Graphene as Electrode for Direct Observation of Hole Injection from Silicon to Oxide

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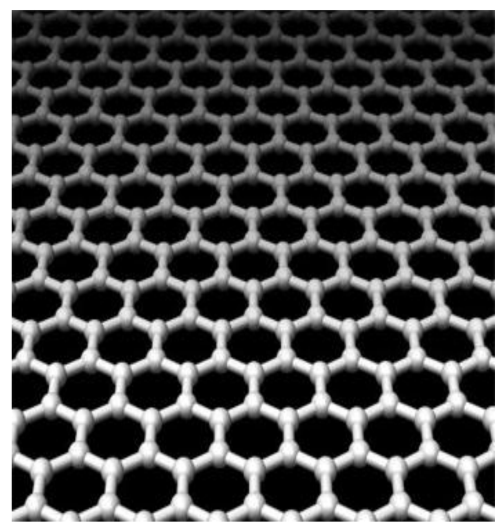
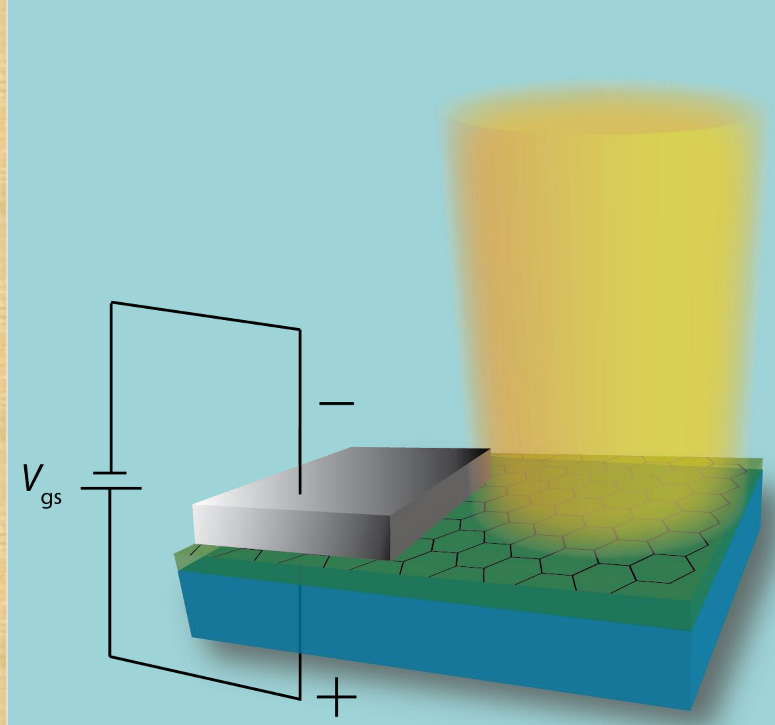
Background

- Internal Photoemission (IPE) spectroscopy is a robust technique to determine the band offset of metal-oxide-semiconductor.
- Typically a metal gate (<15 nm) is used as an optically semitransparent contact to collect photoexcited carriers.
- We demonstrate a novel application of graphene as an elegant transparent electrode in IPE spectroscopy.



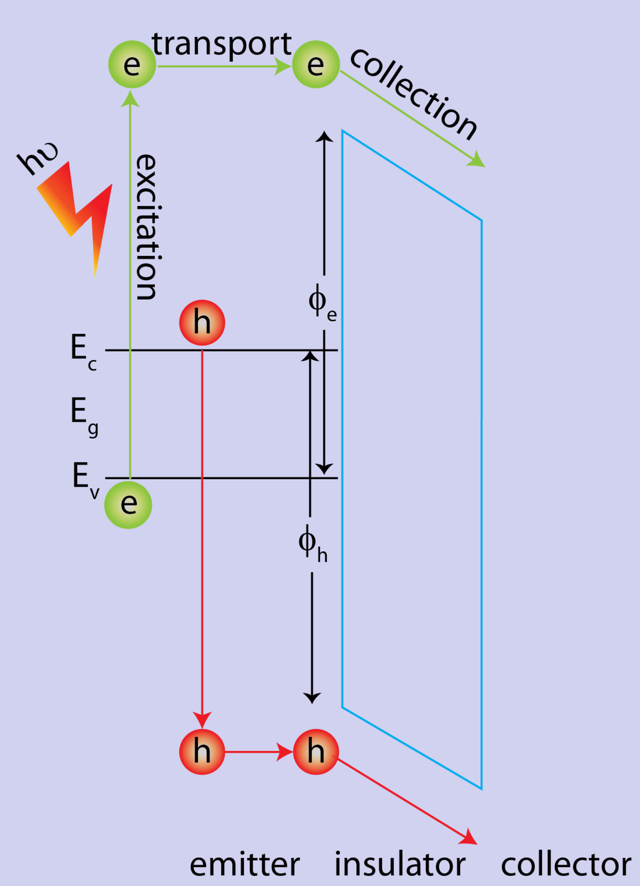
Motivation & Objectives



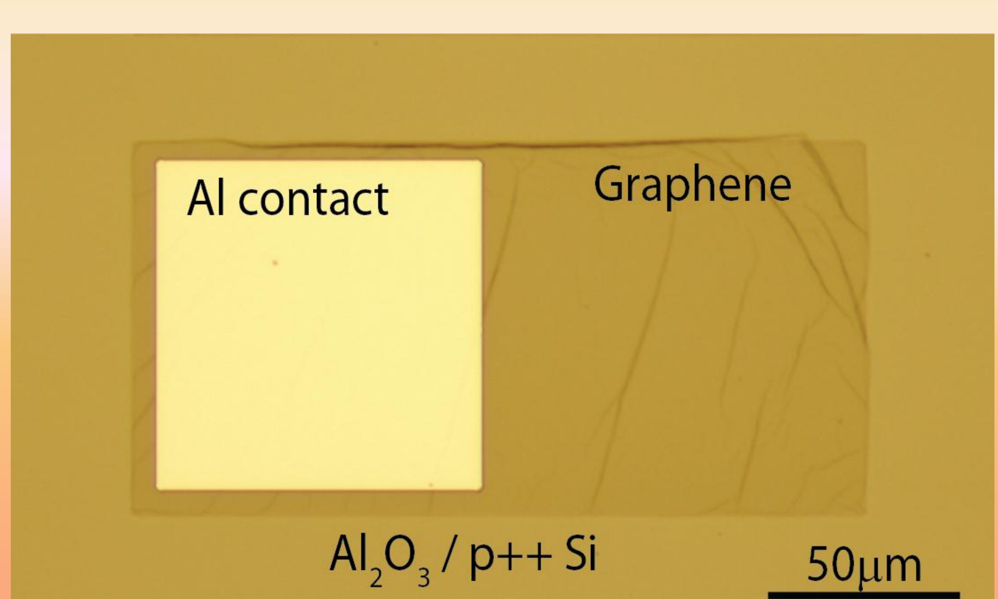
- Previously, IPE can only be used as the tool to characterize the electron barrier height and surface properties due to the lack of ideal transparent electrode. The additional observation of hole injections can be used to determine the complete band alignment at semiconductor/insulator inferface.
- The band gap of the insulator can be obtained.

IPE Principle

- Electron hole pairs are generated inside a solid and then they transport towards the surface or interface of the emitter and escape from the surface, i.e., surmounting the potential barrier.
- The photocurrents can be recorded as a function of incident photon energy, thus the band barrier height can be determined from the thresholds of currents.



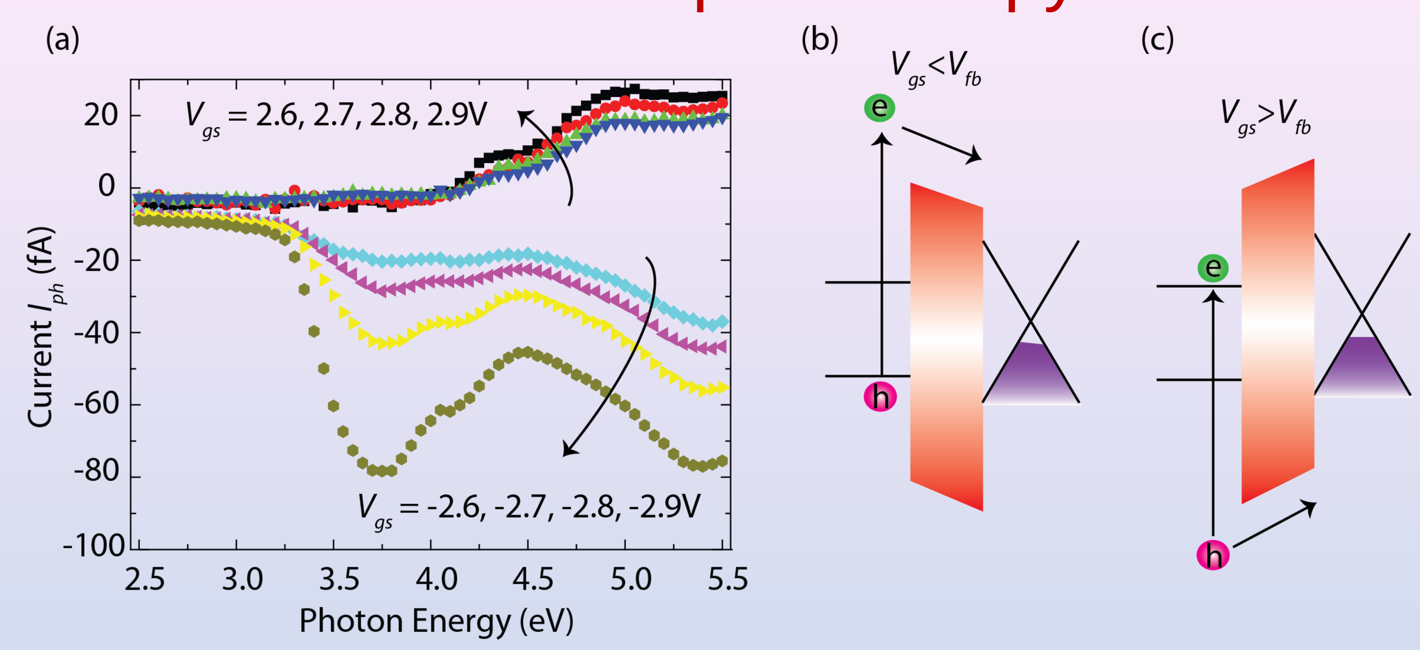
Device Structure



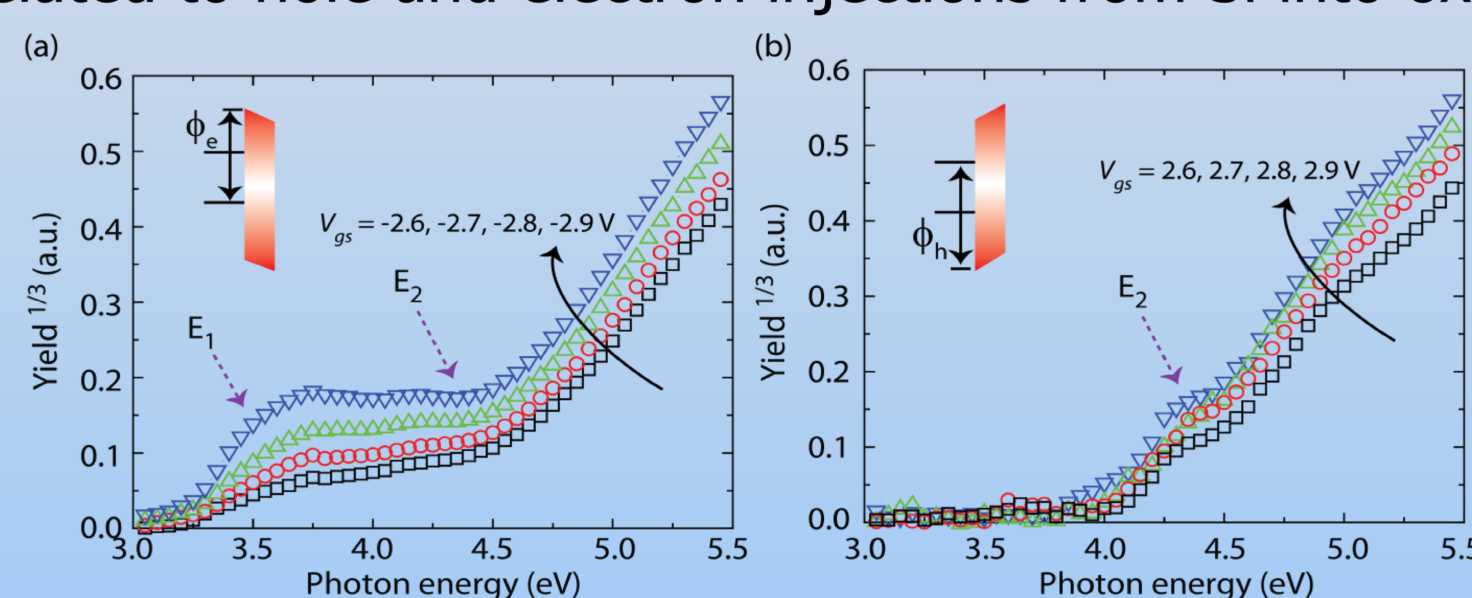
- Large-area CVD-growth graphene is transferred to the 10 nm ALD Al_2O_3 covered p++ Si substrate, followed by oxygen plasma etching to pattern a 100 x 200 µm² rectangular contact. A 180 nm thick Al contact to grapehene is deposited.
- The high quality of CVD graphene is confirmed by Raman.

Analysis and Discussions

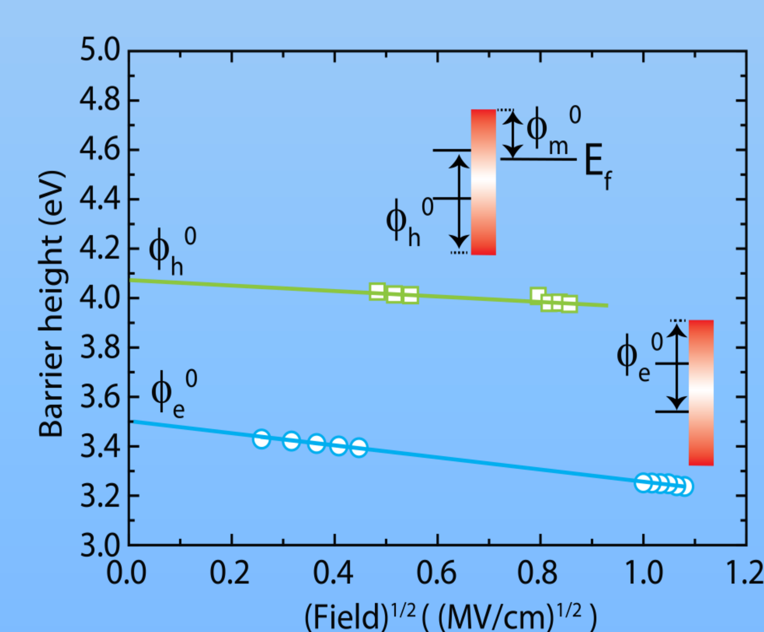
•Internal Photoemission Spectroscopy



- Photocurrents are recorded as a function of incident photon energy. The positive and negative currents are respectively related to hole and electron injections from Si into oxide.

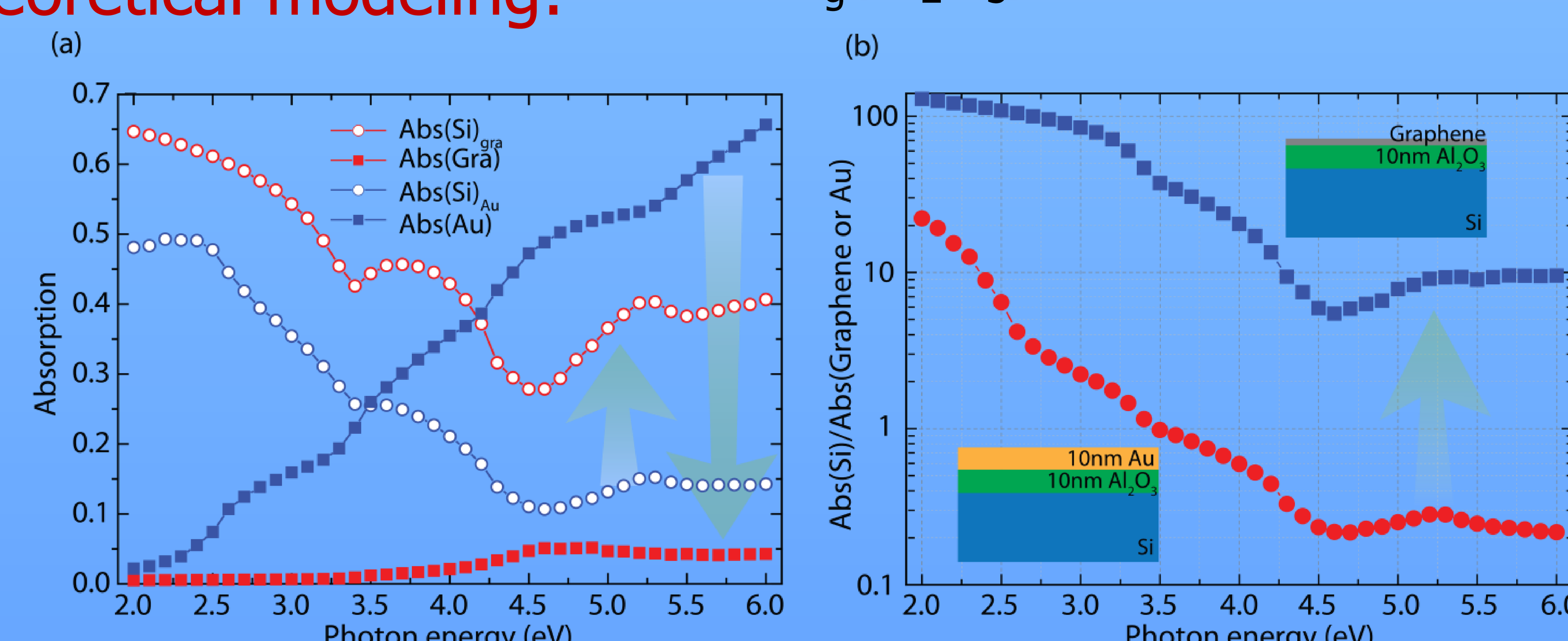


- To extract the barrier heights, quantum yield (Y) is determined using the currents normalized by the incident light power.



- Considering the Schottky barrier lowering effect, the zero barrier height can be achieved by extrapolating the barrier heights under various electric fields. The electron and hole barrier heights are shown to be 3.5 eV and 4.1 eV. Then $E_g(Al_2O_3)$ is 6.5 eV.

•Theoretical modeling:



- Using thin film optics, we calculate the absorption by graphene and show the advantage of using graphene as transparent contact.

Conclusions

- Graphene as collector material enables the direct observation of both electron and hole injections at a Si/Al_2O_3 interface.
- The electron and hole barrier heights are respectively 3.5 eV and 4.1 eV, thus the $E_g(Al_2O_3)$ can be deduced to be 6.5 eV.
- The optical modeling reveals utilizing graphene efficiently enhances the carrier injections from the emitter and suppresses the contribution of the collector electrode.