Thermal and Electrical Properties of Nanocomposites of Reduced Graphene Oxide and Silver Nanoparticles

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Motivation: Thermoelectric applications

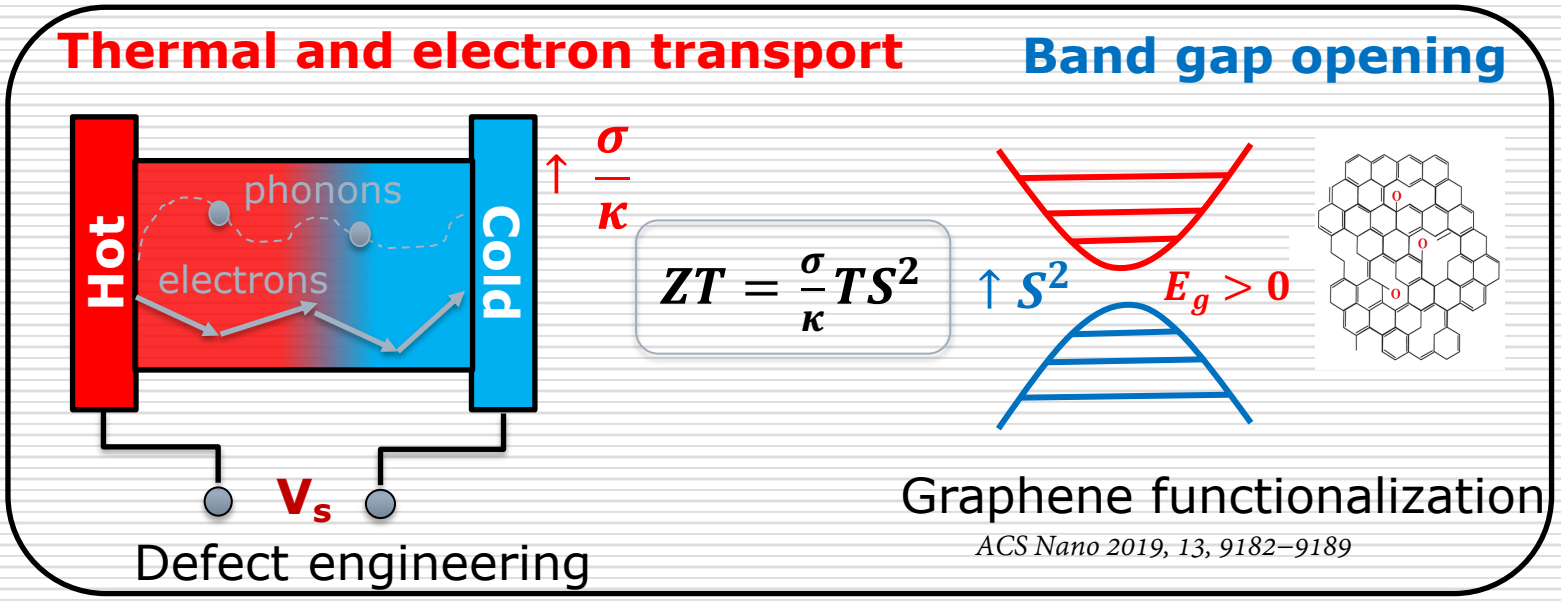


Fig 1: Schematic illustration of thermal and electron transport.

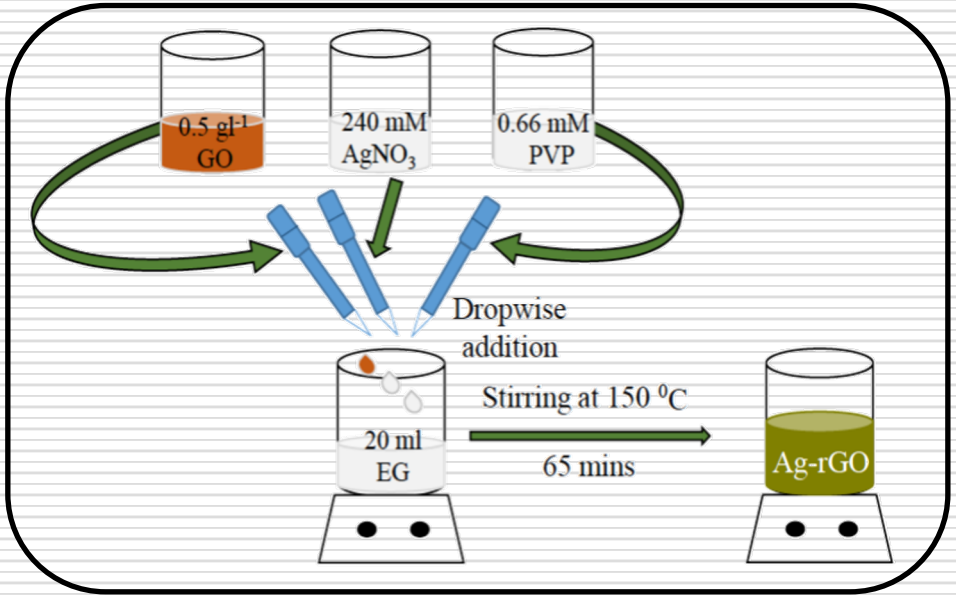


Fig 2: Schematic illustration: synthesis of Ag-rGO.

Prerequisites for efficient thermoelectric materials:

1. High electrical conductivity (σ): Graphene (~10^4 S/m)
2. High Seebeck coefficient (S): Graphene functionalization and bandgap opening (127–287 μV K^{-1})
3. Low thermal conductivity (κ): Defect/dopants and phonon scattering (0.1 W/mK)

Results: Spectroscopic characterization

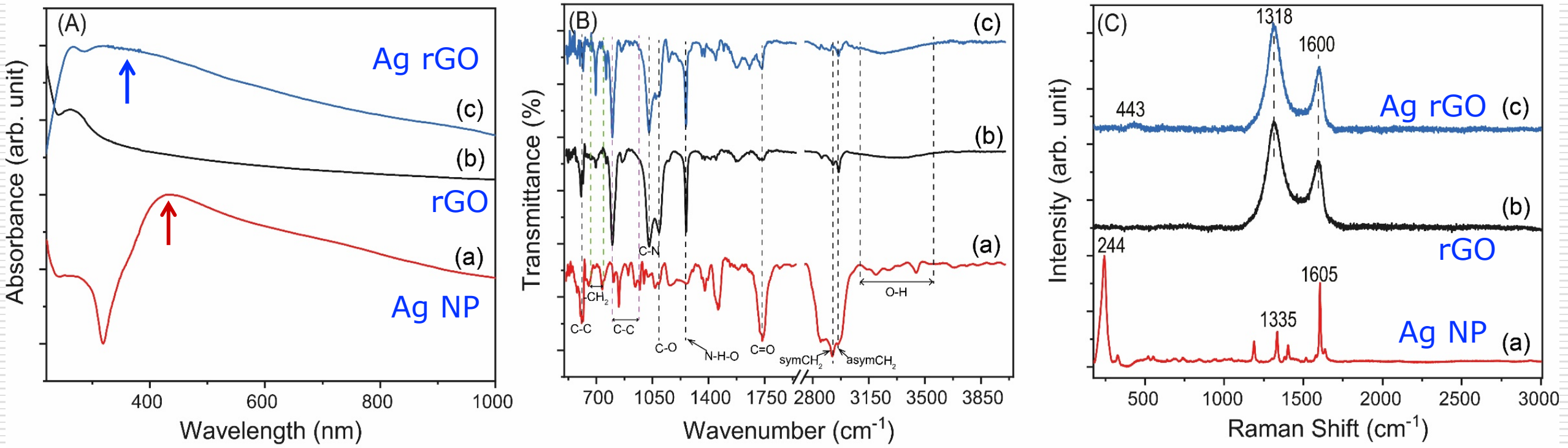


Fig 3: (A) UV-vis absorption spectra, (B) FTIR spectra and (C) Raman spectra for (a),(b) and (c) which respectively
correspond to Ag NP, rGO and Ag-rGO.

- ✓ I_D/I_G ratio is found to be 1.6(2) for rGO and 1.7(5) for Ag-rGO.

Results: Size and Structure

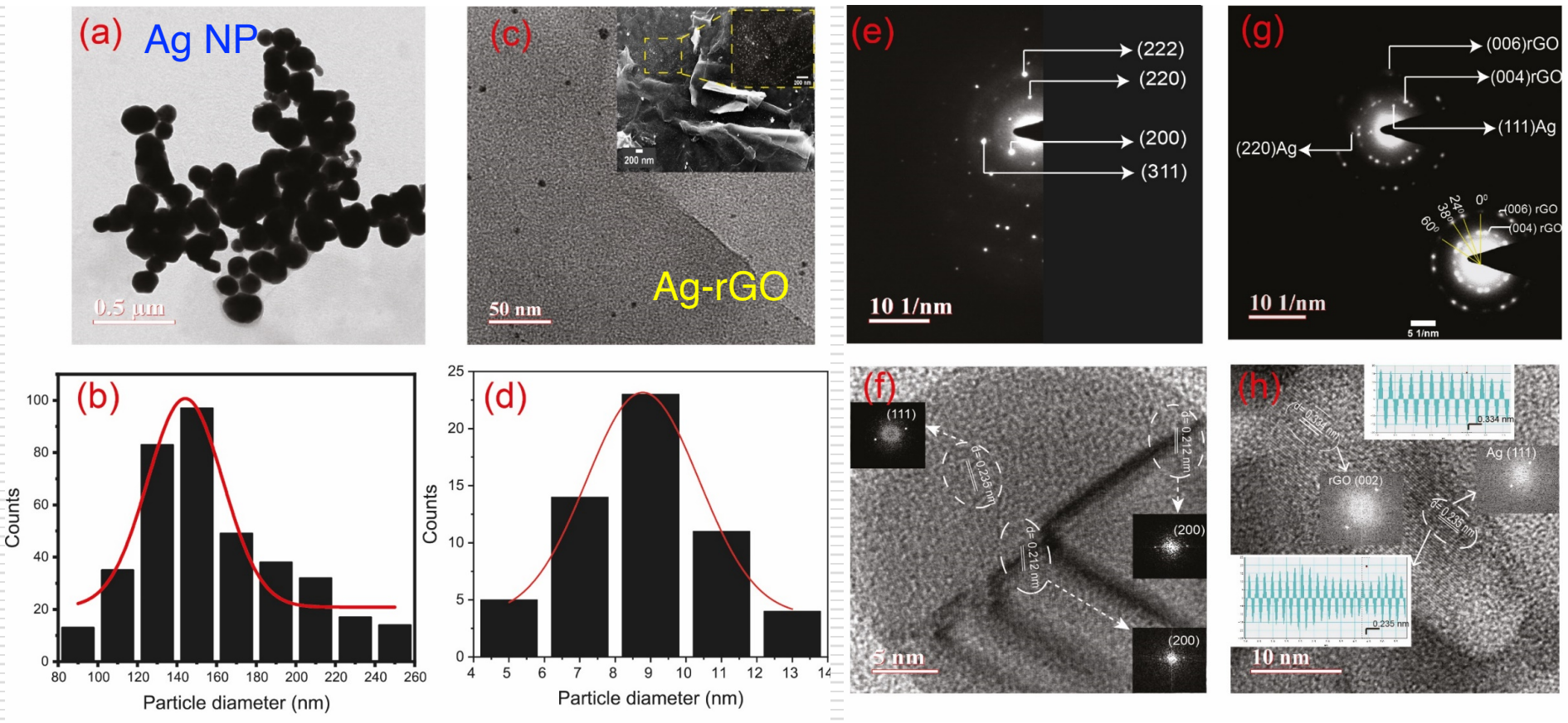
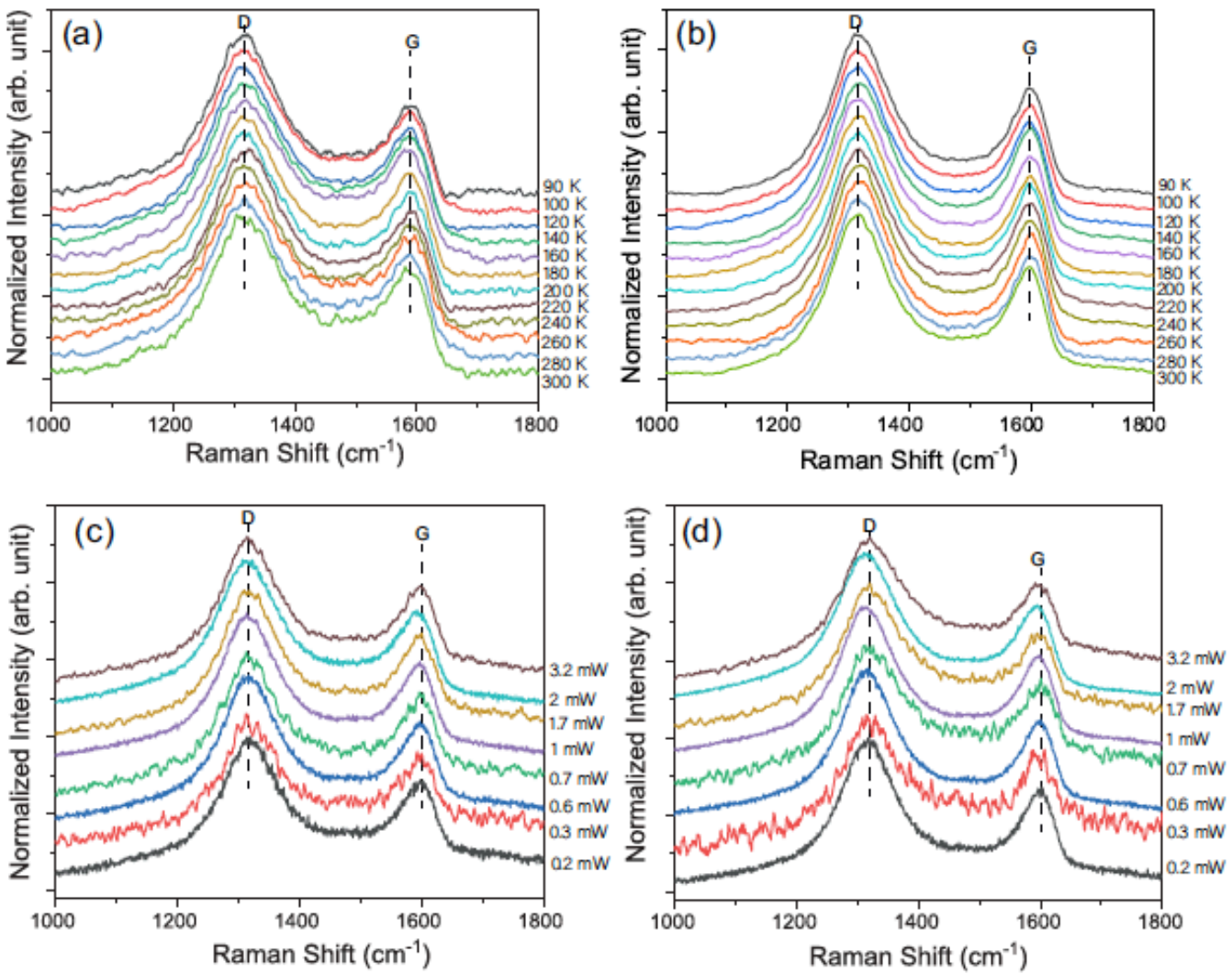


Fig 4: (a), (c) TEM micrographs of Ag NP and Ag-rGO nanocomposite, (b), (d) refer to their corresponding particle size distribution, (e), (g) SAED pattern of Ag NP and Ag-rGO where inset shows angle between the spots corresponding to rGO plane and (f), (h) are their HRTEM micrographs.

- ✓ Simultaneous reduction of Ag and GO leads to formation of smaller sized NP in our study, possibly due to attachment of Ag+ ions with carboxylated carbonaceous fragments present in GO obtained during Hummers method.
- ✓ The angle between 3 spots with respect to a reference spot is found to be 24 , 38 and 60° as shown in inset of Fig.(g).
- ✓ These spots are related to turbostatic layered arrangement of graphene.

Results: Raman thermometry



Variation in Raman frequency with T is related to anharmonic components in lattice potential energy such as thermal expansion and conduction

Thermal variation in Raman frequency ω(T)

$$\omega(T) = \omega_0 + \chi_T T$$

Linear power dependence of ω

$$\frac{\partial \omega}{\partial P} = \chi_P$$

G-band	χ_T (cm^{-1}K^{-1})	χ_P(cm^{-1}mW^{-1})
rGO	-0.014	-0.571
Ag-rGO	-0.012	-0.657

Fig 5: Temperature dependent Raman spectra for (a) rGO and (b) Ag-rGO. Power dependent Raman spectra for (c) rGO and (d) Ag-rGO.

Results: Thermal and electricalconductivity

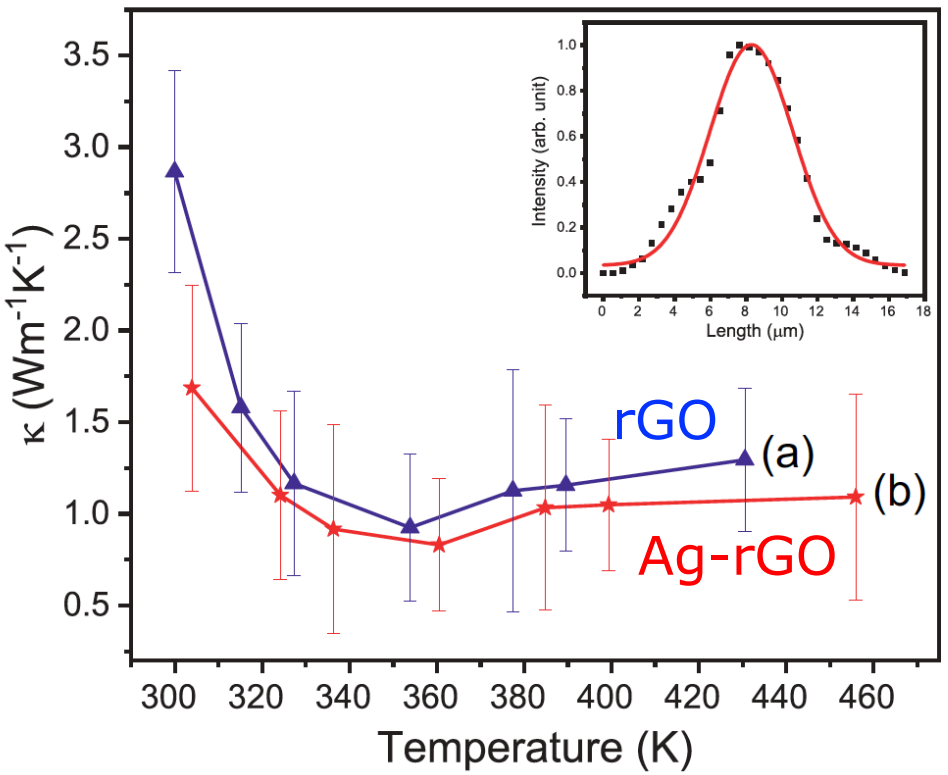


Fig 6: Variation of k with temperature for (a) rGO and (b) Ag-rGO. Inset shows beam profile of 785 nm laser on sample's surface.

- ✓ For rGO and Ag-rGO at 0.3 mW laser power (dT at 6 K and 10 K), κ are found to be 2.86(1) and 1.69(1) $Wm^{-1}K^{-1}$ respectively.

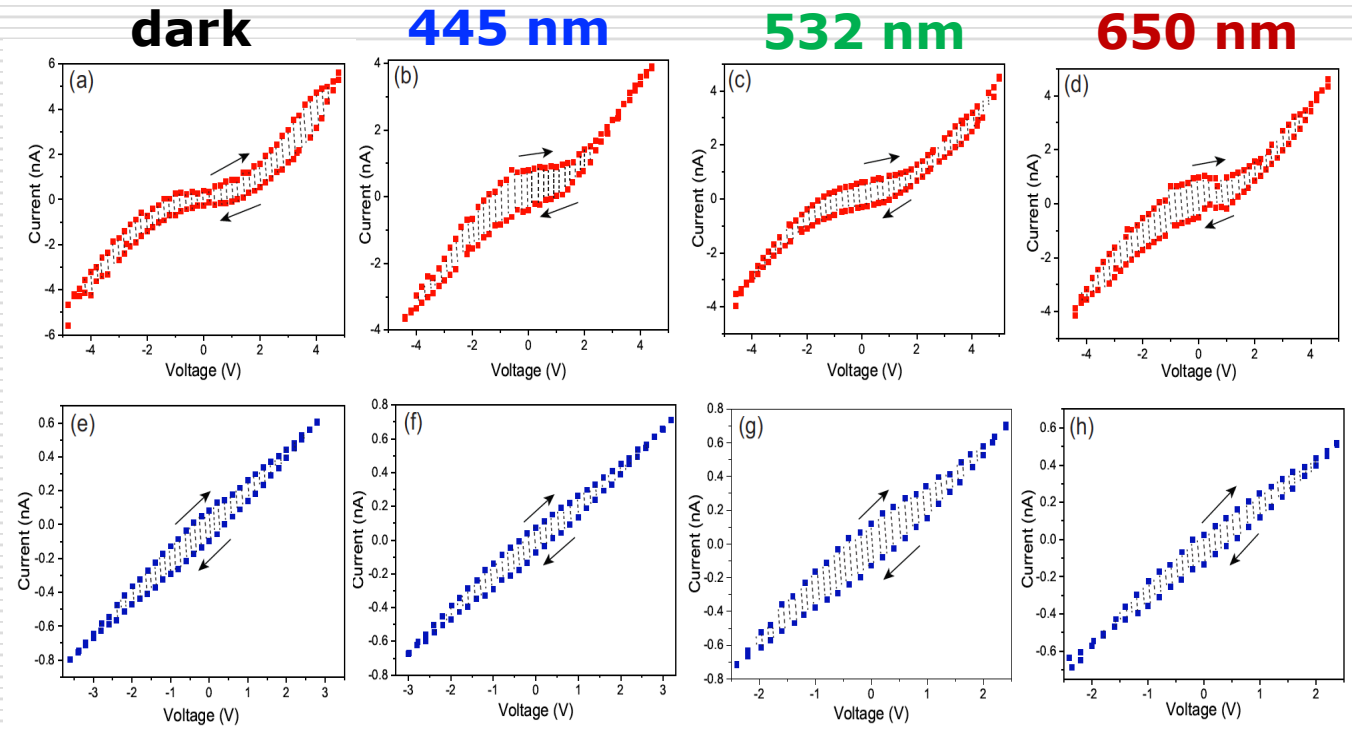


Fig 7: I-V curves obtained while illuminating the sample under different excitation wavelength for rGO: (a) dark, (b) 445 nm, (c) 532 nm, (d) 650 nm and Ag-rGO: (e) dark, (f) 445 nm, (g) 532 nm, (h) 650 nm.

- ✓ Upon illumination, in LSPR of Ag NP, it can improve the EM field in their immediate vicinity resulting in improvement in absorption of light thereby generating light-induced electron-hole pairs.

Conclusion and prospects

- Anharmonicity, thermal expansion and thermal conductivities are examined for rGO, Ag-rGO
- Thermal conductivities of rGO and Ag-rGO at ~ 300 K are 2.86(1) $Wm^{-1}K^{-1}$ and 1.69(1) $Wm^{-1}K^{-1}$ respectively.
- I-V hysteresis loops show variation in space charges and electrical resistances in presence and absence of plasmonic excitations.
- Low thermal conductivity in turbostratic graphene plus photo tunable electrical conductance offer potential applications in fabrication of photo-thermoelectric devices, plasmon-enhanced opto-electronic device, photodetector etc.

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