

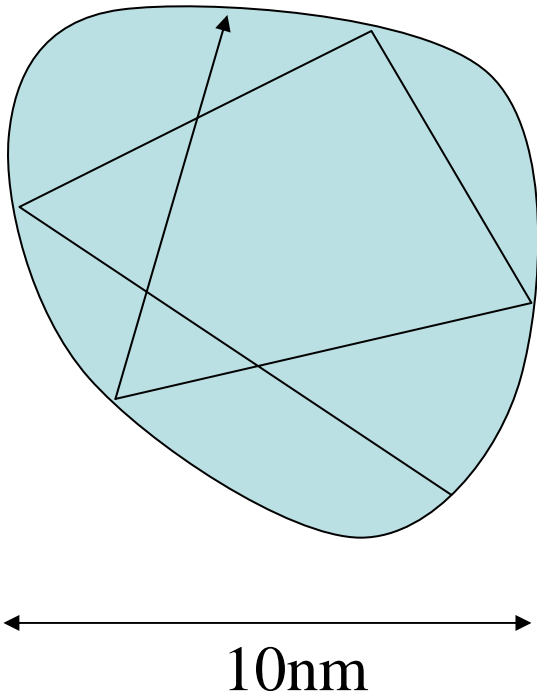
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Taiwan

*Part 1*

# Metal fine particles

the opening of nano-physics

S. Kobayashi



$$\delta = \varepsilon_F / N = 1\text{K}$$

$$v_F = 10^8 \text{ cm / sec}$$

$$\tau_0 = d / v_F = 10^{-14} \text{ sec}$$

$$\Delta\varepsilon = \hbar / \tau_0 = 10^3 \text{ K}$$

$$\delta = \Delta\varepsilon \quad !!!?????$$

DIE SPEZIFISCHE WÄRME DER ELEKTRONEN  
KLEINER METALLTEILCHEN BEI TIEFEN  
TEMPERATUREN

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**Zusammenfassung**

Auf Grund des Sommerfeld-Bloch'schen Metallmodells ergeben sich bei tiefen Temperaturen grosse Unterschiede zwischen der spezifischen Wärme der Elektronen eines unendlich grossen Metalles und derjenigen kleiner Metallteilchen.

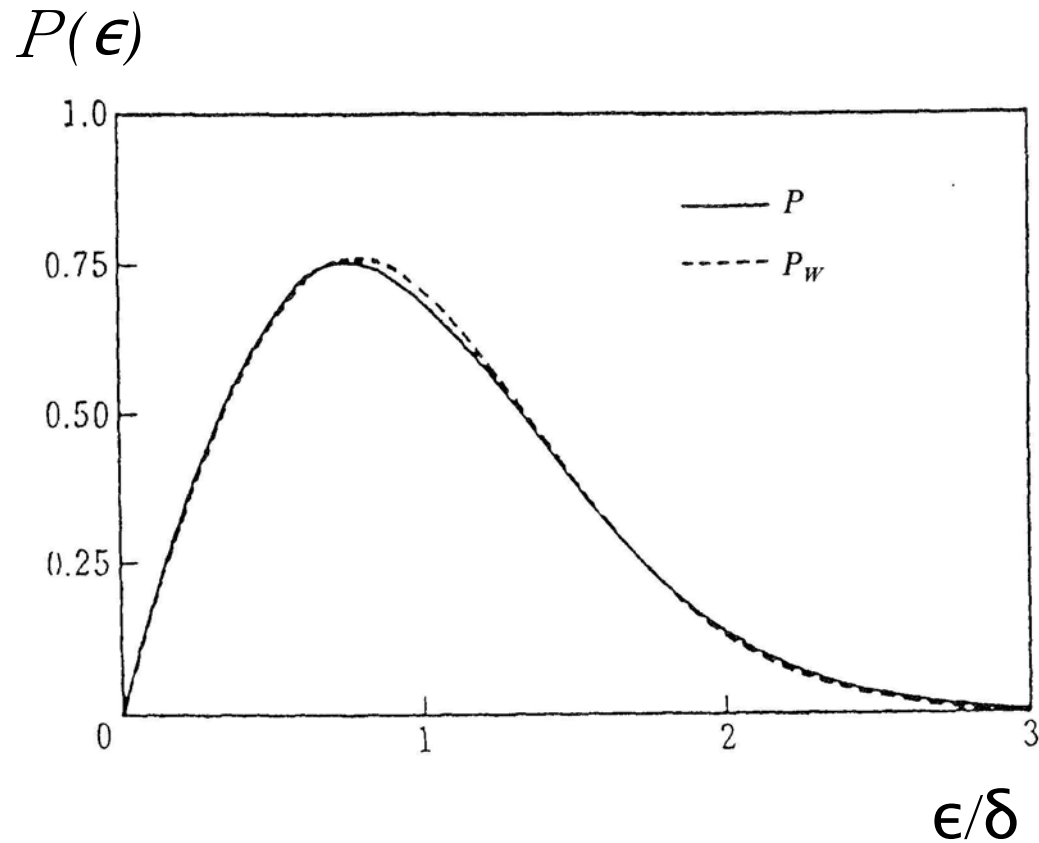
Kubo, R. (1962) J. Phys. Soc. Jpn.

Random distribution of levels  
(poisson distribution)

Single electron charging energy  
(electrical neutrality)

poisson distribution  $\times$

## Random matrix theory (Wigner)



$$P(\varepsilon) \simeq \varepsilon^{n-1} / \delta^n$$

$n=2$  : matrix elements are real

$n=3$  : in magnetic field

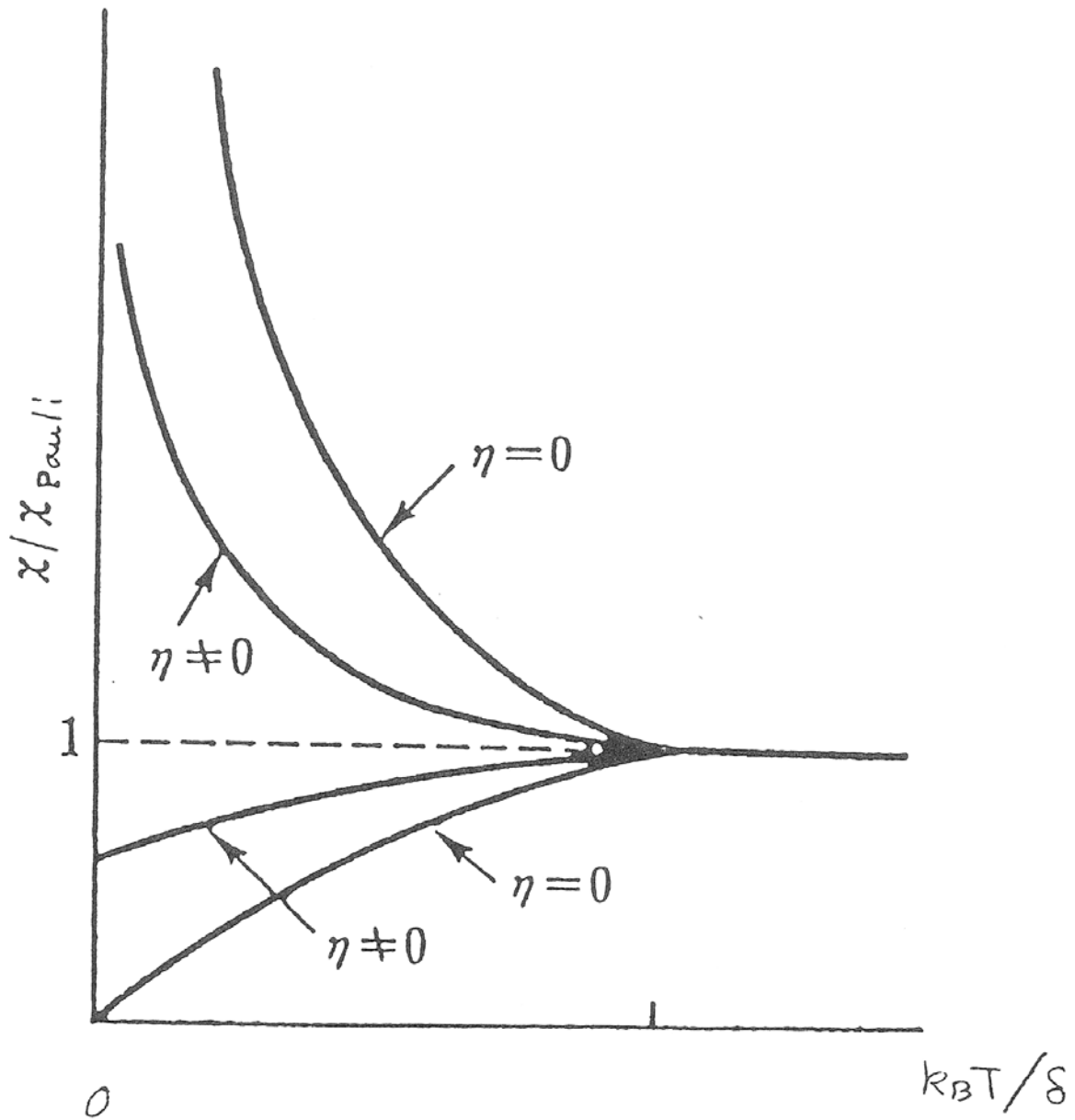
$n=5$  : strong spin-orbit interaction

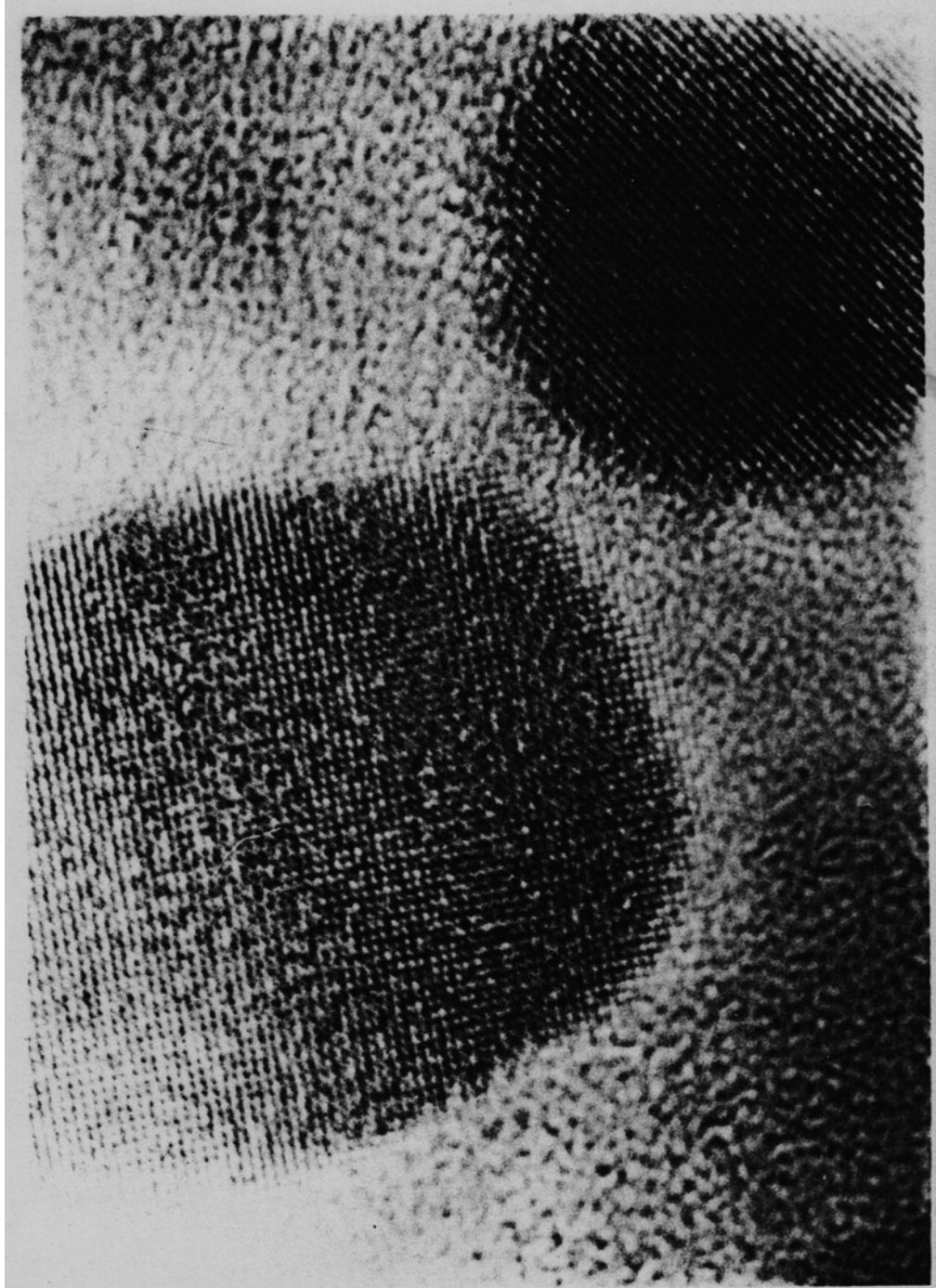
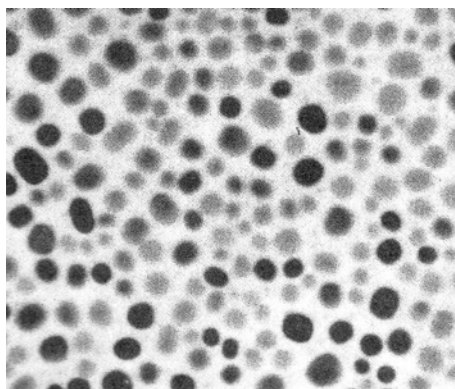
$n=1$  : large Zeeman energy

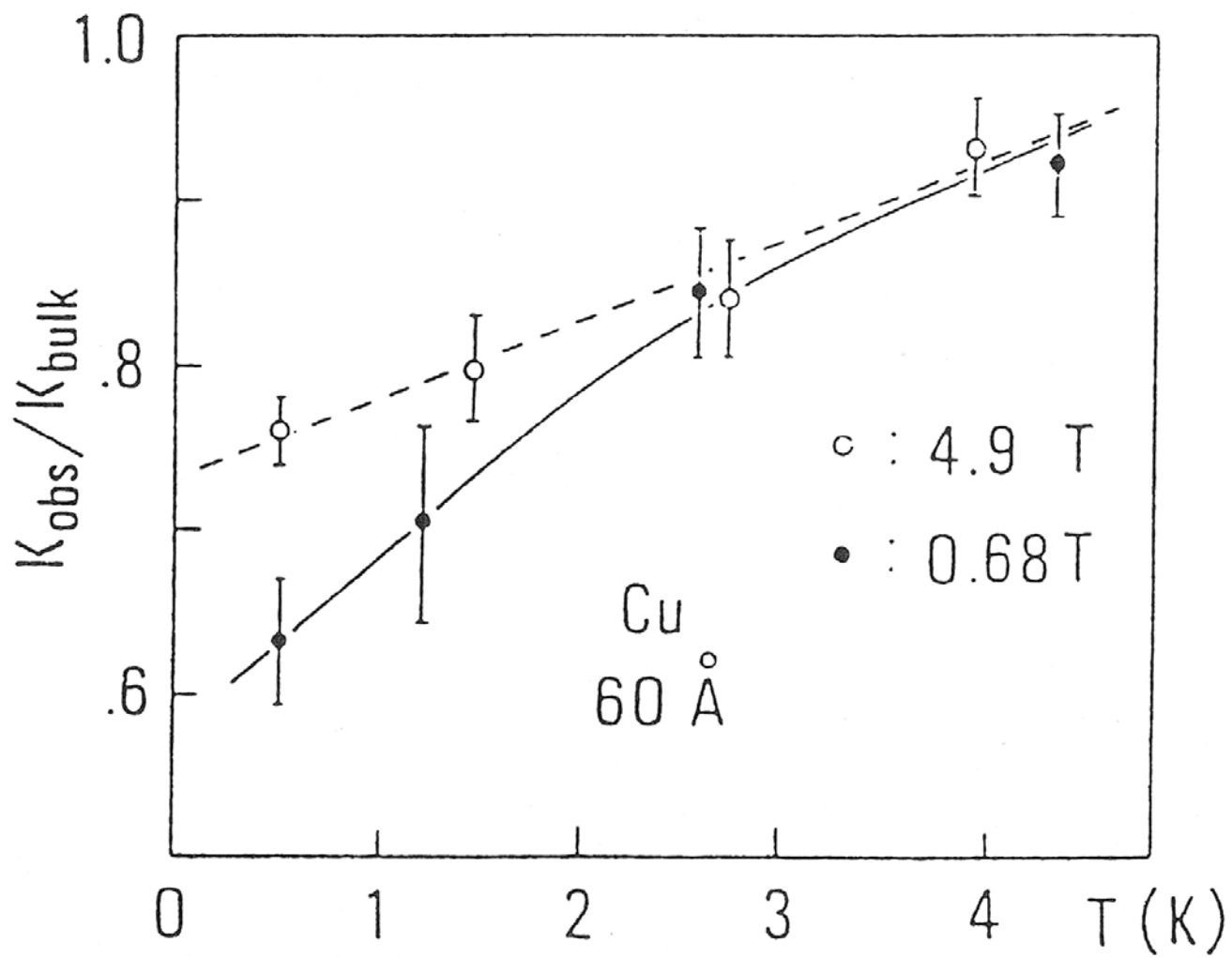
# Elastic scattering vs. inelastic scattering

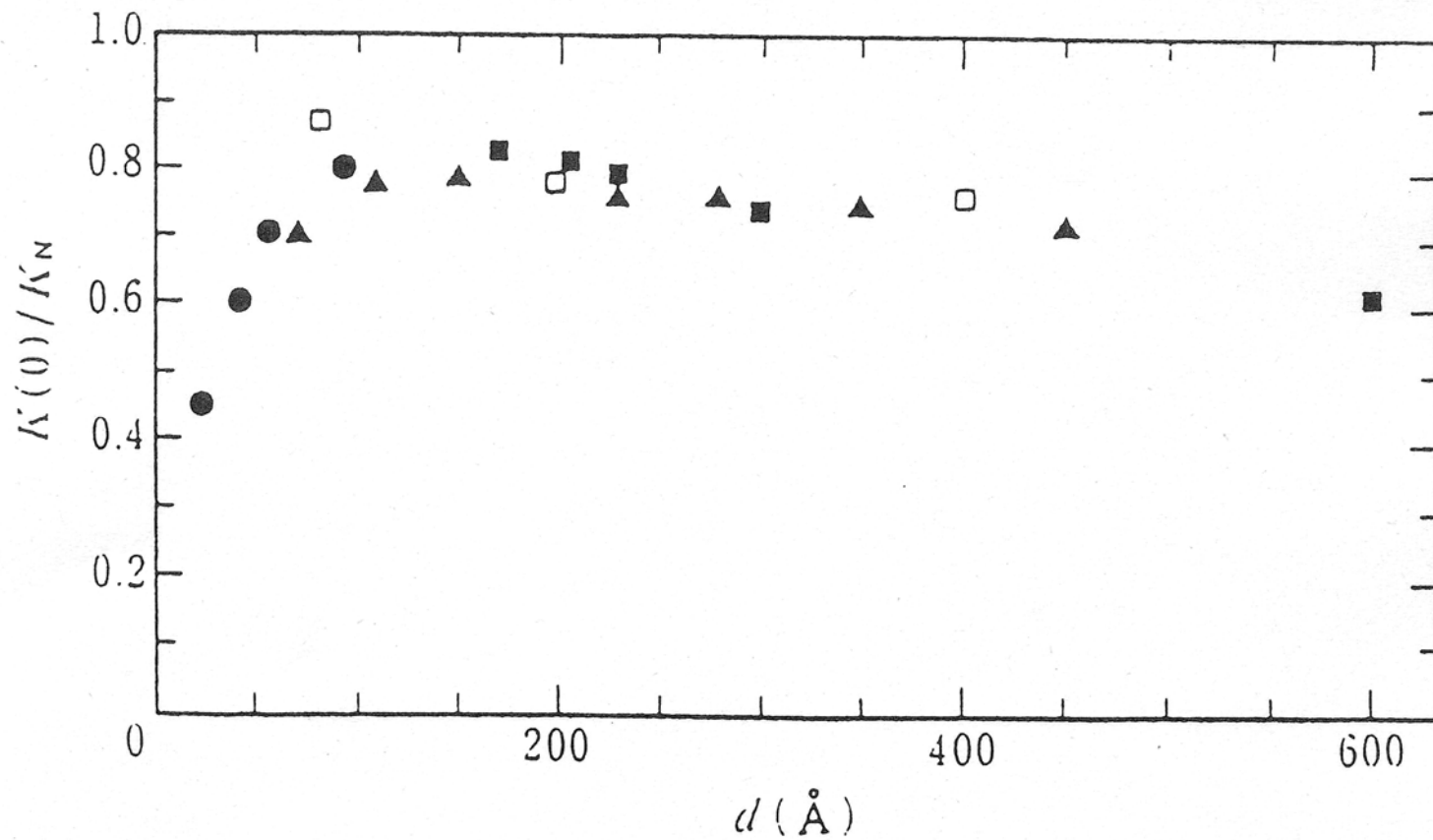
$\tau_0$   $\tau_{el}$  boundary scattering,  
(non-magnetic) impurity scattering  
spin orbit scattering

$\tau_\varepsilon$   $\tau_\phi$  phonon scattering, spin scattering  
electron-electron scattering

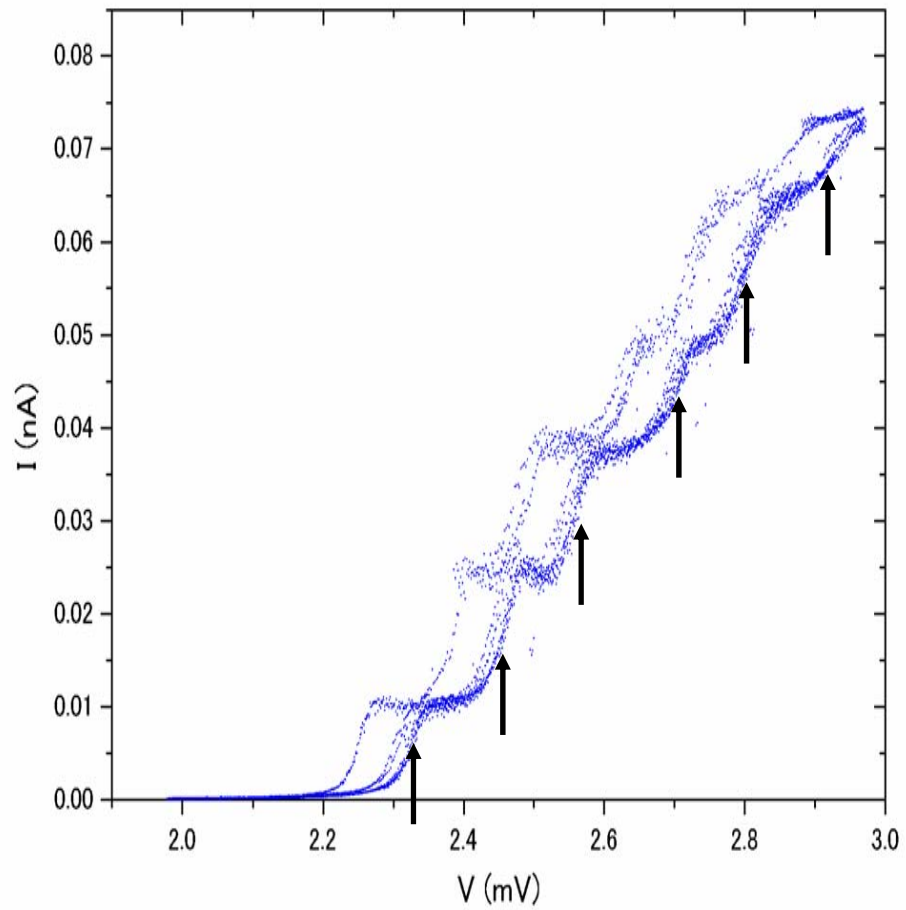








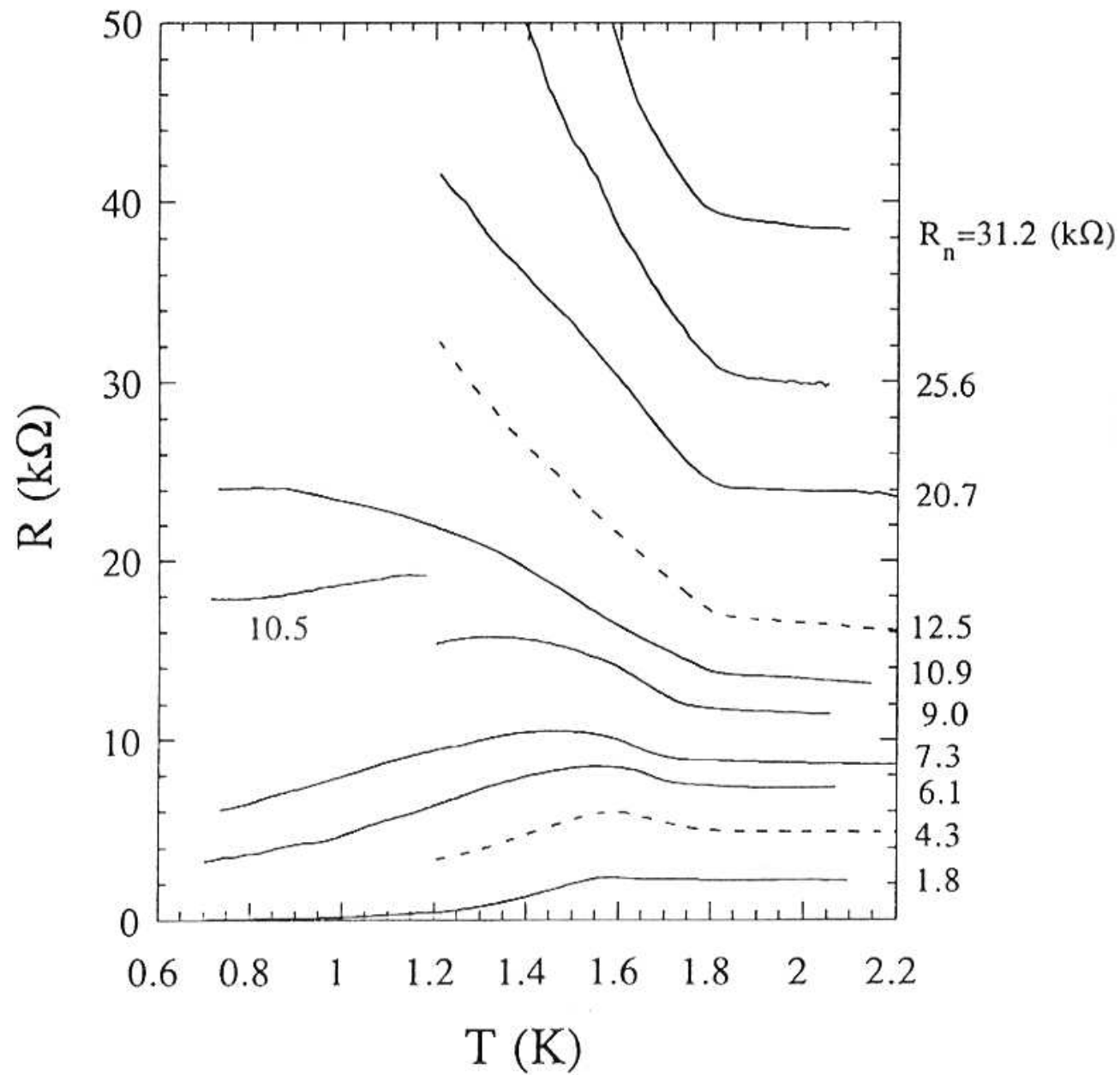
*Spin susceptibility of Sn particles*



*Part 2*

# Coherence and dissipation

S. Kobayashi



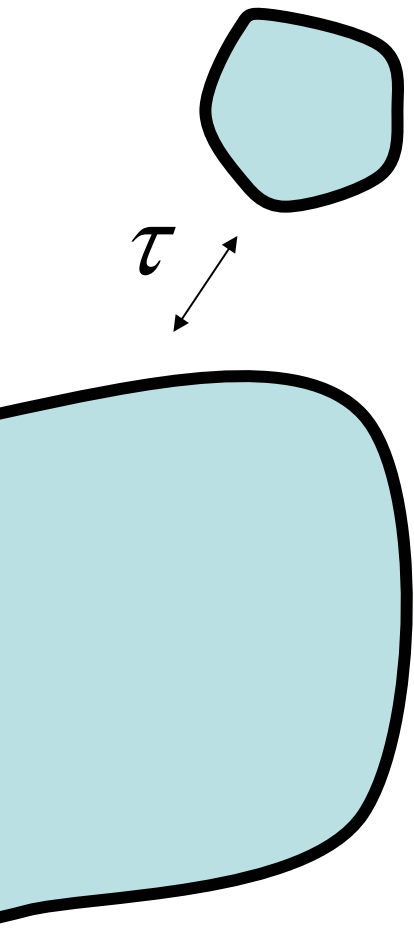
Small Josephson junction

Single electron charging effect

Parallel shunt resistance

$R_Q$ : quantum resistance

$$R_Q = h / 4e^2 = 6.4\Omega$$



Level spacing in small particle =  $\delta$

If  $\delta$  is smeared out by lifetime as  $\delta \approx h / \tau$ ,  
small particle becomes a part of big body, i.e.,  
we cannot say on which side electron is. Then  
charging energy vanishes.

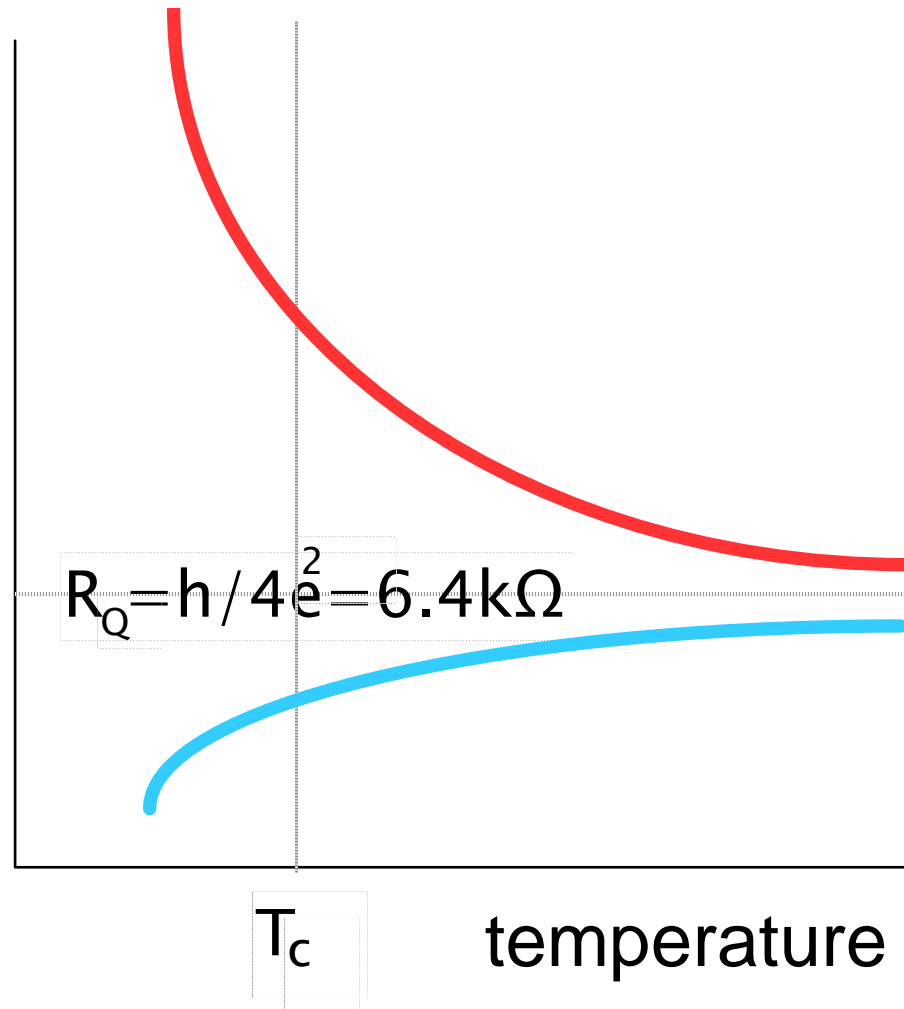
Apply voltage  $V$ .

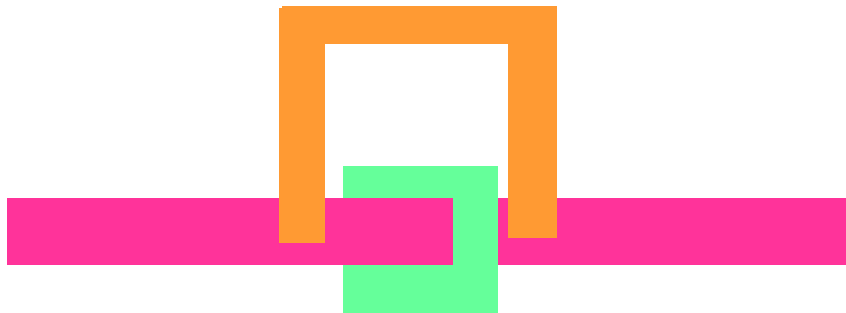
$$I = e^2 V / \delta \tau, R = \delta \tau / e^2$$

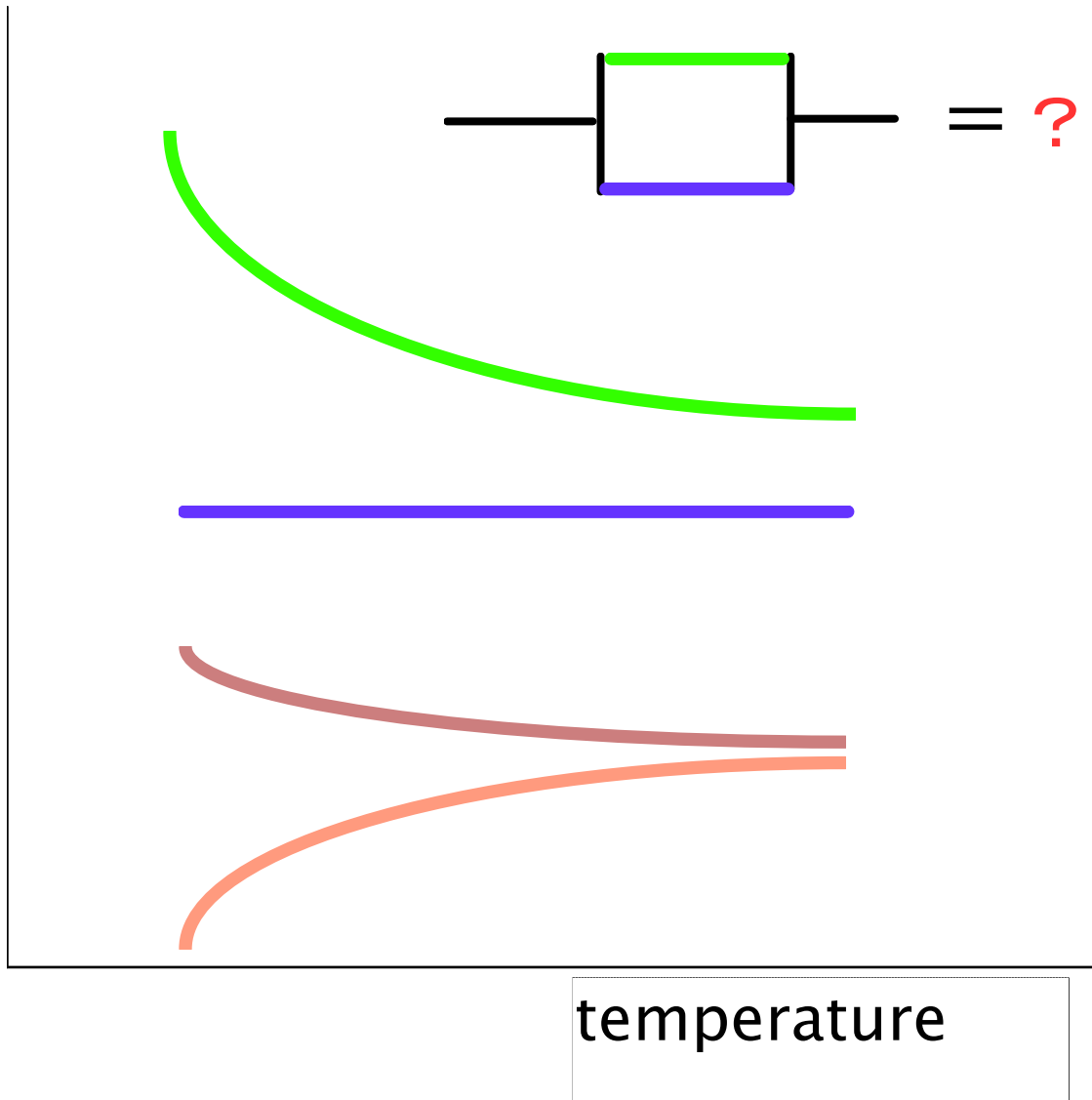
Putting  $\delta \approx h / \tau$ ,  $R = h / e^2$ .

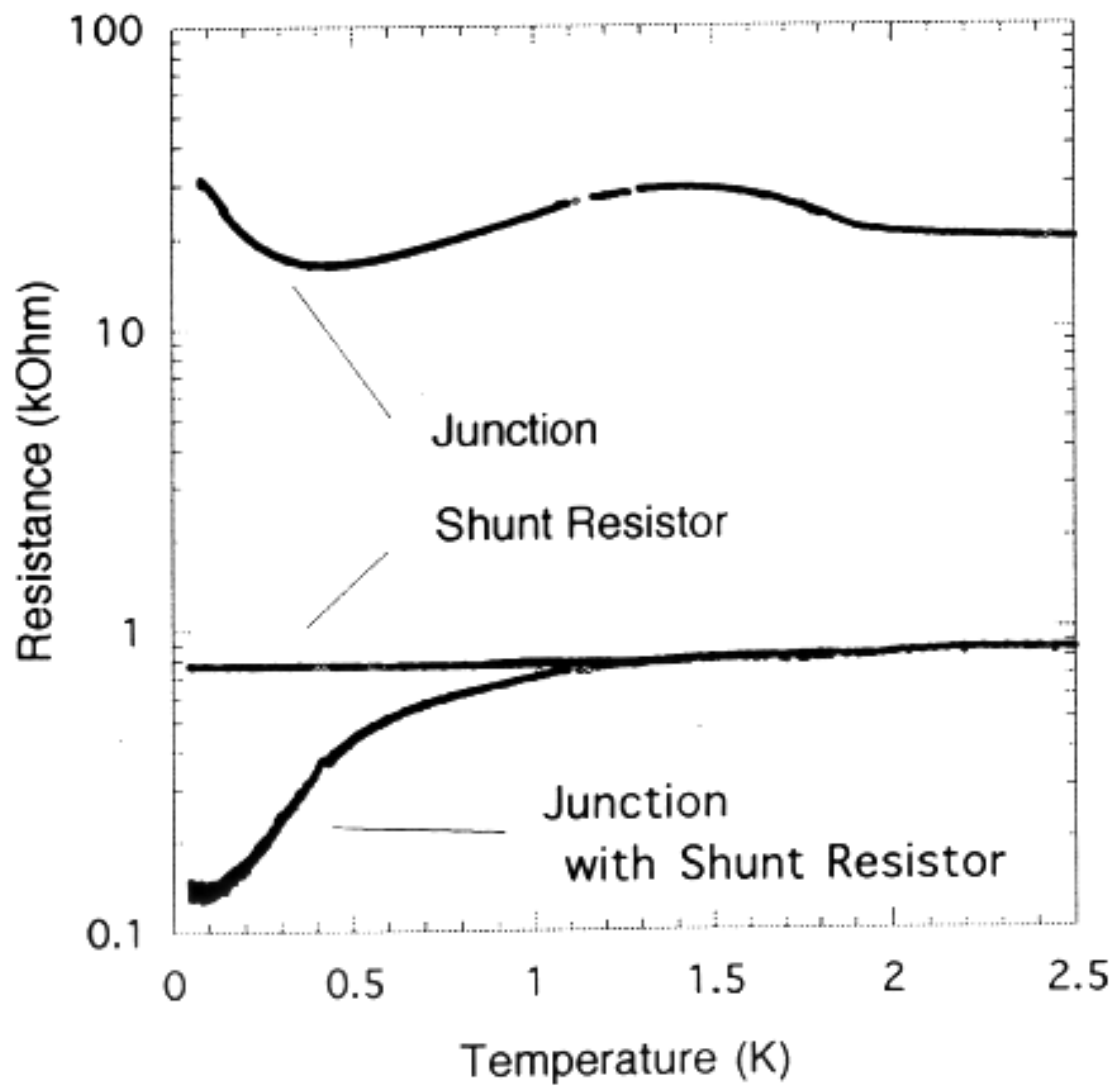
For supercon,  $e \rightarrow 2e$

Then  $R_{crit} = h / 4e^2 = 6.4 \text{ k}\Omega$









万分感謝大家這麼認真安靜地聽我的講話。  
謝謝、謝謝。

Thank you for your attention.