Terahertz Spectroscopy of Graphene: Examining the Substrate and Temperature Dependence of Optical Conductivity

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Graphene is a promising material with many interesting properties, including an ultrahigh electron mobility, a zero-gap and zero-mass band structure, and an astounding mechanical strength. Potential applications of graphene range from incorporation into organic light-emitting diodes to usage in high-frequency terahertz devices. Understanding how to manipulate and control graphene's optical (or dynamic or AC) conductivity is integral to unlocking its potential in the technologically important terahertz and infrared regime. In this study, we examined two factors that affect the optical conductivity of graphene: the substrate used and the adsorption of gas molecules on graphene as well as on the surface of the substrate. Using terahertz time-domain spectroscopy (THz-TDS), we examined the transmission of THz radiation through monolayer graphene on gallium arsenide (GaAs), magnesium oxide (MgO), and silicon. We also determined that surface adsorption of gas molecules increases the optical conductivity of graphene. A sample of graphene on GaAs showed a decrease in optical conductivity after annealing at 420 K under vacuum, remained at the same level of decreased optical conductivity after returning the sample to room temperature under vacuum, and showed an increase in optical conductivity after annealing the sample in air at atmospheric conditions for two days. These results reveal key factors that affect graphene's conductivity, and could be explored further to determine the Fermi shift caused by changes in substrate and temperature.

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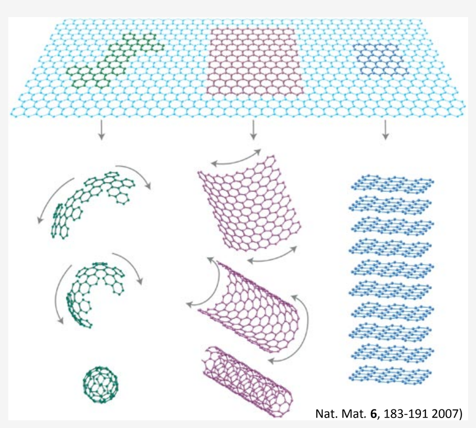
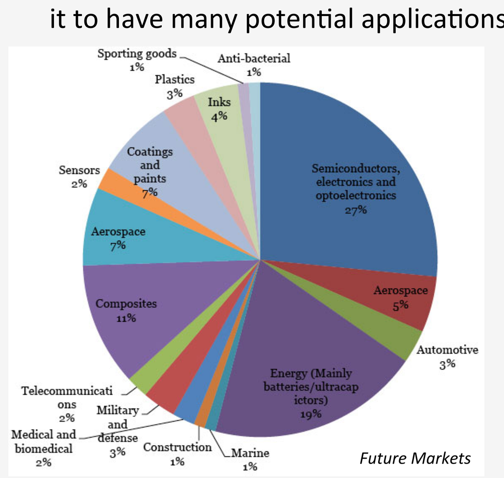
Purpose

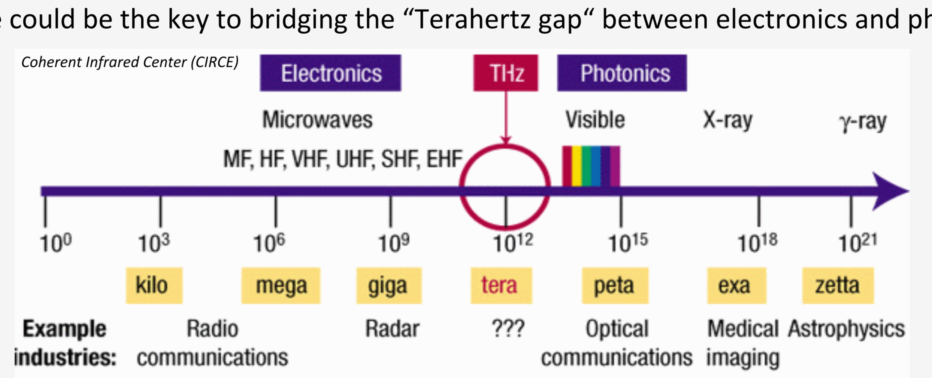
Graphene is a 2D lattice arrangement of carbon atoms, and the "mother of all graphitic forms"



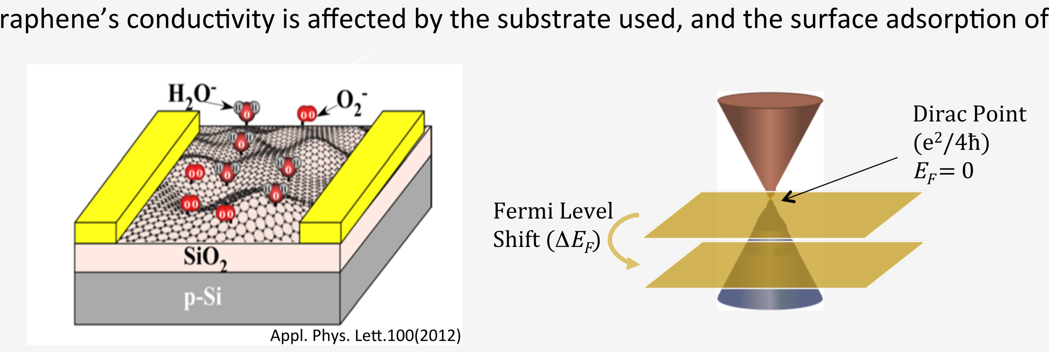
Graphene's incredible properties cause it to have many potential applications



Graphene could be the key to bridging the "Terahertz gap" between electronics and photonics

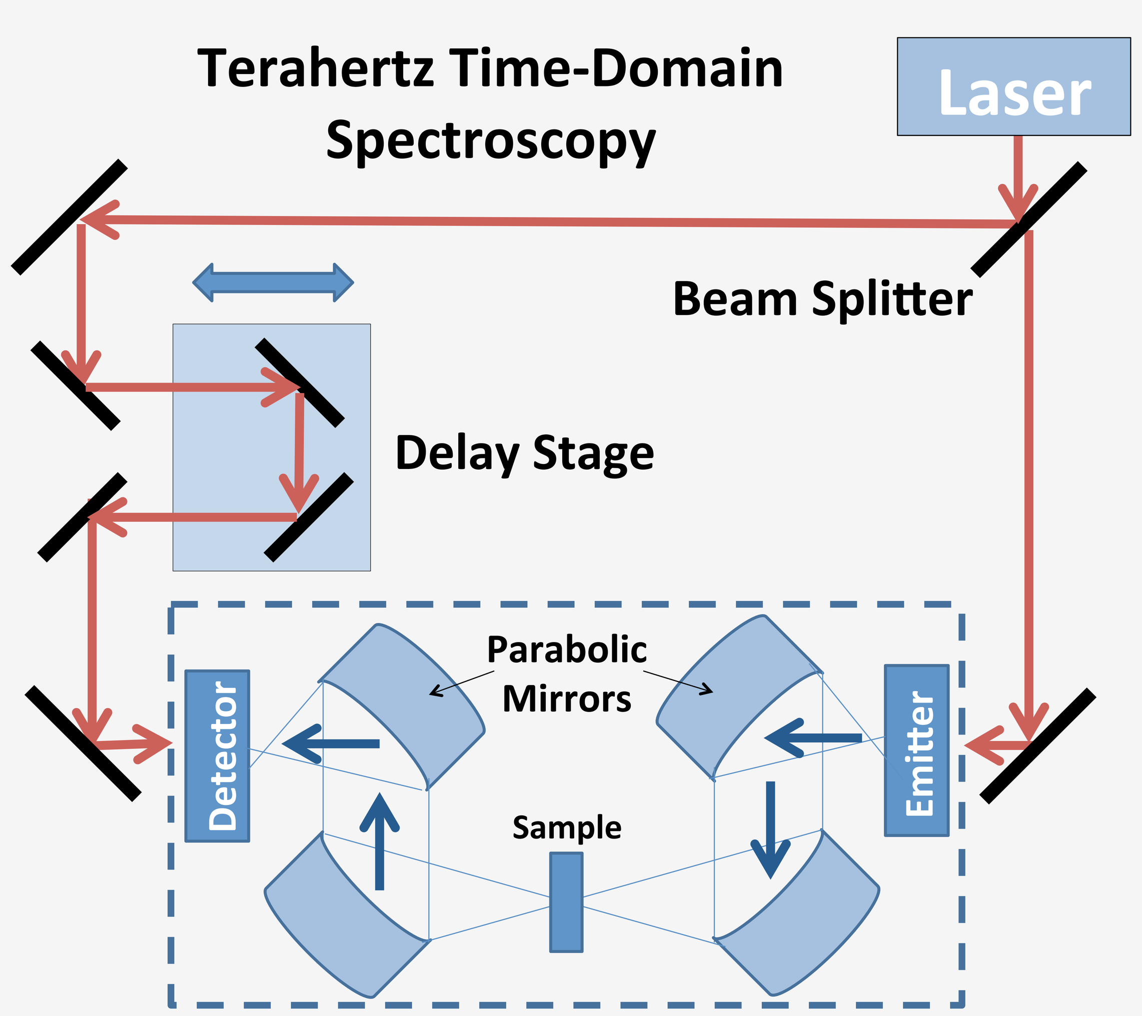


Graphene's conductivity is affected by the substrate used, and the surface adsorption of gases

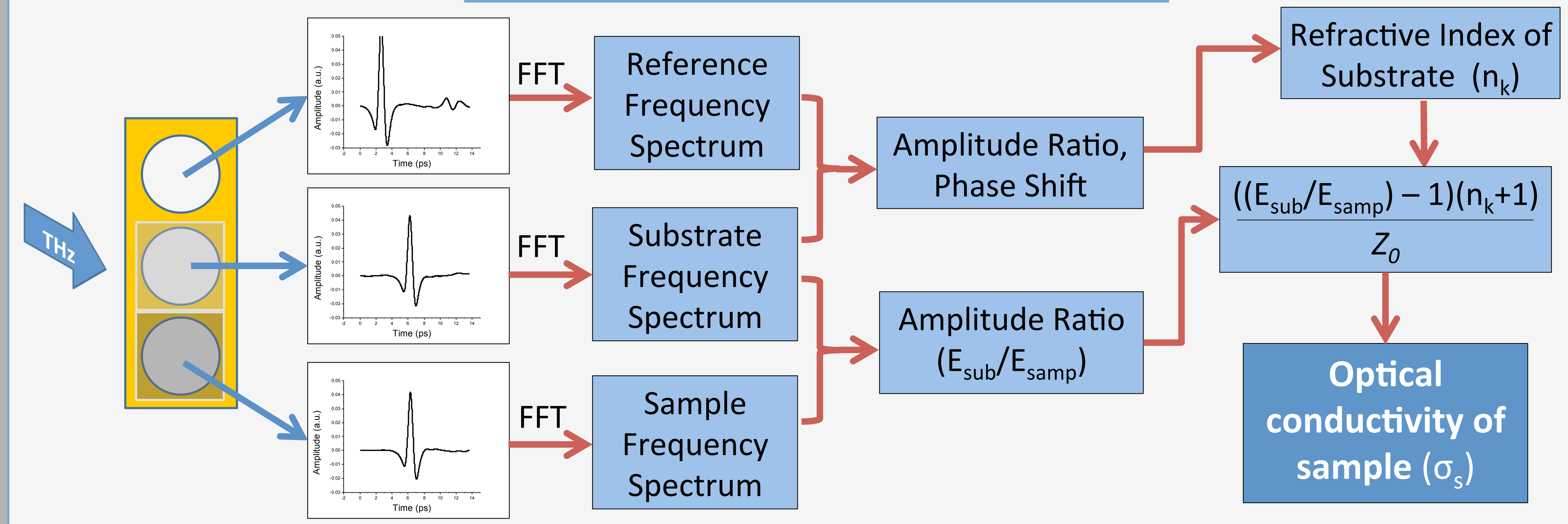


Objective: To determine the Fermi level shift caused by the substrate used and surface gas adsorption

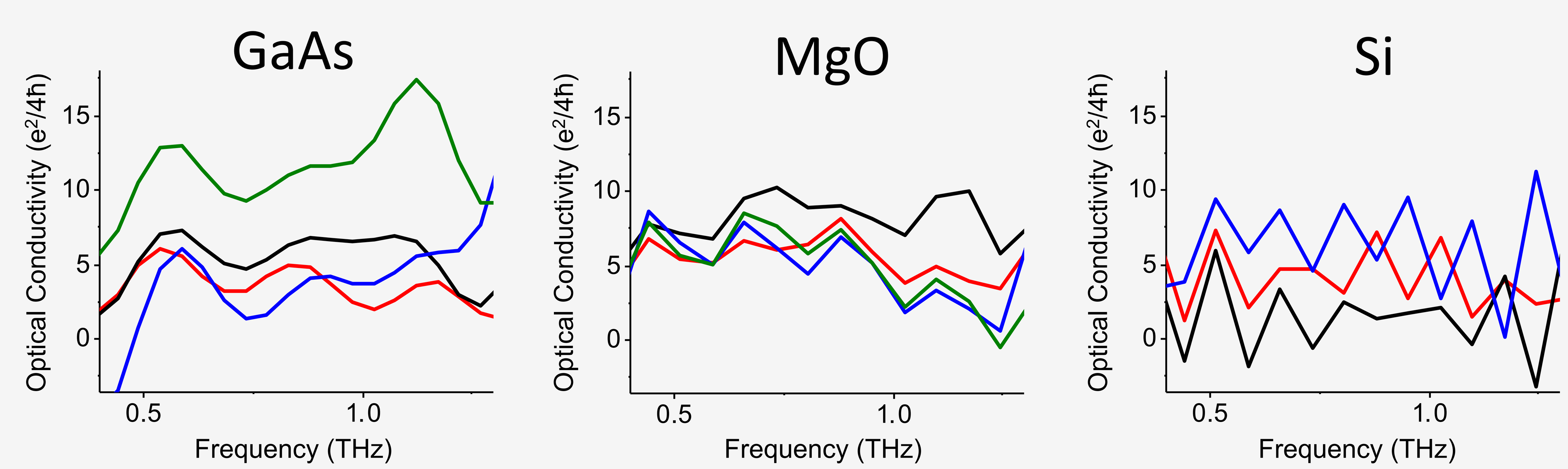
Experimental Setup



Data Analysis

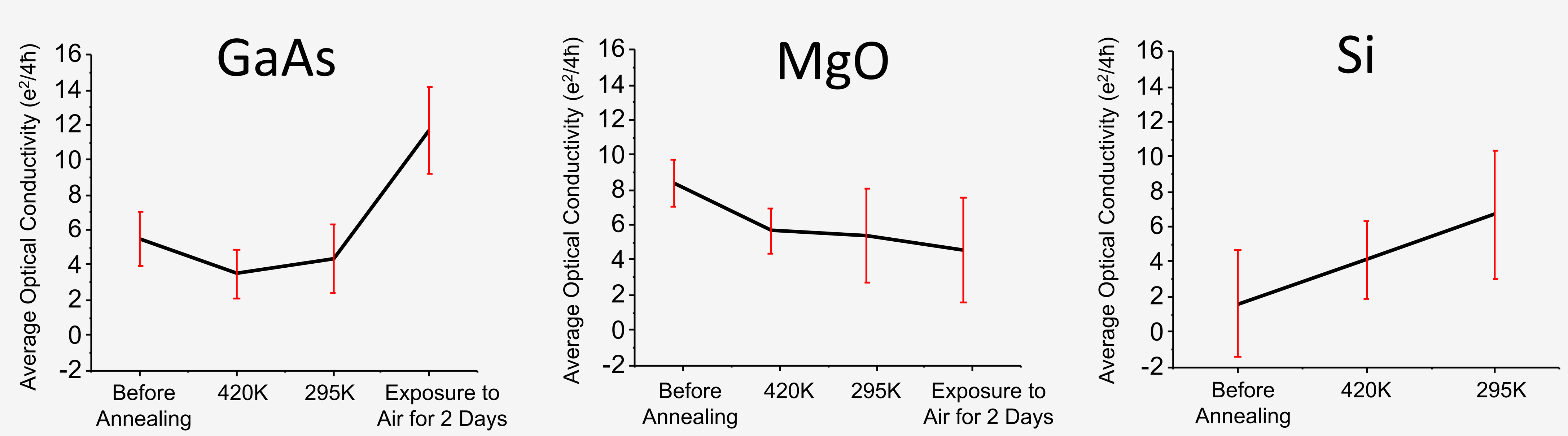


Results: Optical Conductivity

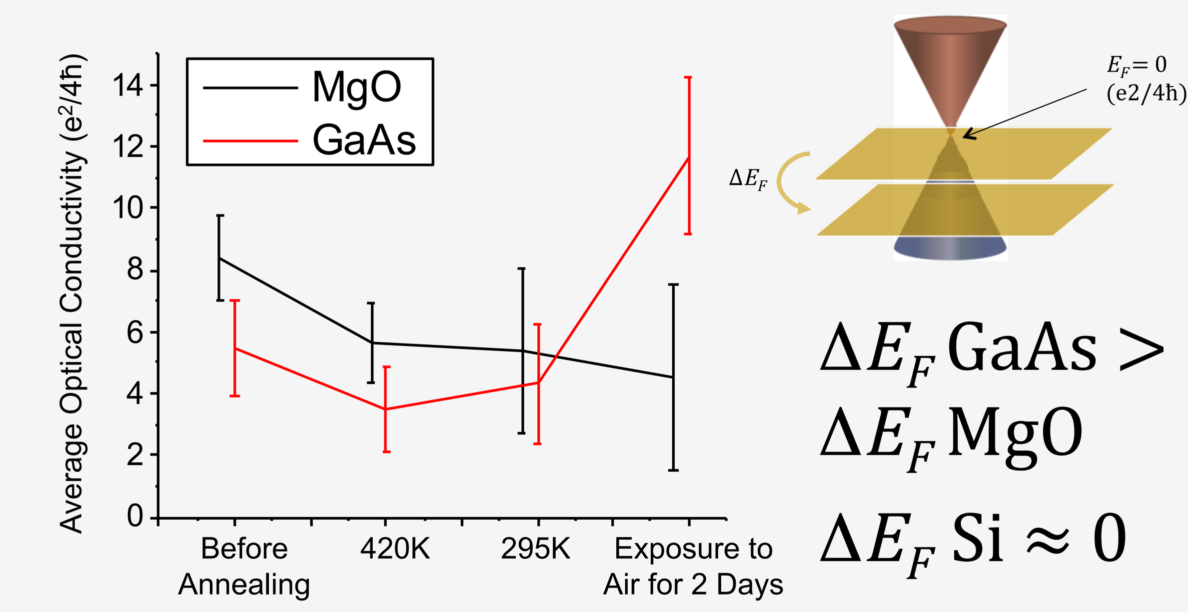


-Before annealing (vacuum) -Annealing at 420K -Annealing at 295K -Exposure to air for 2 days

Results: Average Optical Conductivity



Conclusions



ΔE_F GaAs > ΔE_F MgO

ΔE_F Si ≈ 0

Future Work

- Develop a fitting curve for the optical conductivity data
- Quantify the Fermi level shift caused by varying substrate and temperature
- Continue testing with additional substrates

References

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