Terahertz Spectroscopy of Large-Scale Graphene on Various Substrates

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Graphene is a promising material in a variety of scientific and technological fields because of its many astounding properties, such as its high electron mobility at room temperature, incredible mechanical strength, zero-gap band structure, and zero effective mass of electrons. In particular, we are interested in its electron mobility for potential incorporation in high frequency terahertz (THz) electronic devices. The electron mobility of graphene is affected by gas molecules between it and the substrate as well as by charge impurities at the substrate-graphene interface. Therefore, in this study, we have investigated the dependence on various substrates of THz transmission and optical conductivity of large-scale graphene using THz time-domain spectroscopy (THz-TDS). The substrates we examined are indium phosphide (InP), magnesium oxide (MgO), indium arsenide (InAs), gallium arsenide (GaAs), and black polypropylene sheets (BPPS). We found an unexpectedly large dependence of transmittance and conductivity of graphene on the substrate used. We also investigated the effect of cw laser illumination on graphene with THz-TDS.

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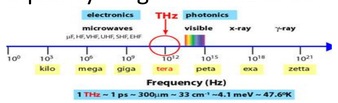
1. Terahertz and Graphene

Terahertz:

- Frequency range 300 GHz to 30 THz



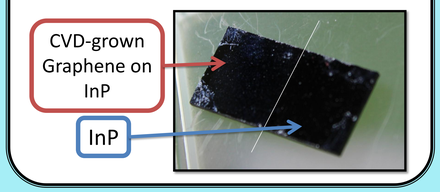
- Terahertz Time Domain Spectroscopy (TDS) measures THz field
- From transmitted and reference (no sample) fields, calculations of transmittance and conductivity are possible

Graphene:

- Astoundingly high electron mobility at room temperature, zero gap band structure, and zero effective mass of electrons
- High potential for high frequency electronics

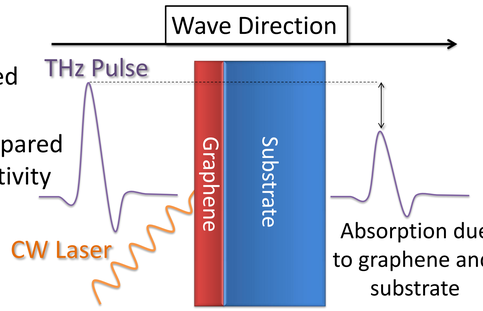
2. Graphene on Substrates

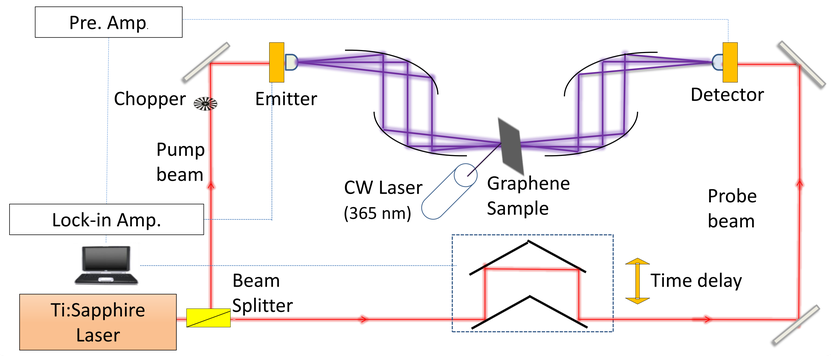
- Graphene's electron mobility should be affected by:
  - Charge impurities on substrate-graphene interface
  - Gas molecules trapped between graphene and substrate
- Investigate this change via transmission and optical conductivity analysis of graphene on various substrates for potential use in high frequency THz electronic devices.



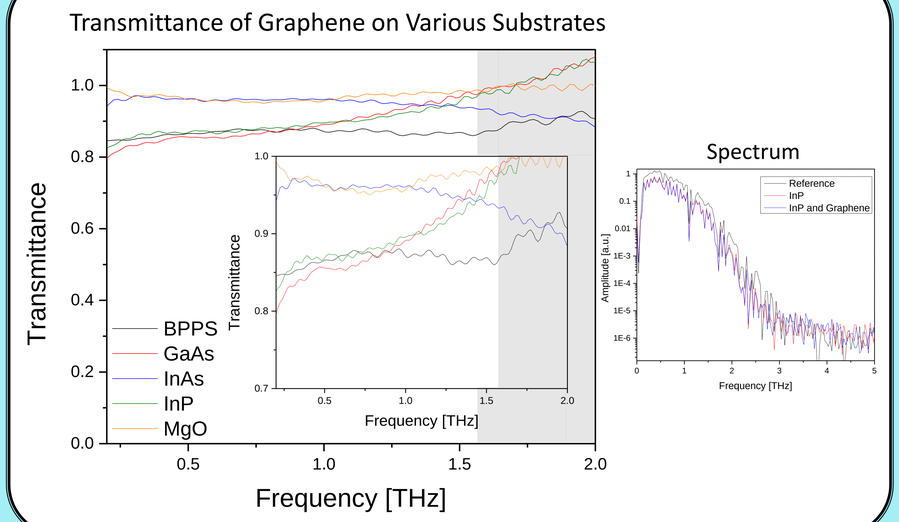
3. Terahertz Time-Domain Spectroscopy

- Graphene grown using chemical vapor deposition (CVD)
- THz pulses generated and detected by GaAs photodiode antennas
- Using conventional THz-TDS, compared transmittance and optical conductivity of graphene on GaAs, BPPS, InP, InAs, and MgO
- Measured same properties when illuminated by 365 nm CW laser

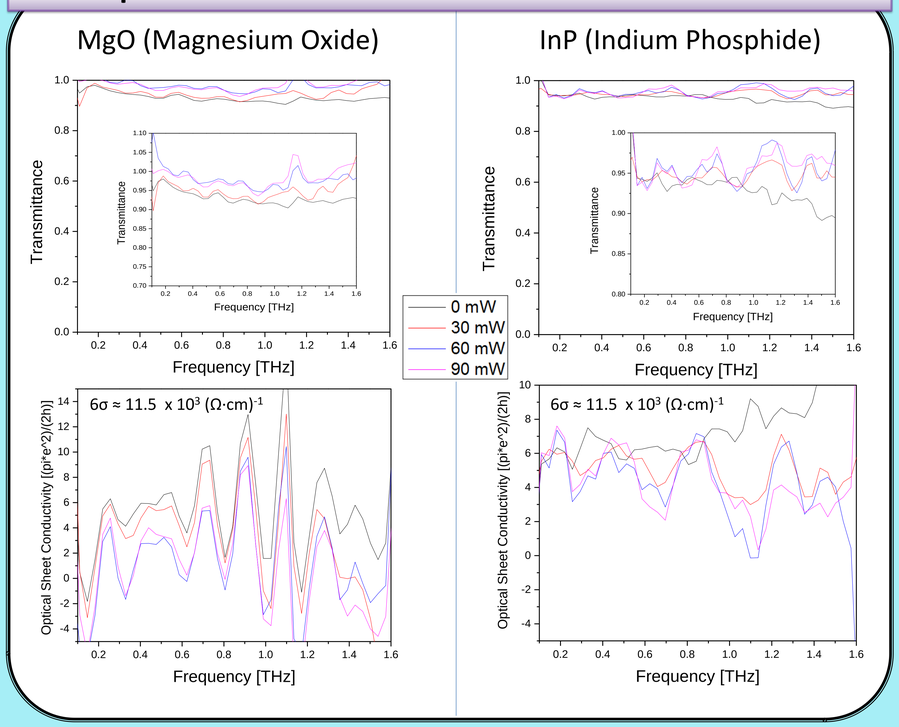




4. Graphene Transmittance Dependence on Substrate



5. Graphene Transmittance Increase Under 365 nm CW Laser



6. Discussion and Future Work

Substrate Dependence

- First time observed in the THz region
- Reason largely unknown
- Most likely related to the substrate-graphene border

CW Laser Dependence

- Several possible explanations
- One is air molecules affecting Fermi level
  - Air molecules bind to graphene
  - Induced electric field moves Fermi level from Dirac point -> increases carrier density -> lowers transmittance
  - Laser removes molecules, resetting Fermi level

- Several more tests needed to confirm mechanism

7. Conclusion

- Possible dependence of transmission of graphene on substrate
- The 365 nm laser clearly affects the transmission and optical conductivity of graphene

8. References

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