Metal Contacts for the Hybrid Silicon Laser

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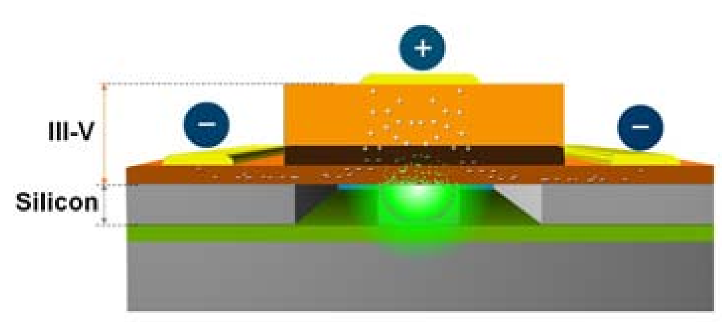
Optical Communication

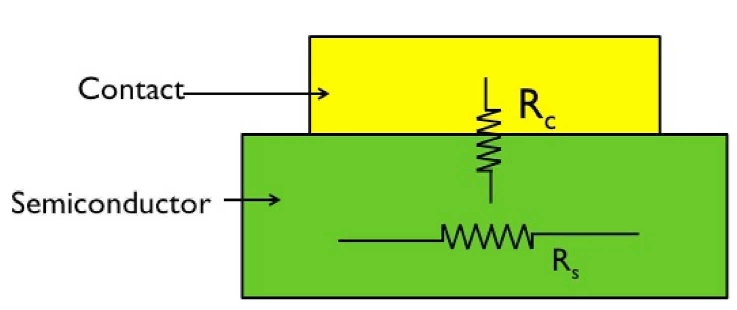
- Optical communication is today a niche technology used mainly for long distance communication (ex. Trans-Atlantic cables) because the cost of components is too high for widespread use.
- Fiber optic cables have at least 10 times the bandwidth of copper cables, which are overloaded by current communication rates.
- Our lab group wants to make this technology less expensive and adapt it for household use by making the light sources (lasers) for the cables cheaper.

Hybrid Silicon Laser



- Laser made partially from expensive, light-producing III-V semiconductors – Indium Phosphide (InP) and Indium Gallium Arsenide (InGaAs).
- Rest made of inexpensive Silicon - brings down cost.
- Multiple metal contacts needed to allow current flow through laser.
- Problem : Conventional lasers made entirely from III-V use contacts containing gold, which is incompatible with Si manufacturing facilities.
- New, gold-free contacts must be designed and tested.

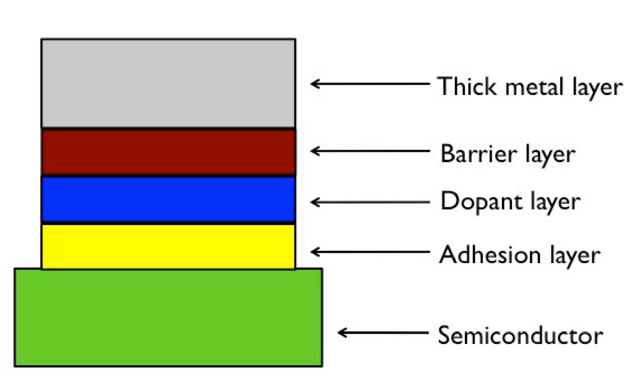
Metal Contacts



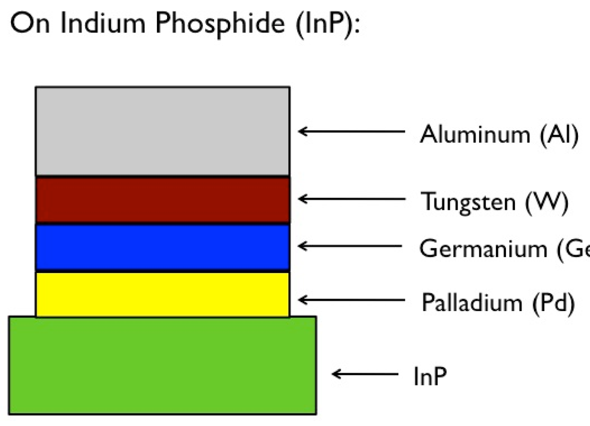
R_c: Contact resistance, which we aim to minimize.
-We record *specific* contact resistance (ρ) which takes into account the area through which the current flows.

R_s: Inherent resistance of semiconductor.

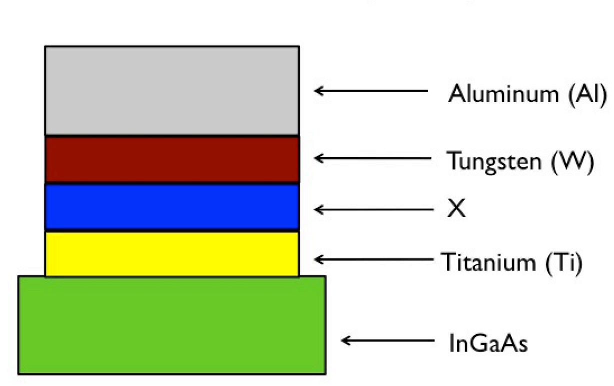
Basic cross-section :



On Indium Phosphide (InP):

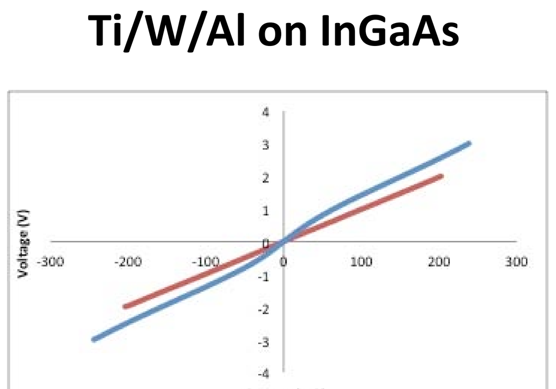


On Indium Gallium Arsenide (InGaAs):

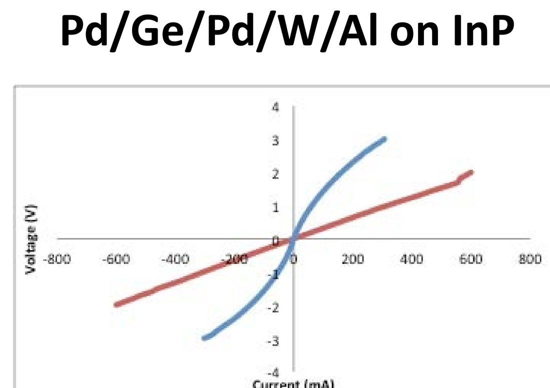


The Importance of Annealing

Ti/W/Al on InGaAs



Pd/Ge/Pd/W/Al on InP



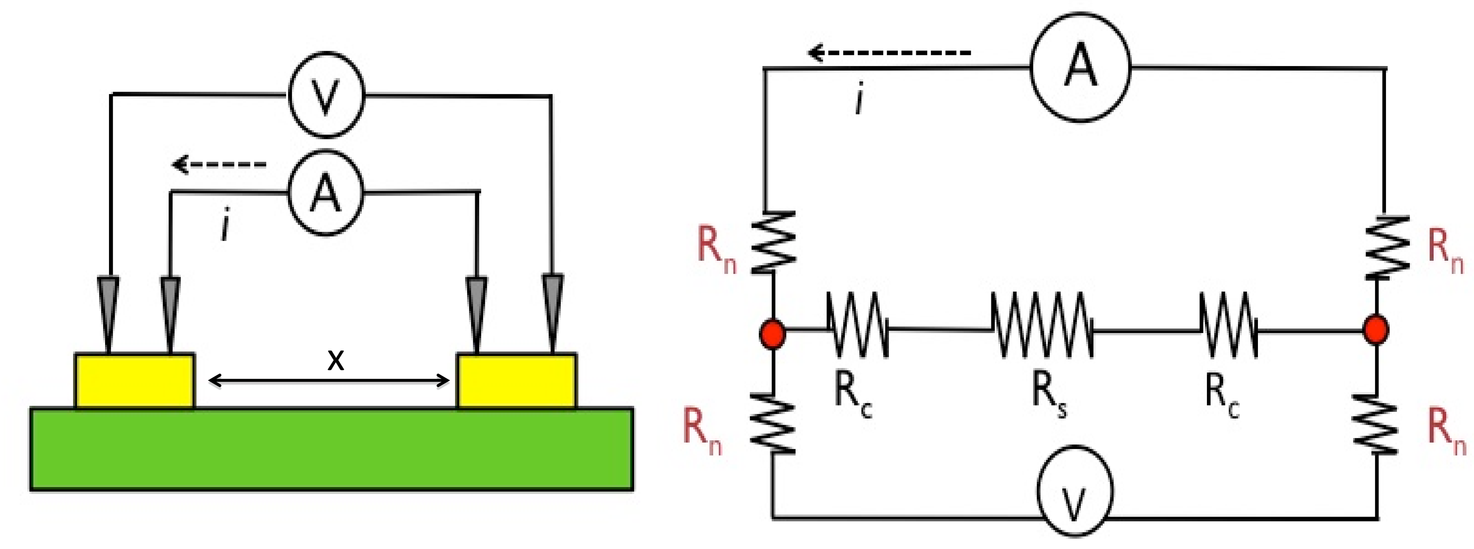
Un-annealed

Annealed at 350°C for 30s

Our model assumes that our samples obey Ohm's Law. To check if they actually do, we chart voltage vs. current. Ohmic samples should have a linear plot. These samples were Ohmic only after being annealed.

Methods

Four Point Probe Measurement



Measured resistance is equal to $2R_c + R_s$.
Using the four point method eliminates error due to needle resistance (R_n)

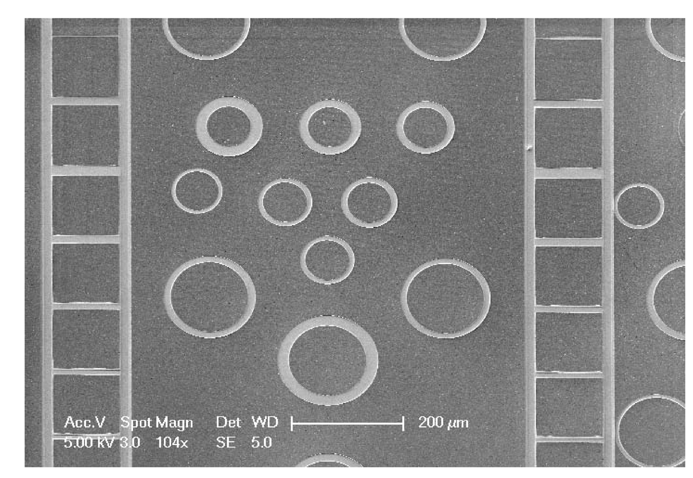
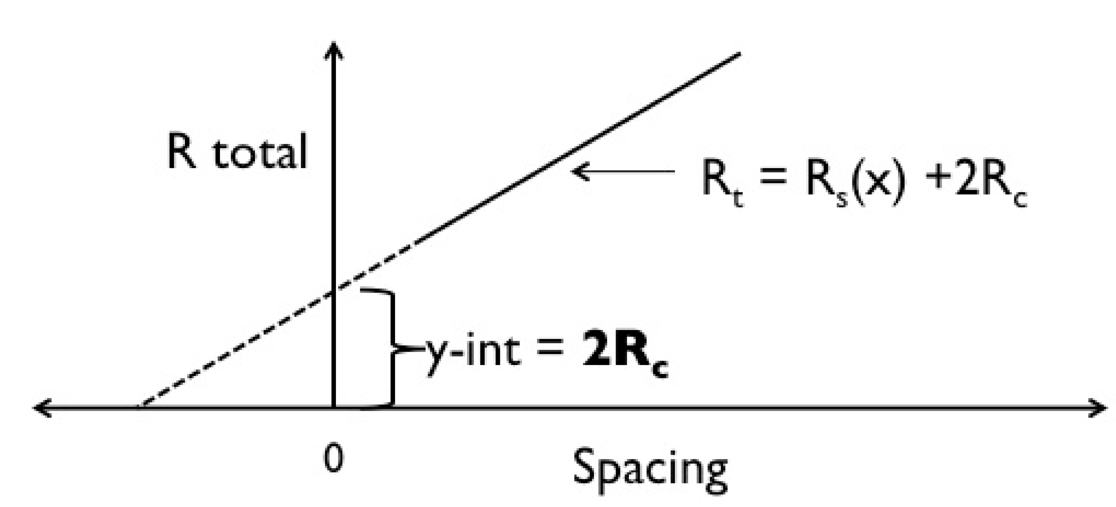


Photo courtesy Siddharth Jain

Use test structures to measure total resistance (2Rc + Rs) across varied spacings

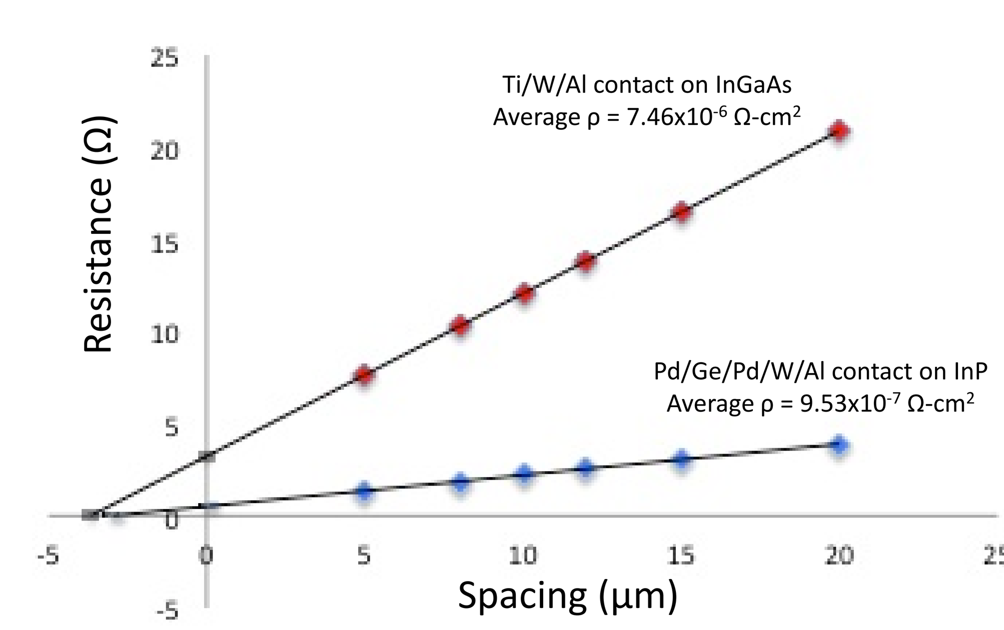
Both circular and square test structures are used – calculations are easier with squares, but circles tend to give more accurate data.

To Find R_c…



- R_s is linearly dependent on the spacing between the contact – larger space → greater R_s.
- Extrapolating to find the y-intercept (spacing = 0) gives $2R_c$, a constant.

Selected Results



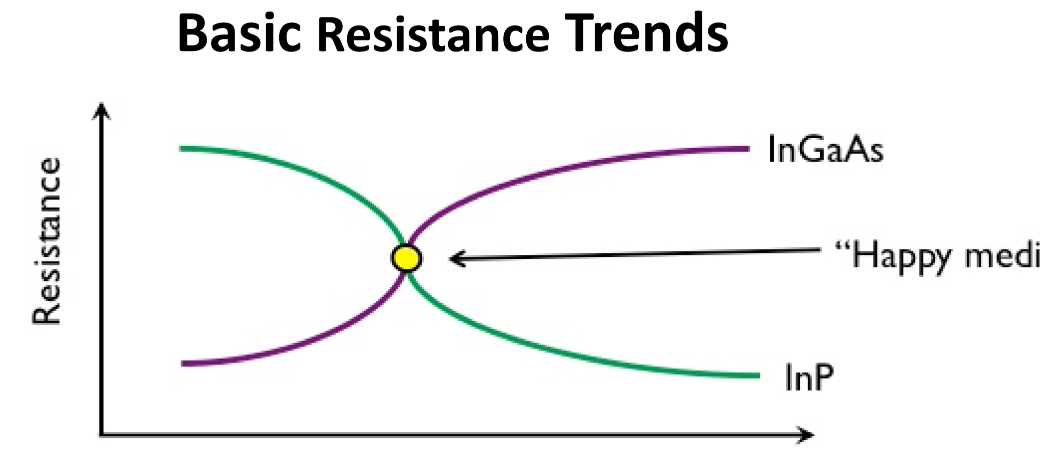
- Best contact for InGaAs was Ti/W/Al (Thicknesses: 100nm/100nm/750nm)
- Best contact for InP was Pd/Ge/Pd/W/Al (Thicknesses: 10nm/110nm/25nm/100nm/750nm)

(acceptable ρ values are anything less than 10^{-5} Ω-cm^2)

Looking Ahead…

Find a contact that works equally well on both InGaAs and InP
- Simplifies manufacturing

Basic Resistance Trends



- Contacts with low Pd:Ge ratios tend to give relatively low resistances on InP.
- Contacts with high Pd:Ge ratios do better on InGaAs.
- Pd/Ge/W/Al contacts will be made with varying Pd:Ge ratios and tested on both InGaAs and InP.
- We'll see if ρ is acceptable at the ratio that gives the same resistance for both semiconductors.