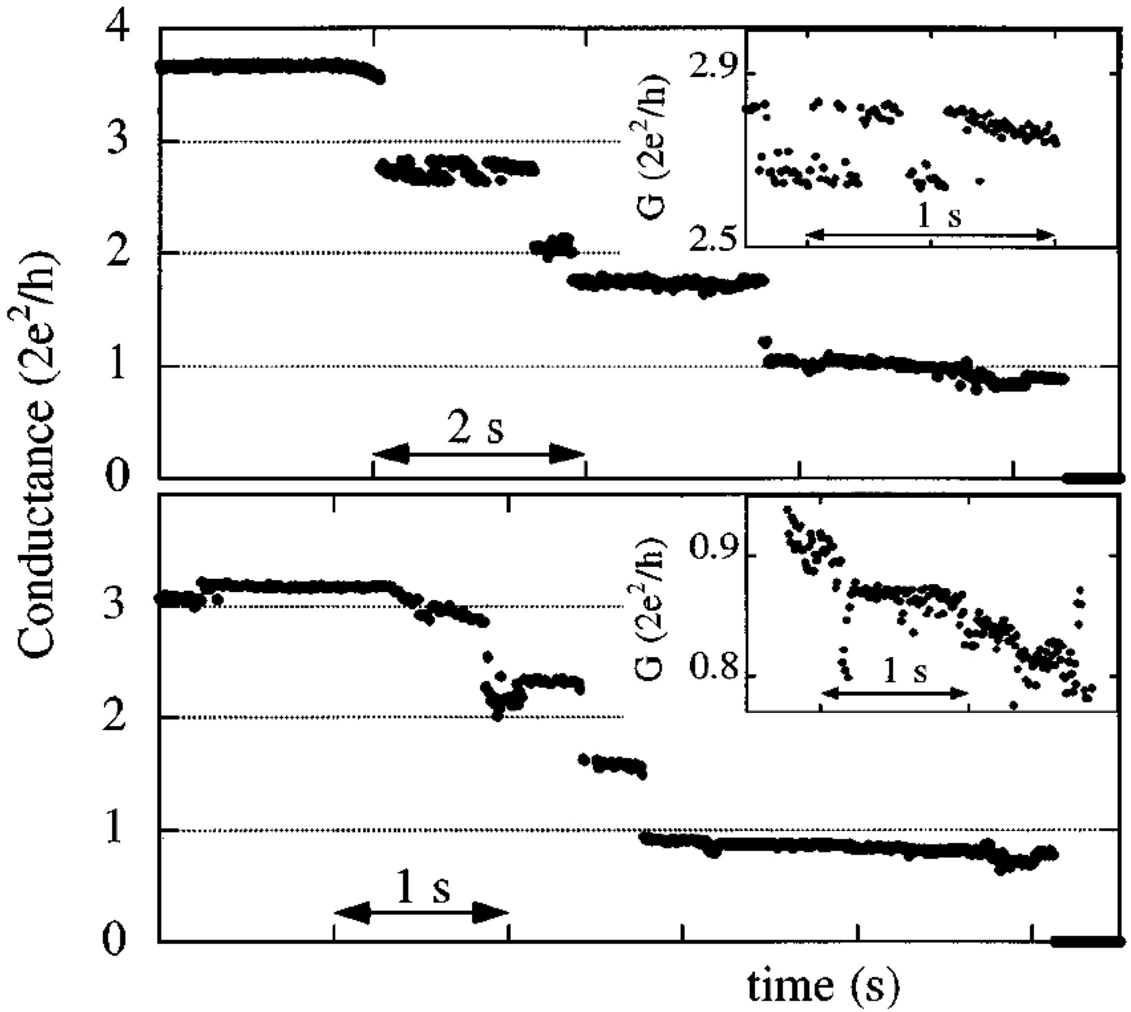
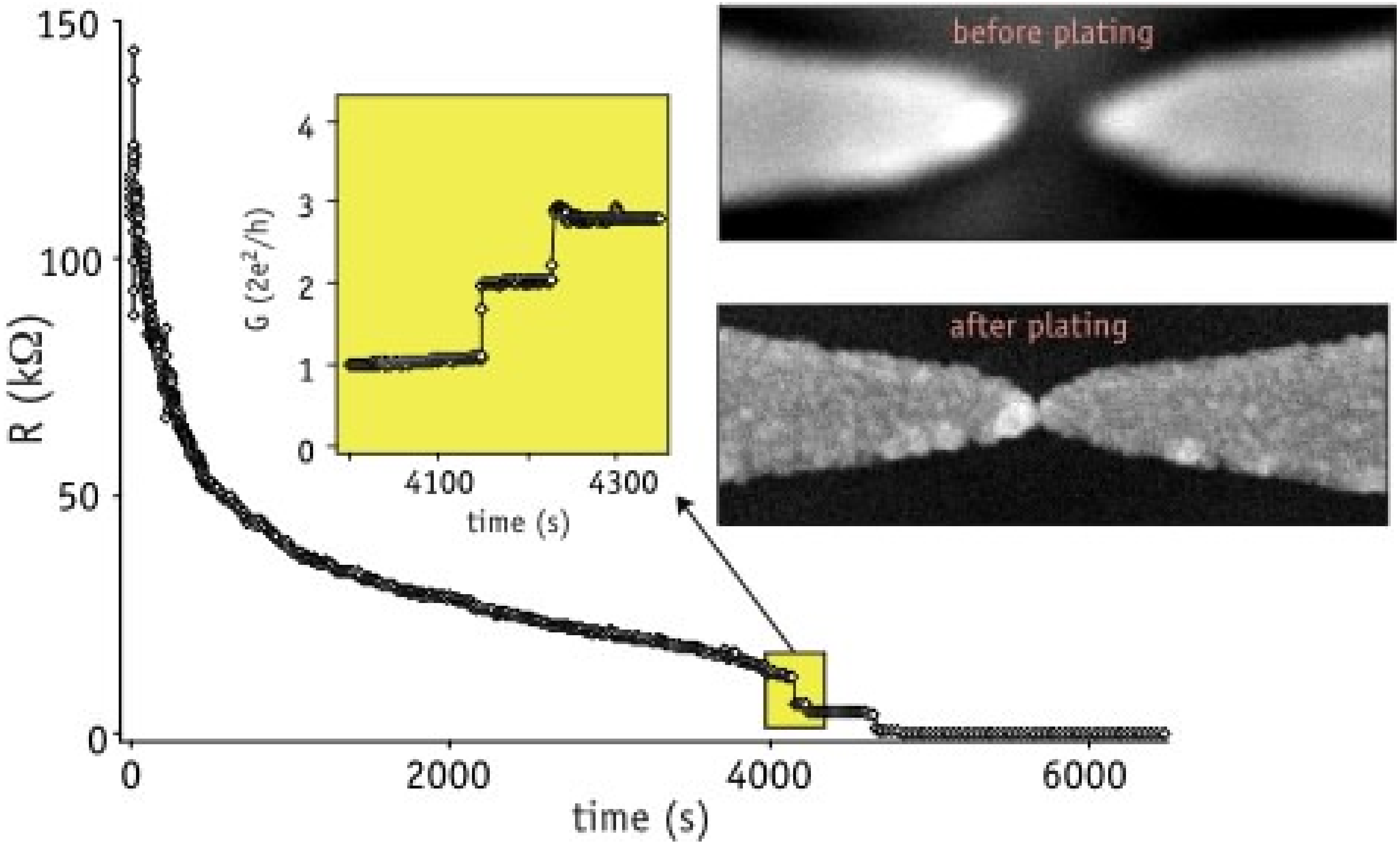


Zhou, et al, Applied Physics Letters **67**, 8 (1995) p. 1160.

Electroplating



A.F.Morpurgo, C.M.Marcus and D. B. Robinson,
Controlled Fabrication of Metallic Electrodes with Atomic Separation, Appl. Phys. Lett. **74**, 2084 (1999).