Measuring the Effects of Ion Implantation on the Photoinduced Carrier Lifetime of Semiconductor Materials

- Mario Johnson (Southern University and A&M College, Baton Rouge, LA 70813)
- Tony Clevenger and Stephen Durbin (Purdue University, West Lafayette, IN 47907)

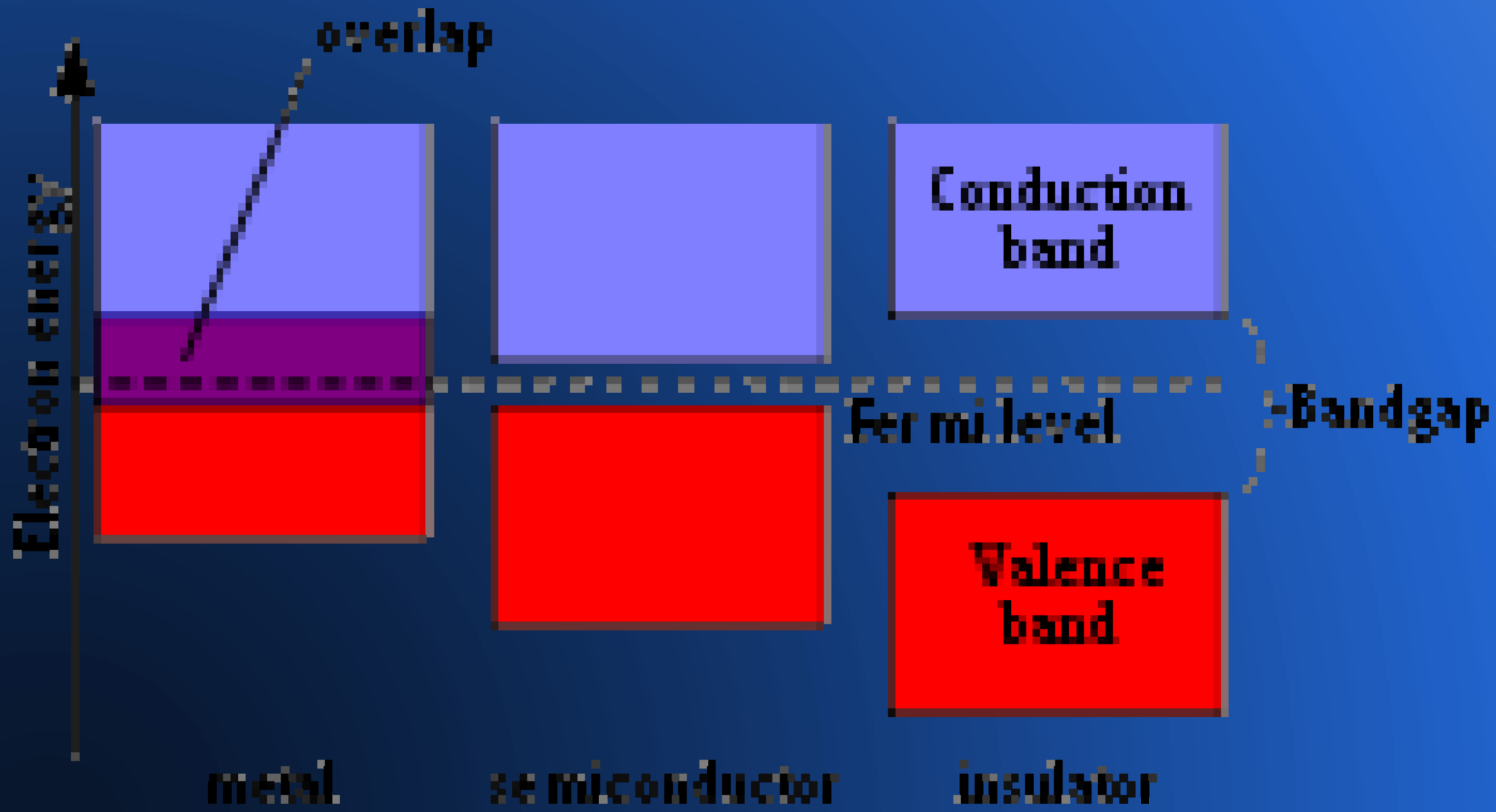
What is a photoinduced carrier lifetime?

- Definition
  - The lifetime of the electron/hole pair that is produced by the interaction of a material with light.
- The lifetime is the time that the electron/hole pair is excited.
- Materials used had a pre measured lifetime of ~250 ps (2.50 x 10^(-10)sec)

Types of Conductors

- Band Theory of Solids
  - Instead of having discrete energies as free atoms, the energy states form bands (valence and conduction)
- Metals – partly empty and partly filled bands; very high conductivity
- Insulators – Have the widest band gap between the two highest energy bands of the material; lower band filled with electrons and upper band empty
- Semiconductors – Special case of insulators; smaller band gaps (approx 1/10);

Band Gap of Conductors



Insulators

Insulators have the largest band gaps of the three types of conducotrs.

- Band gap too large for Fermi energy to be overcome in order to cause conduction at lower temperatures

Metals (Conductors)

Since the valence band and conduction band overlap in these materials, there is no band gap.

- Electrons pass easily from one band to the other.
- Great conductors of electricity (hence the name 'conductors').

Semiconductors

Relatively small band gap when compared to the band gap of insulators.

– Smaller band gap means easier for electrons to overcome Fermi energy and pass into conduction band.
– Small amount of thermal energy is enough to overcome energy.

Semiconductor Materials Used and Band Gap Values (eV)

- GaAs (1.43)
- Si (1.14)
- Ge (0.67)
- CdTe (1.45)

Preparing Samples - GaAs

- The samples of GaAs came from wafers that were approximately 350 microns thick (.35mm).
- Had to be grinded to ~50-70 microns\
  - Grinding jig
  - SiC slurry on glass sheets

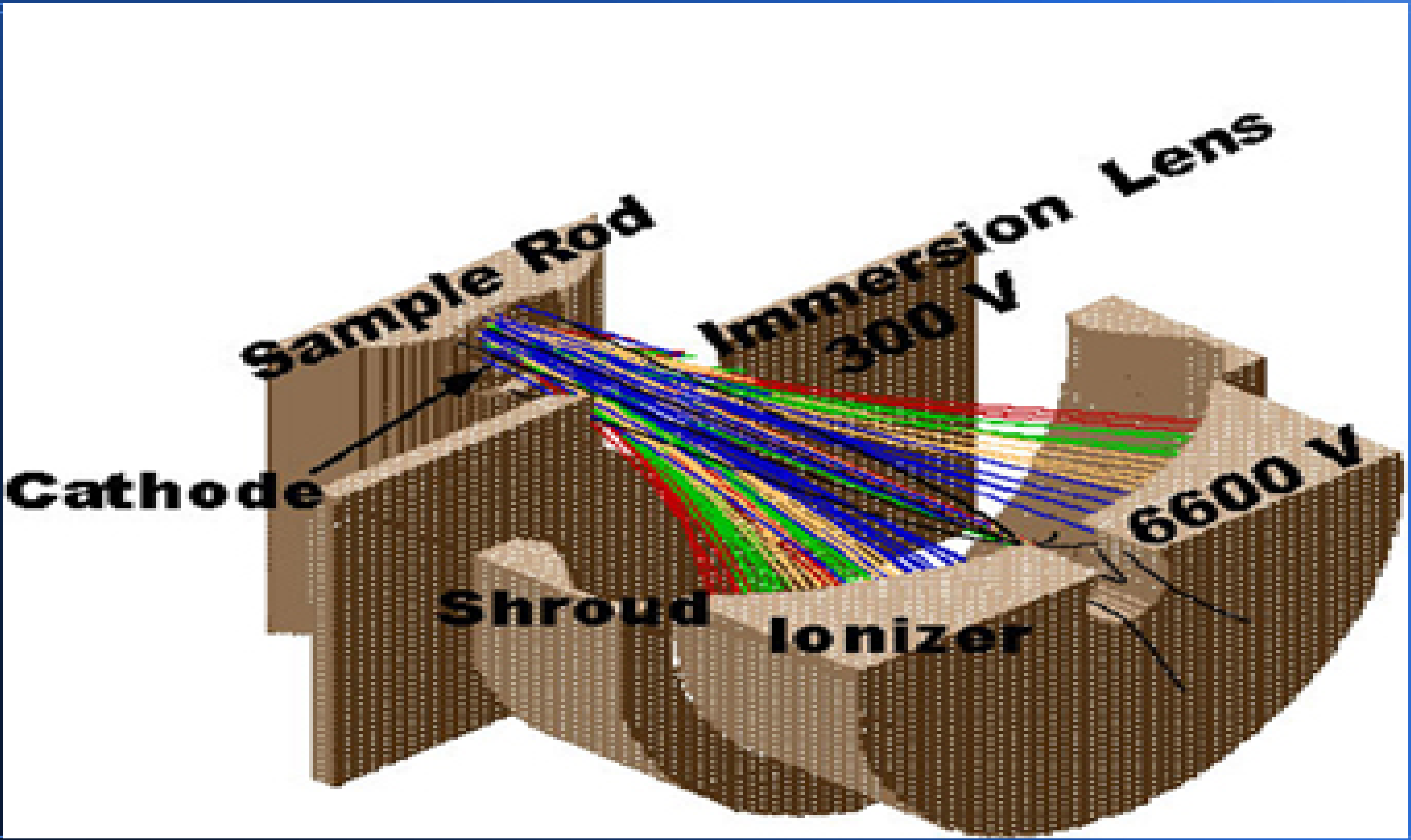
Preparing Samples - Si

- Original pieces had thickness of 750 microns
- Had gold electrodes on original samples
  - Polished with diamond paste to remove
- Grinded to ~60-80 microns

Next Step for Samples

- After samples were grinded, they were take to the PRIME Lab
- Ion Implanted for 1.5 minutes to 137 minutes.
- After radiation faded (enough to be considered non hazardous), they were taken to Argonne National Lab to be tested for their carrier lifetimes.

PRIME Lab Ion Beam



Laser Lab Measurements

Prof. Savikhin's lab was used for experiments.

- Pump/probe set up was used.

Pump/Probe Experiment

How does it work?

- The pump beam excites the sample to the state in which we want it
  - In our case, the state at which the electrons are excited enough to pass from valence band to conduction band.
- The probe beam hits the sample (at varying time delays)
  - We measure the change in the probe beam due to the excitation caused by the pump.

Laser Lab

Synchrotron Applications

The semiconductor materials were tested and are being tested again at Argonne National Lab at the Advanced Photon Source (APS).

- In the Laser Lab at Purdue, we used an optical pump and optical probe. At the APS, we used an x ray pump and an optical probe.
  - The x ray pump is ~1000x more intense than the optical pump.

The Advanced Photon Source

Aerial View of the APS

Inside the APS

Purpose

Measure lifetime as a function of the x ray power.

– In doing so, we were attempting to see the ultrafast “many body response of semiconductors” to x rays.

Why measure the lifetime?

- Short lifetimes mean that the material returns to its ground state as quickly as possible.

It is important to shorten this lifetime for many practical uses in many scientific areas.

Conclusion

- Lasers are unpredictable and aligning lasers to optimize signals is strenuous work.
- It is still uncertain that the ion implantation had any effect on the lifetime of the material.
- More research is needed to conclude whether or not it will have any effect.

Future Work

- Attempt ion implantation at varying intensities and lengths of time to see what effect, if any, it has on the lifetime.
- Find out what is the optimal amount of implantation needed in order to decrease the lifetime as much as possible.