Electron Carrier Density and Mobility in Semiconductors

OU REU 2019

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Preliminary Work:

- Equations
- Used to make predictions of the band gap energies
- Different material compositions have different properties that are also affected by doping

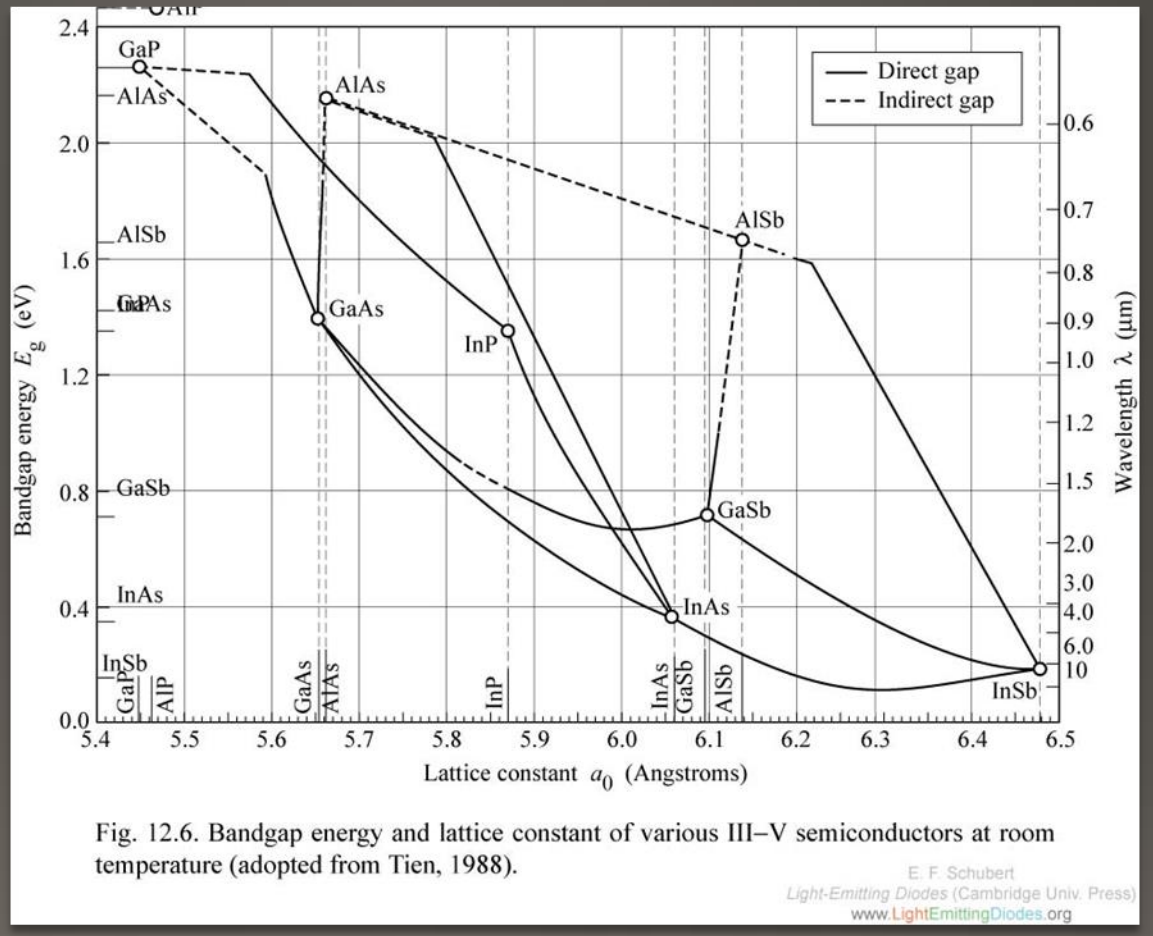


Fig. 12.6. Bandgap energy and lattice constant of various III–V semiconductors at room temperature (adopted from Tien, 1988).

Material Compositions:

- Two sample sets:
  - B086, 1 sample, III-V, Dr. Santos, doped
  - CdSe, 3 samples, II-VI, Dr. Shi, doped
- Properties: Materials for solar cells and transparent conductors
  - PN junctions in solar cells
  - allow light to pass through the metal in infrared detectors

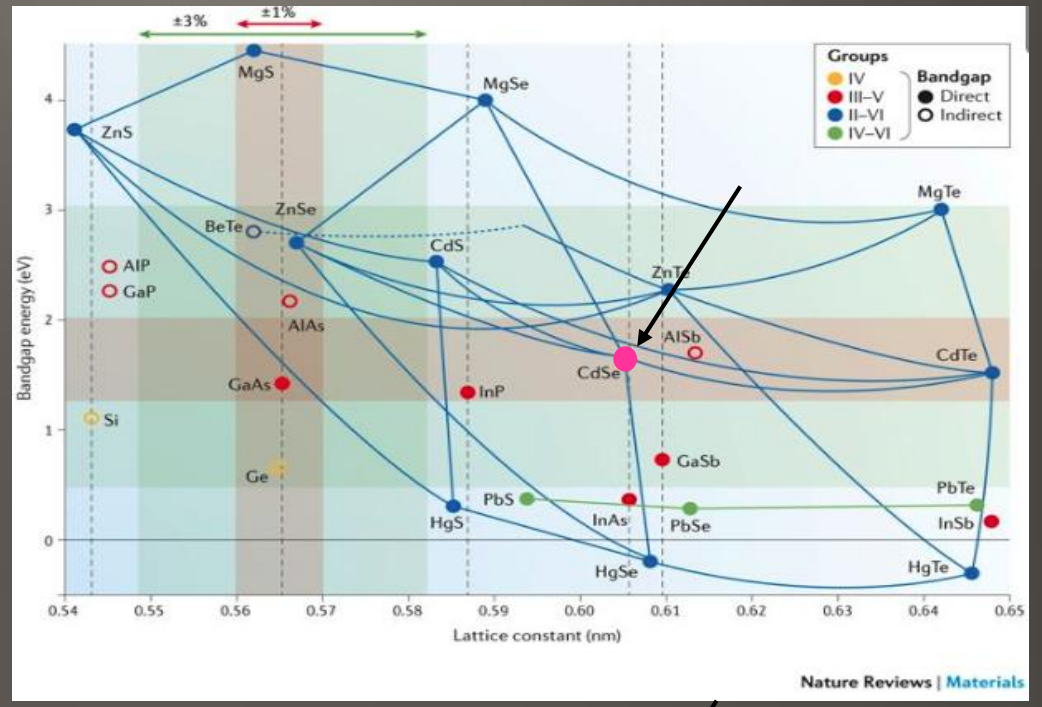


Fig. 1

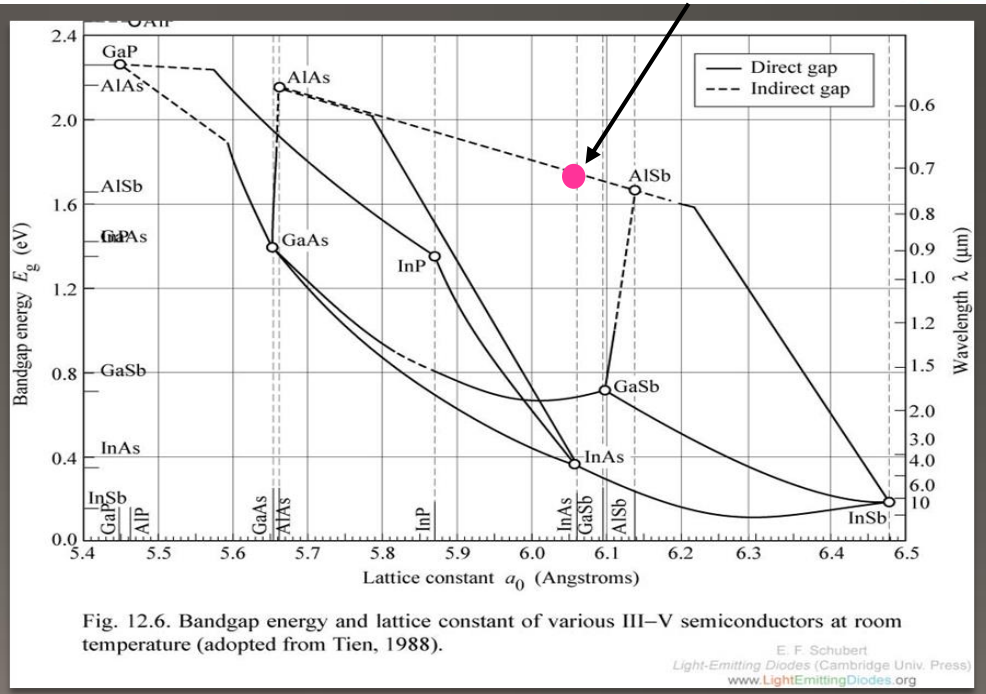
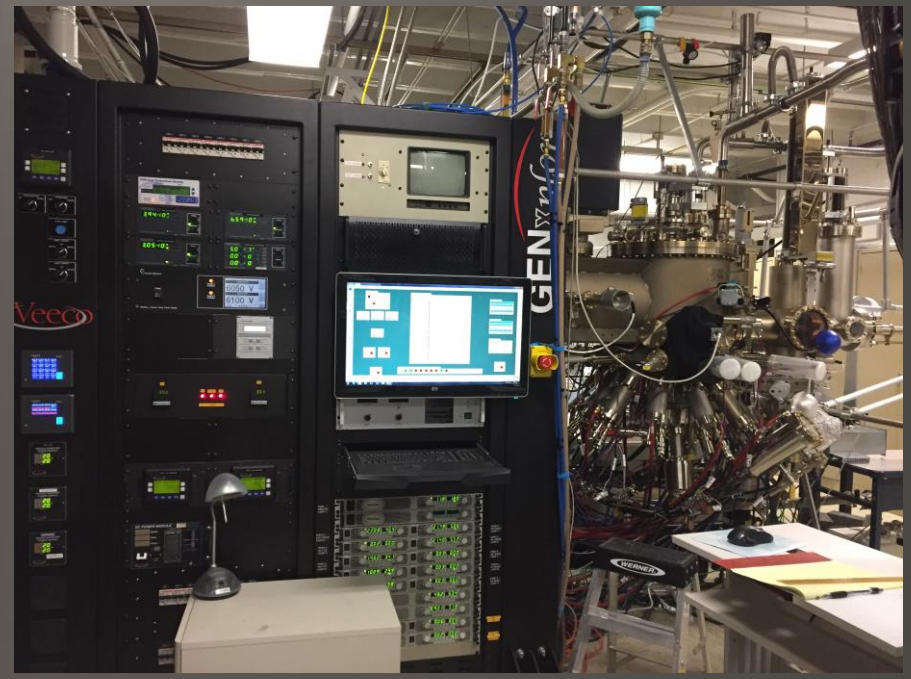


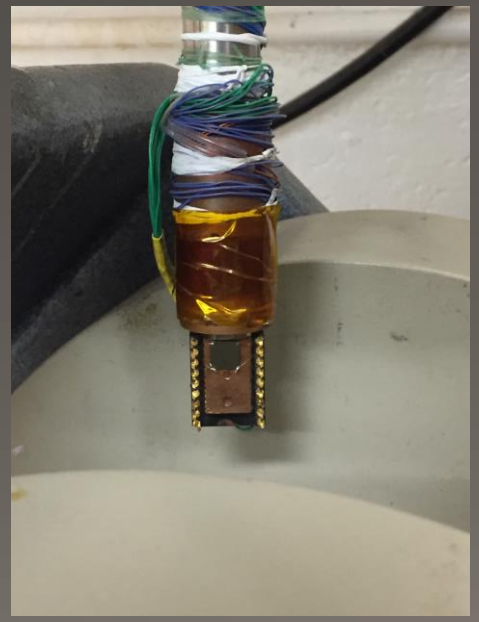
Fig. 2

Fig. 1: Ning, Cz. "Bandgap Engineering in Semiconductor Alloy Nanomaterials with Widely Tunable Compositions." *Nature Reviews Materials* 2.12 (2017): 17070. Web.

Growing Process:

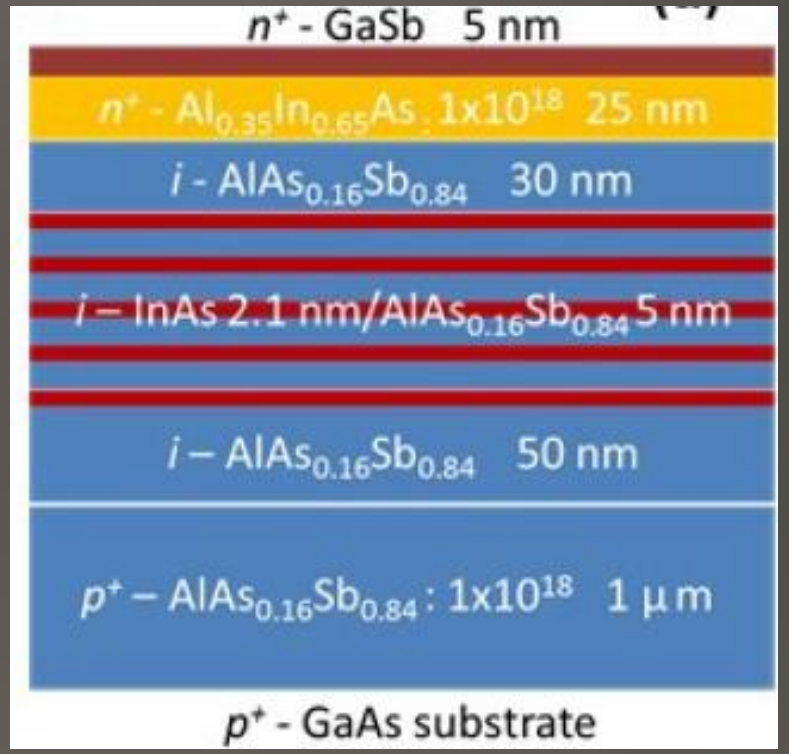
- B086 grown in an MBE
- Dr. Shi’s samples were grown through an evaporation process





Layer Structure:

- Grown in layer structure that uses the materials' crystalline structures
- Super Lattice is created, but we are focused on a single layer
- B086:
  - 5 nm GaSb
  - 50 nm doped w/ Te
  - 100 nm n-type doped w/ Te
  - 1000 nm AlAsSb
  - 500 microns GaAs



Vincent R. Whiteside *et al* 2019 *Semicond. Sci. Technol.*

The Hall Effect:

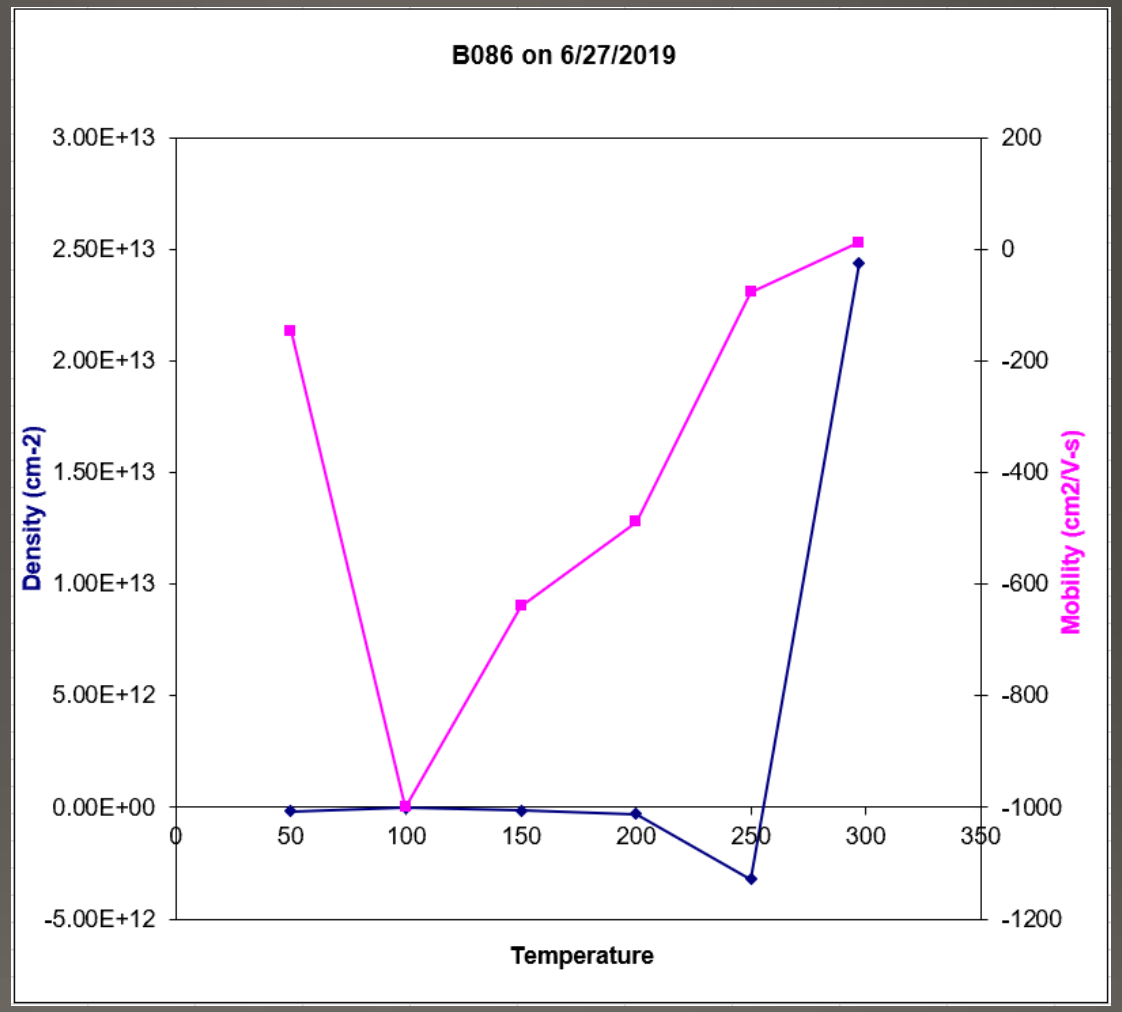
- Measurement Method
  - Sample wired with gold to In contacts
  - Reduced temperature, ranged from 297K to 25K
  - Electric current run through the contacts

Measurements:

- 2pt, checks that the contacts are ohmic relation, conductivity
- 4-pt, resistivity of the sample
- Hall Measurement; the Hall Voltage created, a magnetic field is present, carrier density deduced
- Combination of the measurements results in the mobility

The Hall Effect and its Interpretation:

- B086, Dr. Santos
- Interpolation of the information:
  - The carrier changes from n- to p-type
- Need more information on the effects caused by the dopant

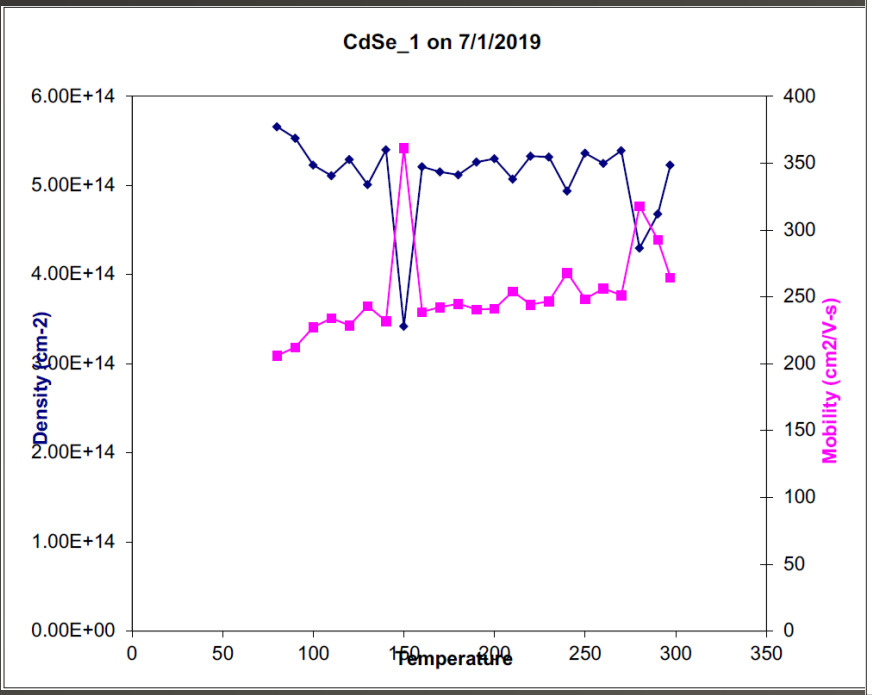


The Hall Effect and its Interpretation Cont'd…

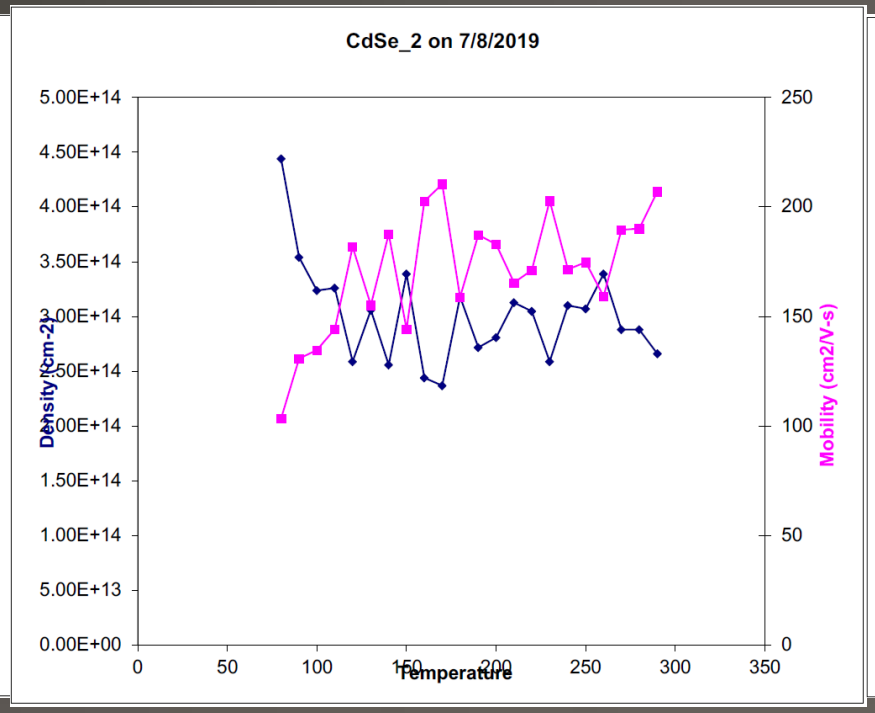
- 3 samples from Dr. Shi
- Specifically searching for the carrier density and the mobility
  - Looking at the electron density
  - Varied results

Sample Parameters:

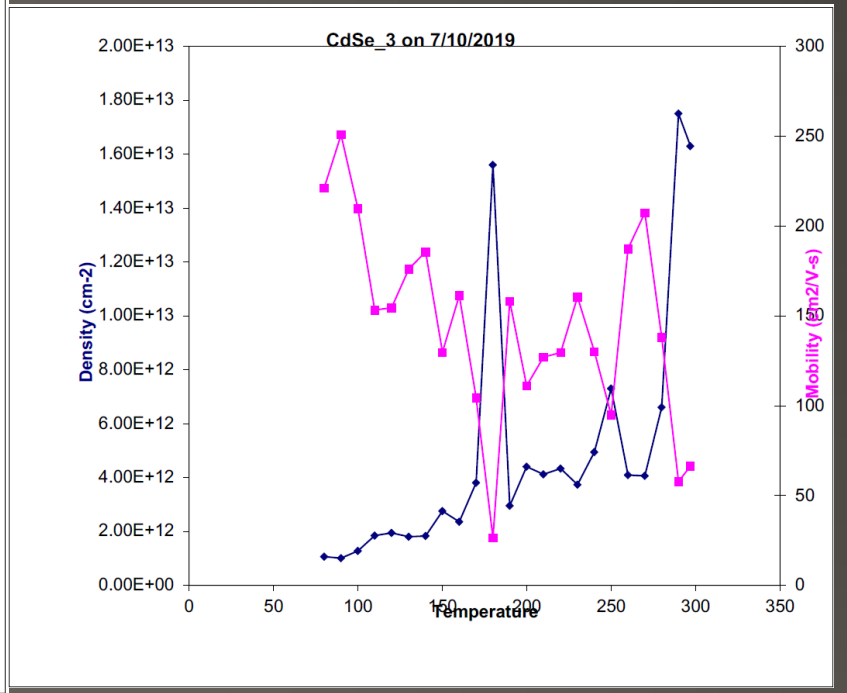
- CdSe_1:
  - Unannealed, 1800 nm
- CdSe_2:
  - Annealed at 200 C for 40 min, 1200 nm
- CdSe_3:
  - Annealed at 350 C for 30 min, 1200 nm



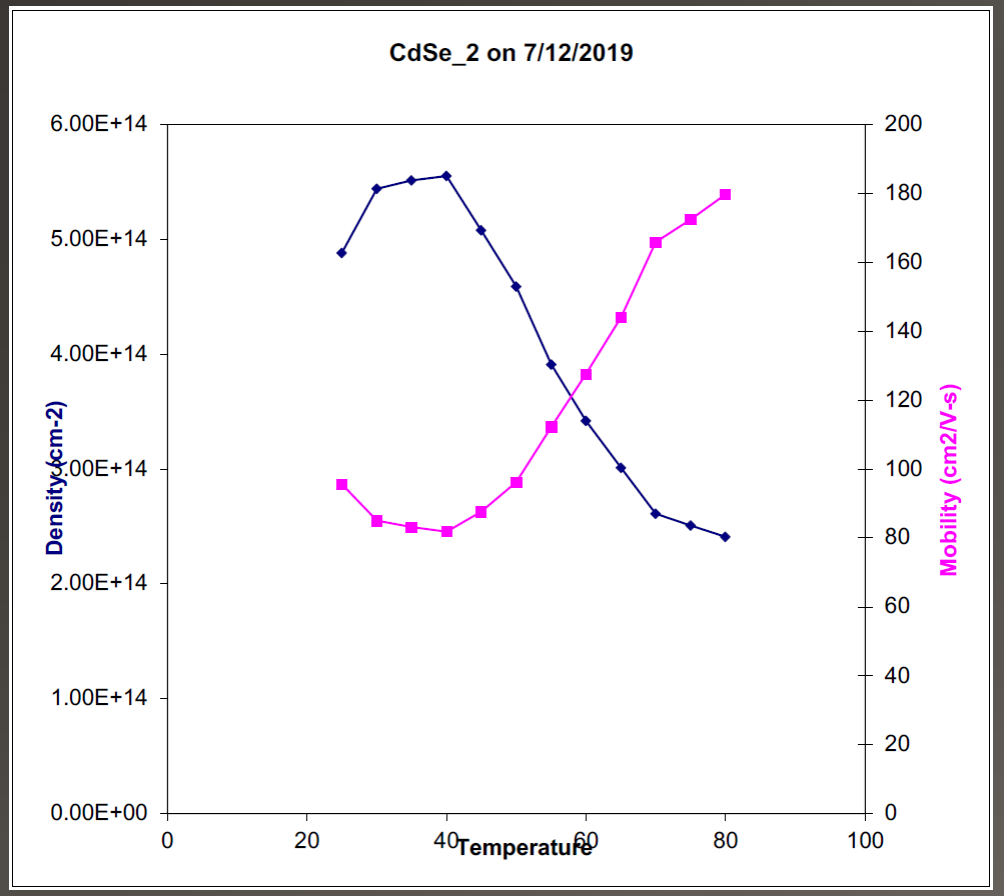
3D Density CdSe_1:
2.9E10^18 cm-3

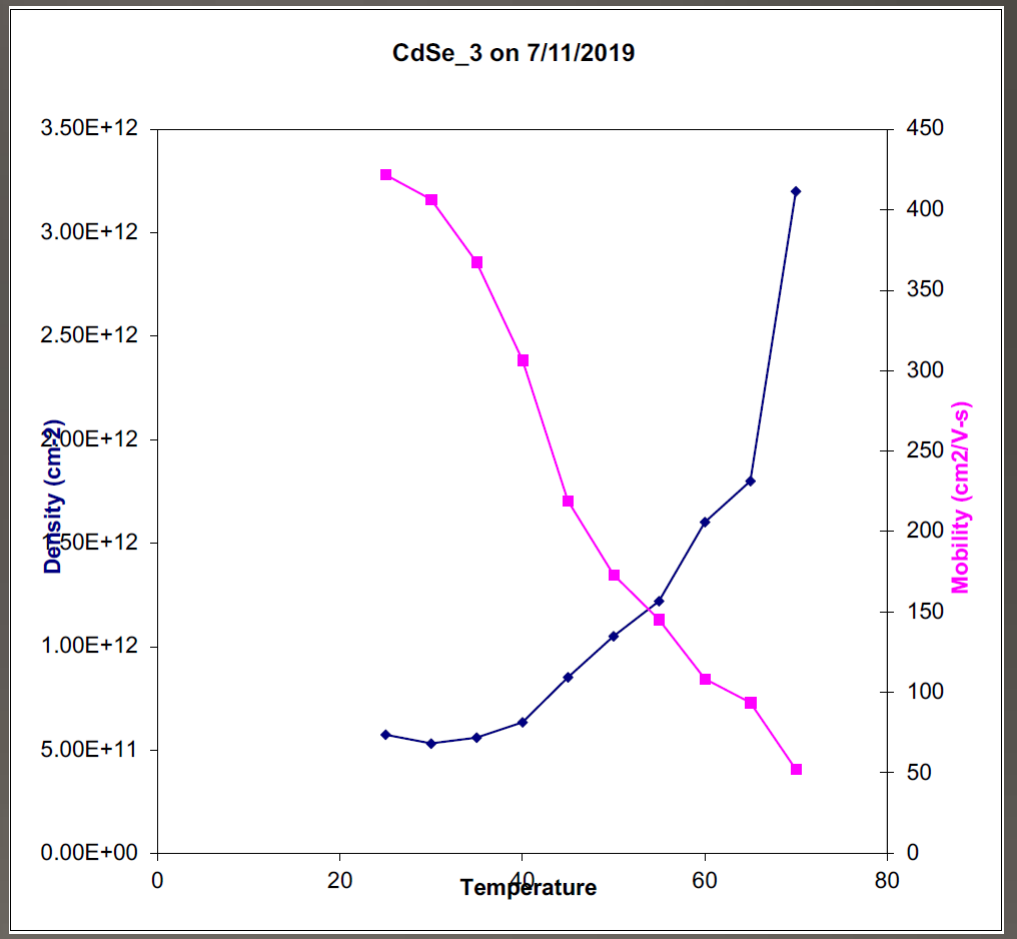


3D Density CdSe_2:
2.5E10^18 cm-3

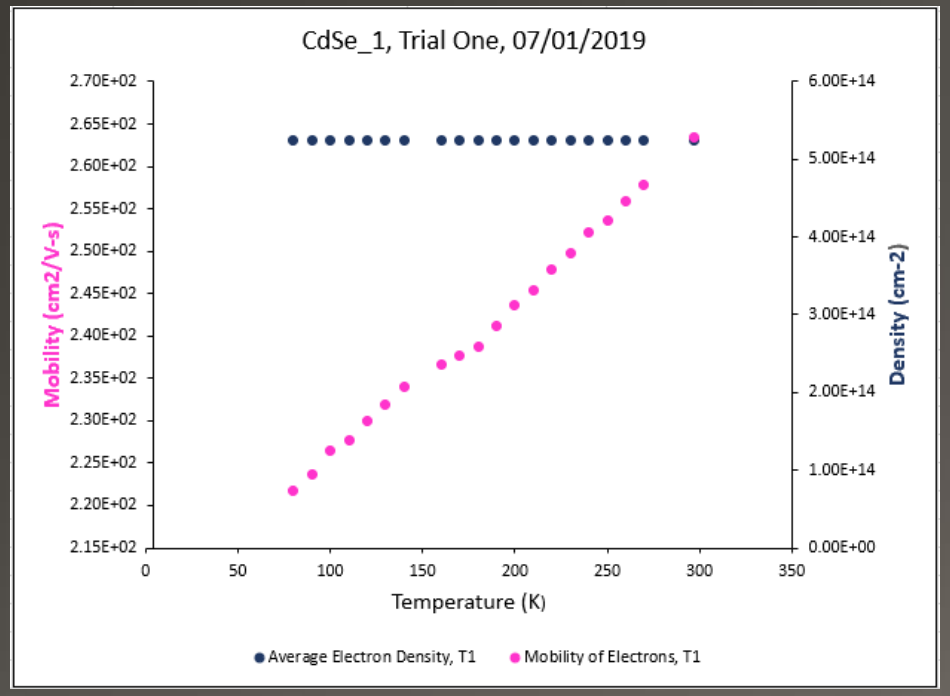


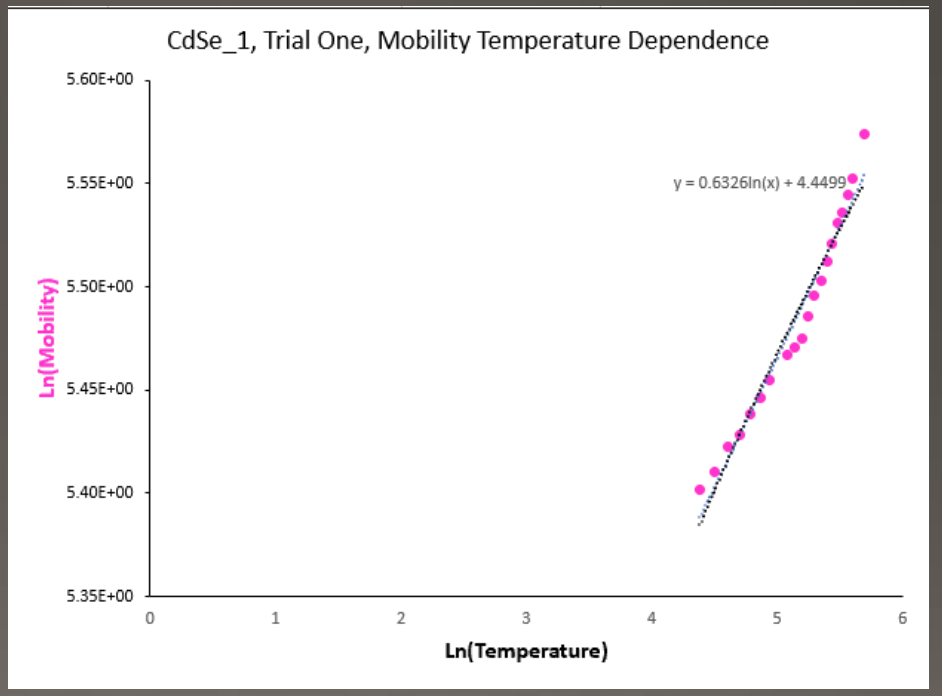
3D Density CdSe_3:
3.3E10^16 cm-3


CdSe_2 on 7/12/2019
6.00E+14
5.00E+14
4.00E+14
2.00E+14
1.00E+14
0.00E+00
Density (cm-2)
200
180
160
140
120
100
80
60
40
20
0
Mobility (cm2/V-s)
0
20
40
60
80
100
Temperature


CdSe_3 on 7/11/2019
3.50E+12
3.00E+12
2.50E+12
2.00E+12
1.50E+12
1.00E+12
5.00E+11
0.00E+00
Density (cm-2)
450
400
350
300
250
200
150
100
50
0
Mobility (cm2/V-s)
0
20
40
60
80
Temperature

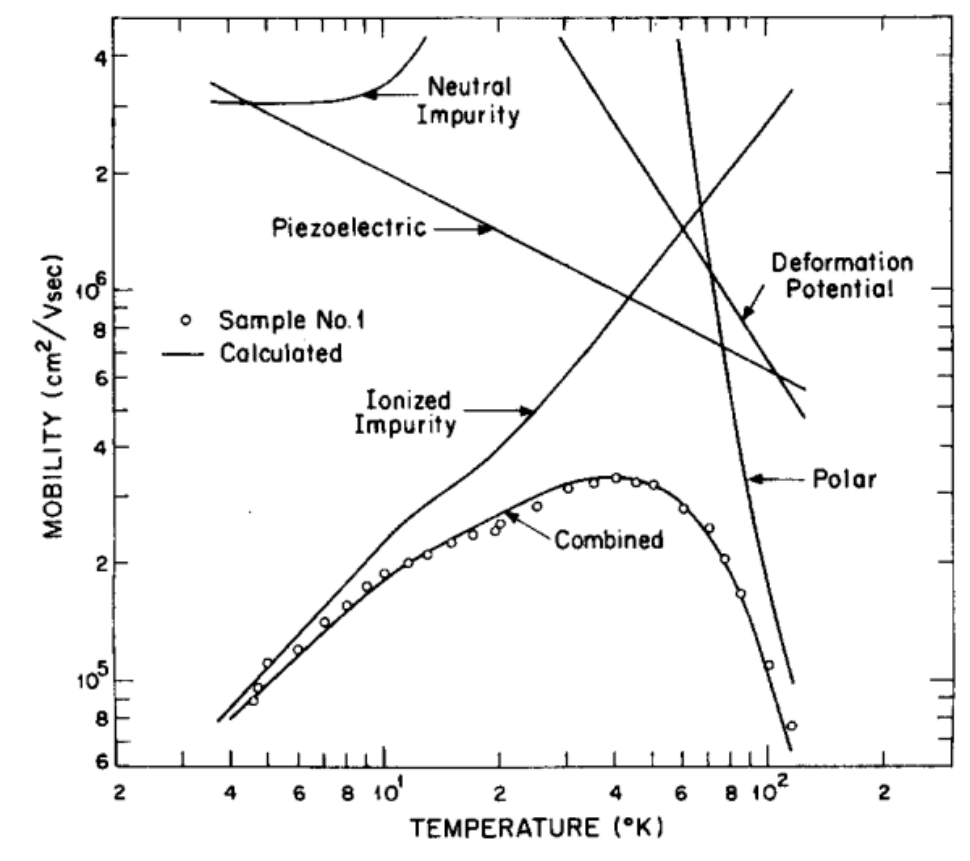
Mobility Temperature Dependence:





Expected Results:

- Dopant (Ionized Impurity)
- Piezoelectric effect



Wolfe, C M., et al. "Electron Mobility in High-Purity GaAs." *Journal of Applied Physics*, vol. 41, no. 7, 19 Nov. 1970, pp. 3+, doi:10.1063/1.1659368.

Significance and applications:

- Applications in industry, particularly components of solar cells and infrared detectors
- CdSe is a good transparent conductor in the infrared

Acknowledgments:

- Dr. Shi's Research group
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- OU REU Program Coordinators