Graphene: Optical properties

What does optical spectroscopy measure?

Spectroscopic ellipsometer + ultraviolet-vacuum ultraviolet (UV-VUV) reflectometer

Graphene: Optical properties at high energies range (theory)

Linear band dispersion in the vicinity of K point in Brillouin Zone[4,5]

Valence band conduction band at a point crossing the Fermi level, resulting in many exotic phenomena.

Graphene: Optical properties

Focus on low energies (vicinity of B band, left figure)

Universality of optical conductivity (middle figure)[7,8]

Fine structure constant defines transparency in graphene (right figure)[6]

What does optical spectroscopy measure?

Reflectivity (R) measurement using 0 to 35 eV excitation energies (left) from 3.5 to 35 eV using UV-VUV reflectometer at SUPERLUMI/HASYLAB (upper right and lower right figures).

Ellipsometry measurement using 0.5 to 5 eV excitation energies for normalizing the "high energies" (right figure).

All done at room temperature.

$R_{\text{ll}} = R_{\text{ll}} - R_{\text{bb}}$

$R_{\text{bs}}$ is reflectivity of "buffer layer" + 6H-SiC + substrate

The sample thickness is determined by measuring the Raman shift using attenuated substrate peak method described in Ref. [14].

Graphene: Optical properties at high energies range (theory)

Left figure: From ref[9], excitonic (boudned electron – hole) effects at 4.7 eV. It occurs in the vicinity of 0 to e* bands at M point.

Right figure: From ref[10], resonant excitonic (RE) effects at 8.3 eV. It occurs in the vicinity of 0 to e* bands at M point and is related as a function of layer number (N; thus probing the screening effect).

Does the RE exist at higher energies? A systematic study of RE effect at higher energies is related as a function of layer number (N; thus probing the screening effect).

Graphene: Optical properties at high energies range (experiment)

Interband transition from 0 to 0* bands at M point.

Interband transition from 0 to e* bands along Γ-M.

Resonant (Dipole) Functional Theory calculation yields similar result to our data and confirms the previous calculation [15].

III. Data and results

Si description process of 6H-SiC(001) at high temperature (T) in ultra high vacuum (UHV) condition. This was done under evaporation of Si flux at evaporation 1-450°C[13].

The sample thickness is determined by measuring the Raman shift using attenuated substrate peak method described in Ref. [14].

Thickness dependence of reflectivity data as a function of excitation energy.

Significant difference between substrate, graphene, and graphene data.

IV. Discussion

Substrate Effects? (no)

Plasmonic excitation?

Resonant exciton (RE) ? (yes for peak B)

What is the origin of these A, B, C peaks?

V. Conclusions

New finding of high energies excitations in epitaxial graphene: Resonant exciton (transition energy of 6.3 eV) appears at room temperature.

Resonant exciton effects are very likely responsible for the electronic structure in graphene and still exist for very large number of layers -> showing the poor screening.

Resonant exciton energy is red-shifted by 2.0 eV in epitaxial graphene. This is due to the influence of charge transfer from the substrate.

References


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