GRAPHENE AND 2DM VIRTUAL CONFERENCE & EXPO

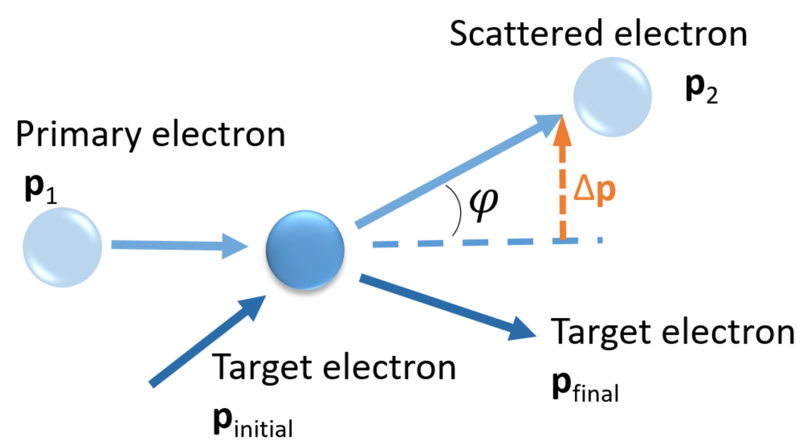
Graphene online 2020 October 19-23

Electron Compton Scattering and the Measurement of Electron Momentum Distributions in Solids

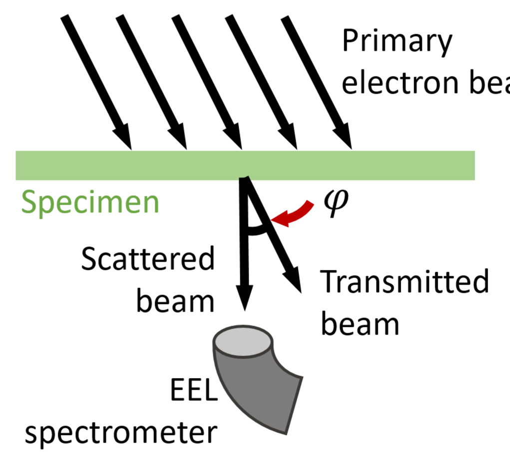
Alina Talmantaite, Michael R.C. Hunt, Budhika G. Mendis. Centre for Materials Physics, Durham University, Durham, DH1 3LE, United Kingdom

Electron Compton scattering experiments in TEM

Electron Compton scattering is a technique used for measuring the electron momentum density of states in solids[1].



Momentum conservation: the scattering angle of the incident electron is related to the momentum of the target electron.



By controlling the beam tilt angle in a TEM-EELS experiment, we control the scattering angle.

Typically experiments are carried out in a high momentum transfer regime (high φ) to satisfy the impulse approximation (see below).

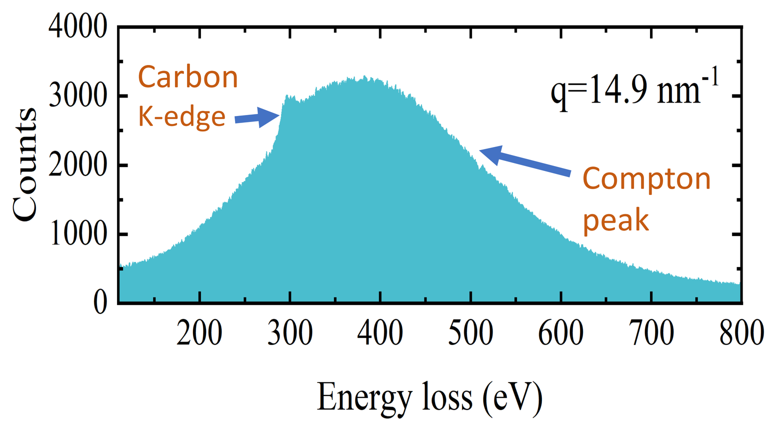


Fig. 1. Compton peak in the high momentum transfer regime.

Novel Compton scattering experiments are carried out in the low momentum transfer regime, at low φ .

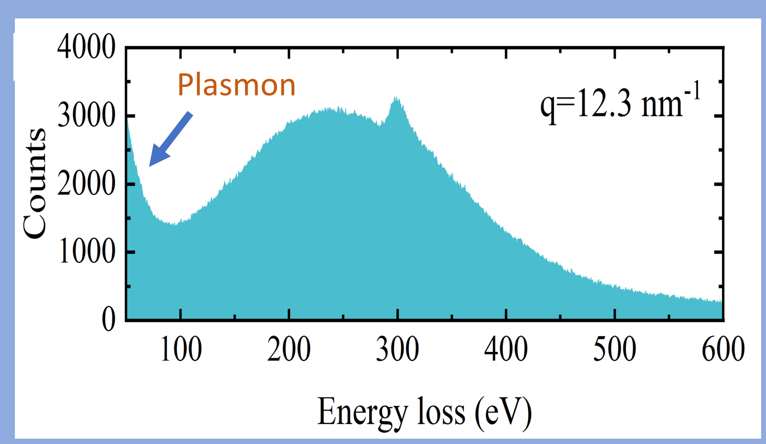


Fig. 2. Compton peak in the low momentum transfer regime.

Projected electron momentum density profiles in amorphous carbon films

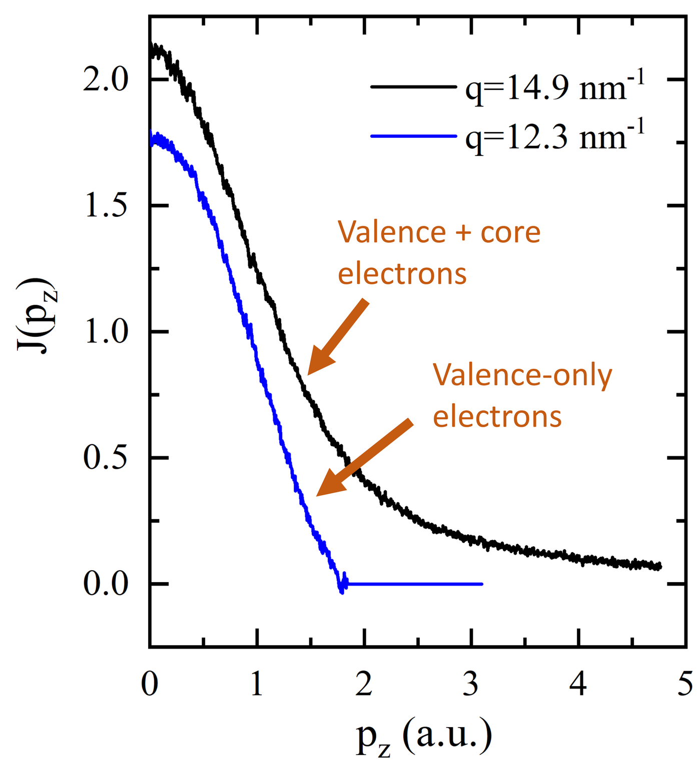


Fig. 3. Compton profiles in the high (black) and low (blue) momentum transfer regimes.

Compton profiles of amorphous carbon films in Figs. 1 and 2 were converted into projected momentum density profiles, $J(p_z)$ (Fig. 3)[2]. Plasmon background was subtracted via power law technique.

The $J(p_z)$ for valence electrons is similar to that reported for graphite and measured via standard methods[3].

Advantages and perspectives:

- In the low momentum transfer regime, only valence electrons participate in Compton scattering → core electron background subtraction using DFT is no longer required[3-5].
- Higher electron count rate at low momentum transfer values.
- **New avenue to study 2D materials such as graphene and transition metal dichalcogenides (TMDs)!**

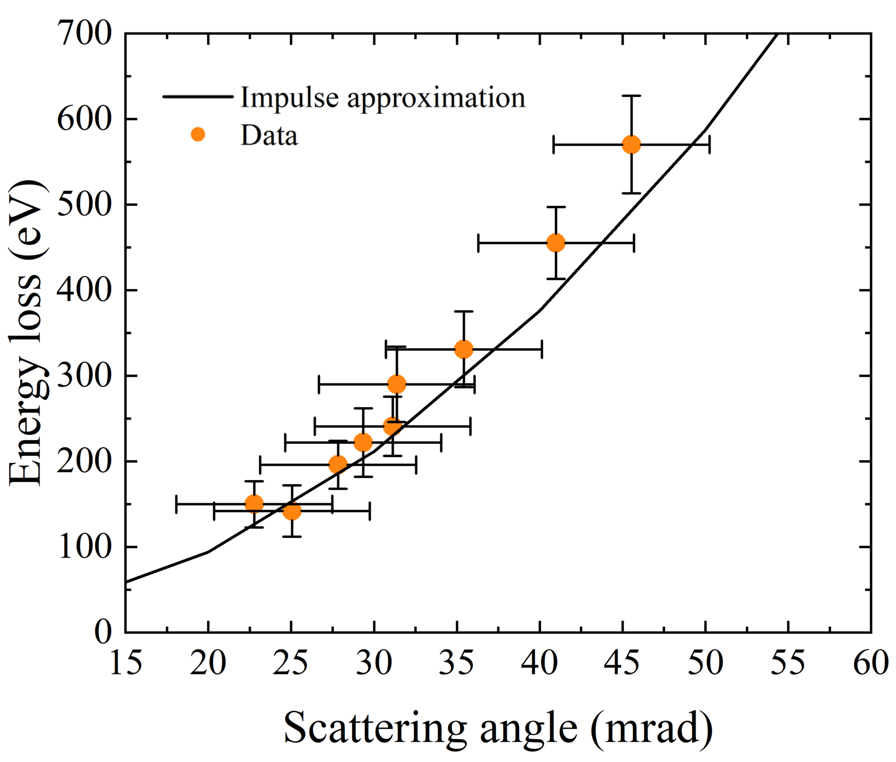
Background work

Impulse approximation

Interpretation of the Compton spectrum assumes the impulse approximation, i.e. there is no relaxation of background electrons in the solid. It is generally valid at high momentum transfer (or scattering angle) values[1,6].

Its accuracy in the low momentum transfer regime was tested by comparing the measured values of electron energy loss at the peaks of Compton spectra with theoretical prediction as a function φ.

Fig. 4. Comparison between predicted and experimentally obtained Compton peak positions in the EEL spectra.



Compton profiles in the low energy transfer regime are still expected provide accurate measurements!

Possibilities in plasmon background subtraction

A near constant plasmon shape and peak position was observed over a range of scattering angles (Fig. 5).

Plasmon background can be removed by subtracting a suitably normalized zero-tilt EELS spectrum from the tilted spectrum containing the Compton profile.

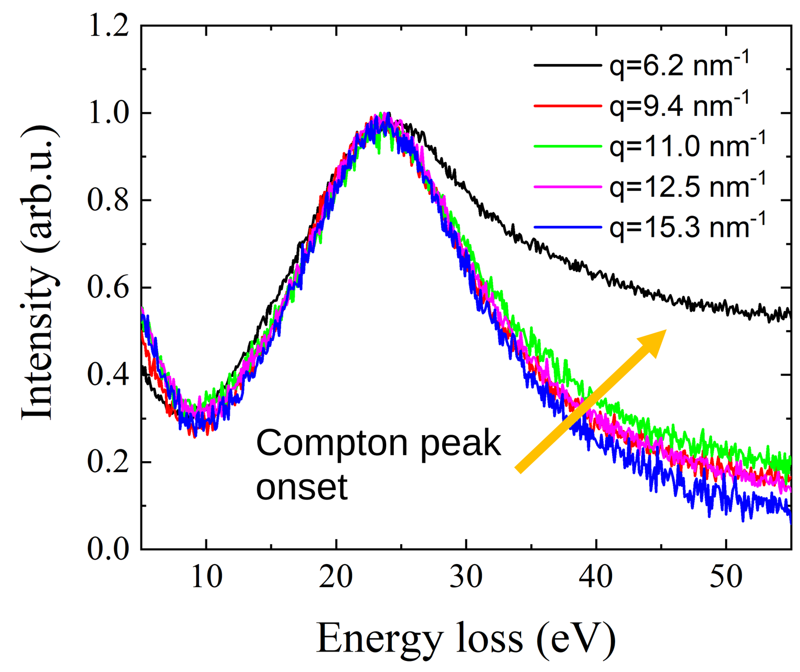
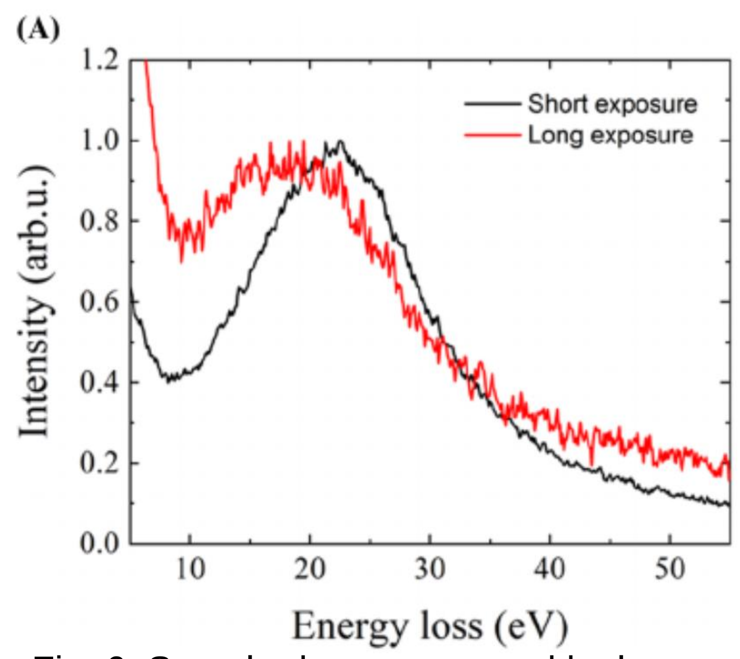


Fig. 5. Plasmon peaks measured at a range of different energy and momentum transfer values.

But...

Plasmon shape may change due to beam damage on the amorphous carbon film during prolonged acquisition of the Compton spectrum (Fig. 6).

The described background subtraction technique can only be used on more robust materials or with beam energies below the knock-on threshold.



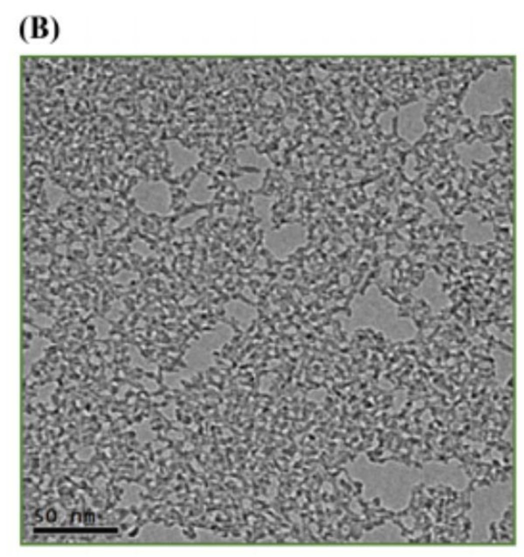


Fig. 6. Sample damage caused by long exposure (exaggerated for clarity) to electron beam causes widening and shifting of the plasmon peak, (A). (B) shows the corresponding highly damaged sample area.

CONTACT PERSON

Alina Talmantaite
alina.talmantaite@durham.ac.uk

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