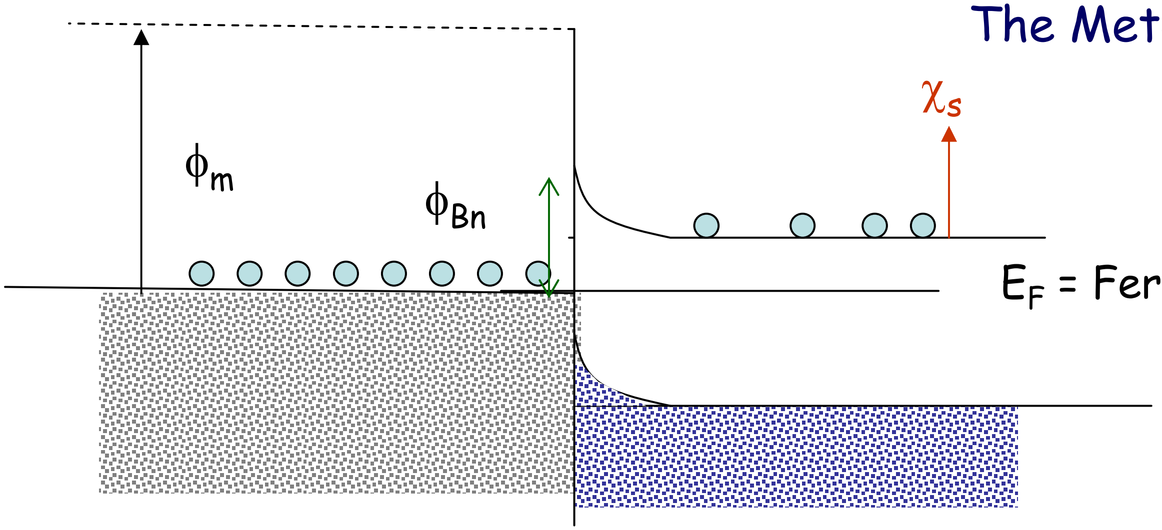
The Metal-Semiconductor Interface



<u>A natural barrier to electron flow is built up</u>

$$q\phi_{Bn} = q\,(\phi_m - \chi_s)$$

For Aluminum on silicon:

$$q\phi_{Bn} = q\,(4.3 - 4.05) = 0.25\text{ eV}$$

Example of a METAL contact to a SEMICONDUCTOR: the basis of all electrical contacts to semiconductor materials....

Control of the interface???

IF

$$q\phi_{Bn} = q\,(\phi_m - \chi_s)$$

THEN we should be able to find the right choice of metal and semiconductor so that

$$q\phi_{Bn} = 0$$

a completely transmissive interface (we're not using 'ohmic' yet)

If χ_s= 4.05 eV for Si, a metal with work function ~ 4 eV should have a very small barrier, but …

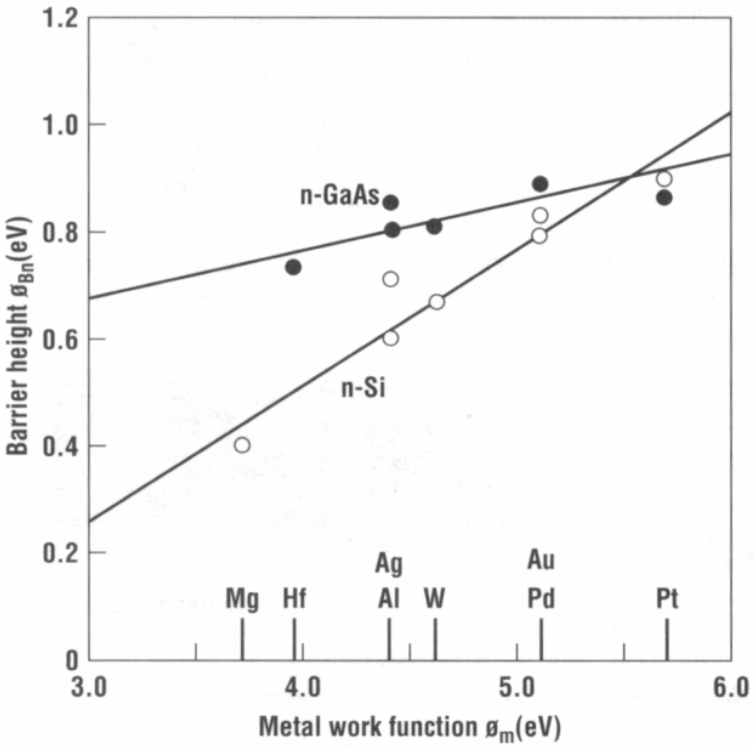
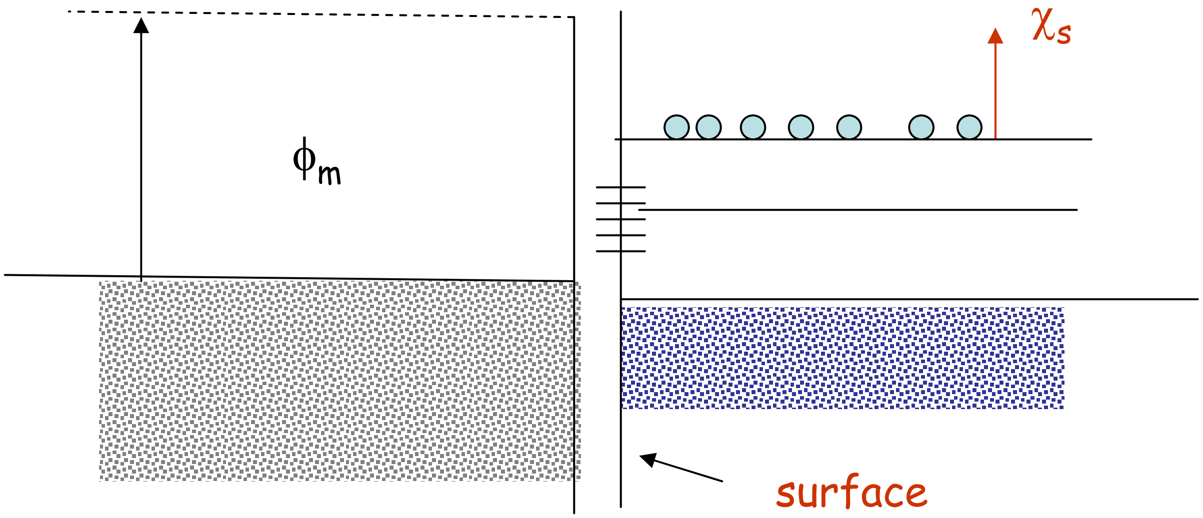
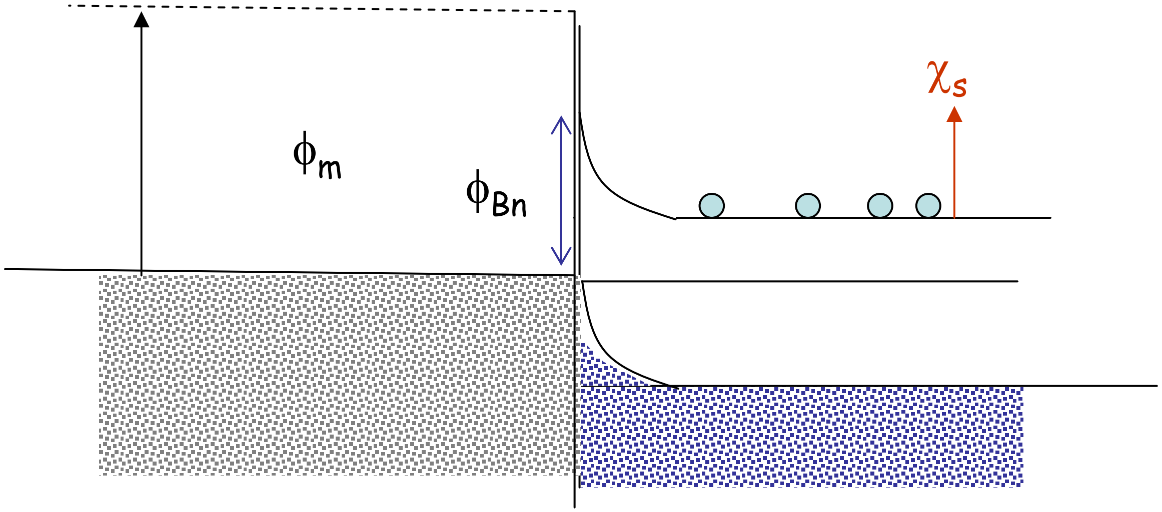


Figure 15.20 Experimentally measured Schottky barrier heights for silicon and GaAs *(from Sze, reprinted by permission, Wiley).*



Electrons from semiconductor transfer to *surface states* AND metal



There is no longer a predictable expression for the barrier, ϕ_{Bn}

So how can we form a transmissive interface????

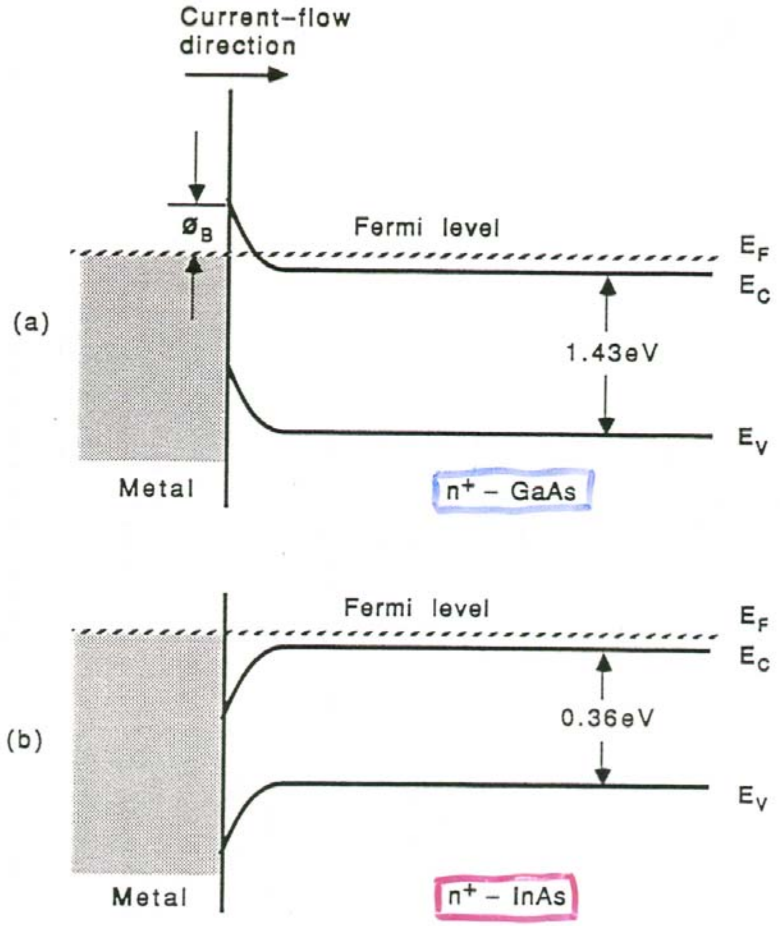


Fig.1.1 Band diagrams for (a) metal on n$^+$–GaAs (b) metal on n$^+$–InAs

"Graded-Gap Ohmic Contacts",
Murali Rao, Ph.D. Thesis
Feb. 1989

Some ‘pinning’ can occur within the conduction band

A transmissive interface…

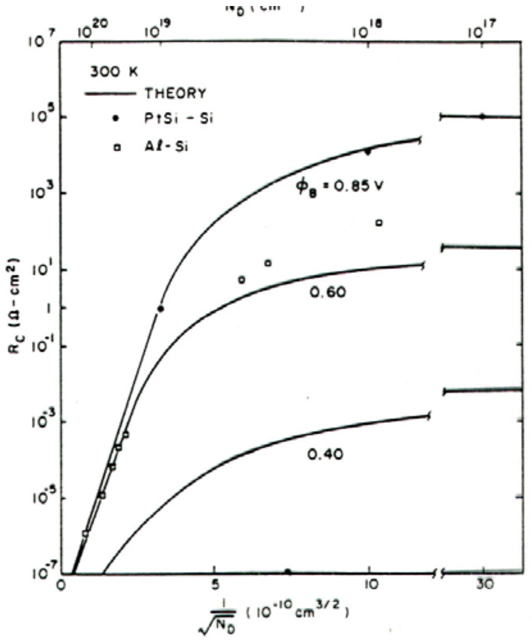


Fig. 43 Theoretical and experimental values of specific contact resistance. (After Chang, Fang, and Sze, Ref. 67; Yu, Ref. 68.)

SZE,
PHYSICS OF SEMI-
CONDUCTOR
DEVICES

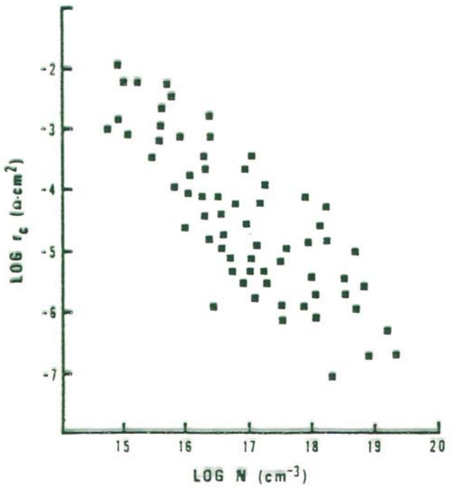


Figure 11.4 Experimental determinations of contact resistance as a function of n-GaAs doping concentration (after reference [41]).

Gallium Arsenide Processing Techniques, Williams

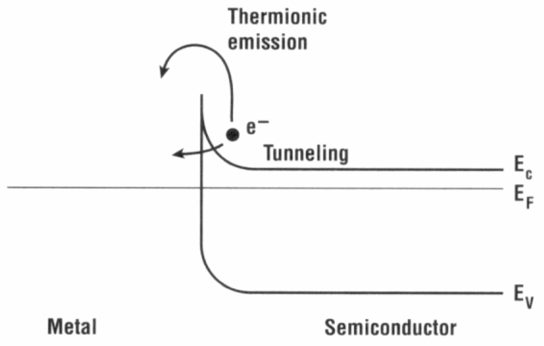


Figure 15.23 Two carrier transport mechanisms typically found in metal semiconductor contacts.

Alloyed Contacts: AuGeNi on GaAs

Electron microscope studies of an alloyed Au/Ni/Au-Ge ohmic contact to GaAs

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Kuan et al., Journ. Appl. Phys.**54** (1983)

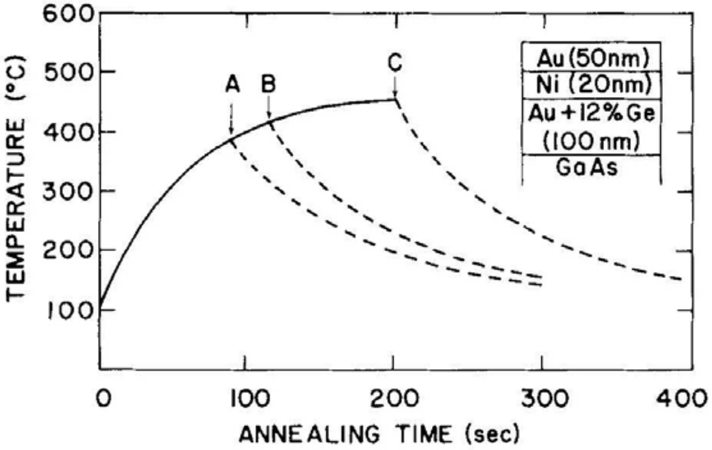

FIG. 1. Temperature vs time curves of the three samples during and after the annealing.

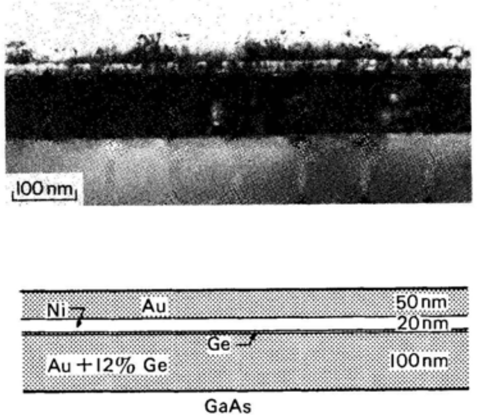

FIG. 2. Bright-field image of the as-deposited structure.

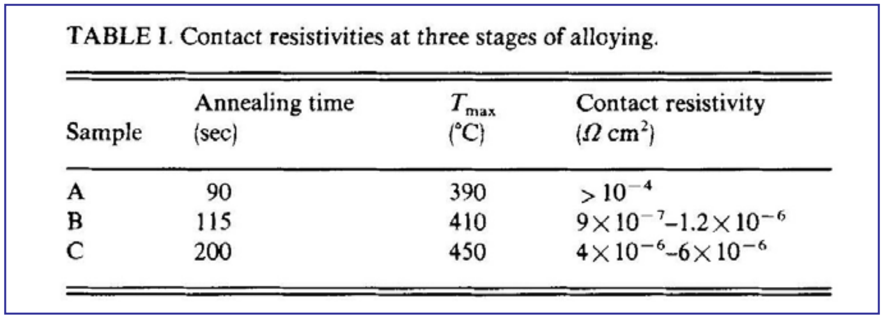

TABLE I. Contact resistivities at three stages of alloying.

Sample	Annealing time (sec)	$T_{\max}$ (°C)	Contact resistivity (Ω cm^2)
A	90	390	$> 10^{-4}$
B	115	410	9×10^{-7}–1.2×10^{-6}
C	200	450	4×10^{-6}–6×10^{-6}

Understanding the microstructure of Au-Ge-Ni ohmic contacts on GaAs

TEM, compositional analysis, electron diffraction

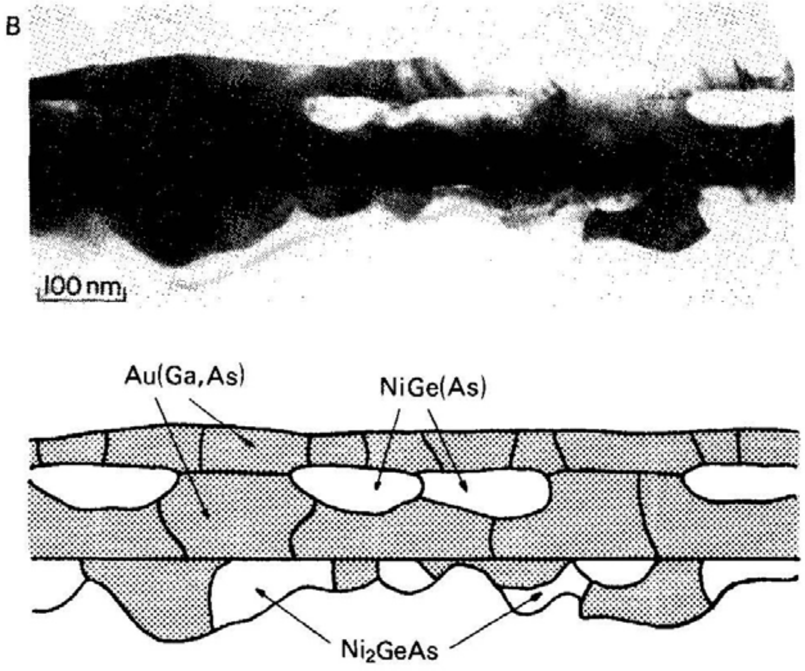

FIG. 7. Bright-field image of sample B. The phases and their chemical compositions are indicated in the diagram below the image.

Association of lowest resistance with a particular phase of AuGeNi: N++ doping of GaAs with Ge

Surface appearance of AuGeNi *alloyed* contact

From R.E. Williams, *Gallium Arsenide Processing Techniques*, Artech House, Inc. 1984, p. 239

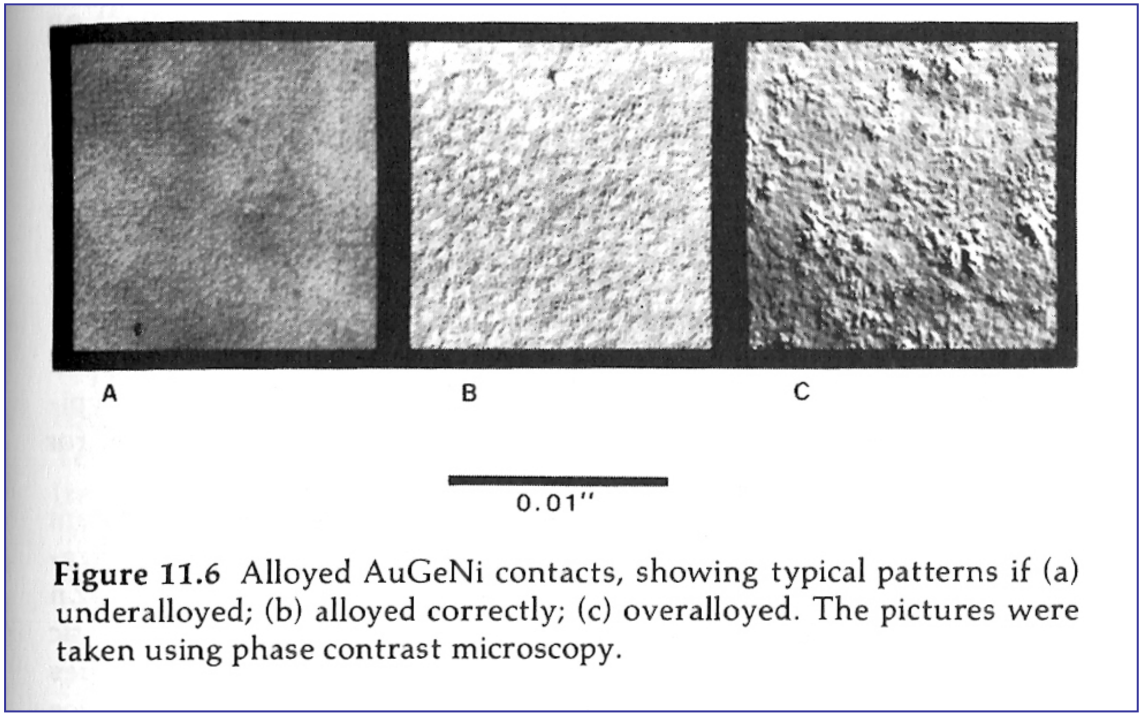

Figure 11.6 Alloyed AuGeNi contacts, showing typical patterns if (a) underalloyed; (b) alloyed correctly; (c) overalloyed. The pictures were taken using phase contrast microscopy.

Note: separate measurements have to be done to determine what 'underalloyed', 'alloyed correctly' and 'overalloyed' correspond to in terms of contact resistance. Only then can these images of the metal morphology be a good guideline for processing