Devices for Photoactivity Characterization of Point Defect Ensembles in h-BN Monolayers

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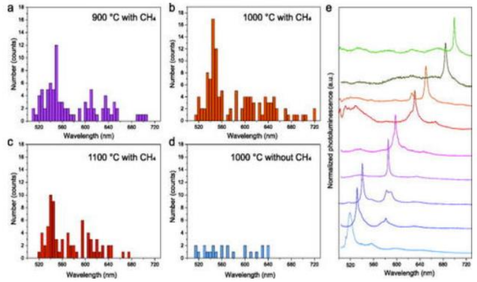
Introduction

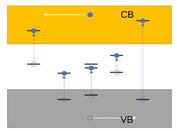
- Hexagonal boron nitride (h-BN) defects may provide a new platform for quantum information science.
- Defect characteristics can be controlled with sample preparation methods.
- Photon absorption in defects can produce charge carriers, resulting in photocurrent.
- A photocurrent spectrum is a systematic characterization of defect ensembles.
- Time and temperature dependent photoconductivity measurements can provide additional detailed insights.



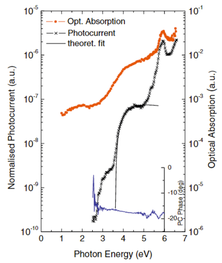
a)-d) Histograms of ZPL energy distributions for different annealing treatments. e) Photoluminescence spectra showing the wide range of ZPL energies among emitters prepared via annealing in carbon. [1]

Principles of Photoconductivity Measurements

Examples of transitions measured during a photoconductivity spectrum.

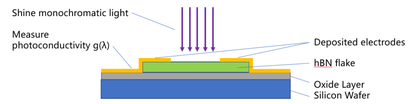


Photoconductivity spectra measure optically induced electronic transitions that produce charge carriers. Sub-bandgap excitation selectively measures defect-associated transitions.



h-BN photocurrent and absorption spectra. [2]

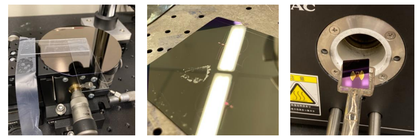
Device Fabrication



General idea of h-BN device and measurement.

Process Development

- Increased substrate oxide layer to eliminate background
- Annealed (sintered) nanocrystals
- Replaced conductive paste with solder
- Added plasma cleaning steps for exfoliation

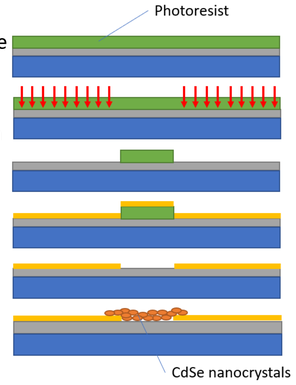


Flake transfer, PVD, and annealing processes.

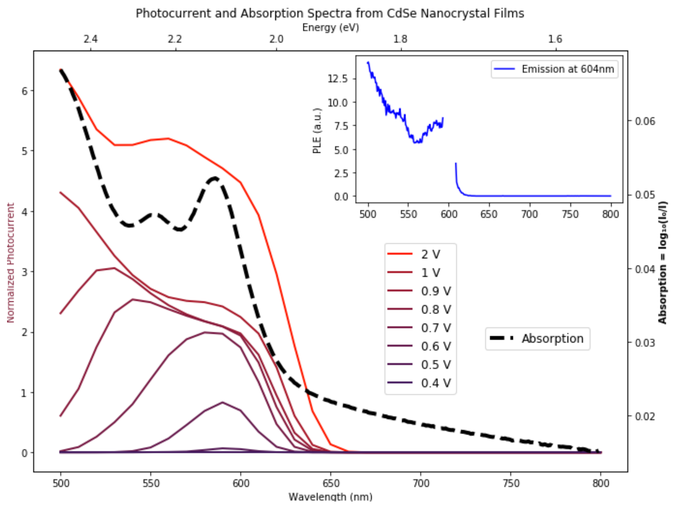
CdSe test devices are made by spin-coating nanocrystals after fabrication. h-BN devices are made by transferring flakes onto the substrate prior to fabrication.

Fabrication Steps:

- Spin-coat positive photoresist
- Direct write the electrode pattern
- Develop
- PVD metal
- Lift-off
- Spin-coat CdSe nanocrystal dispersion



Measurement Results

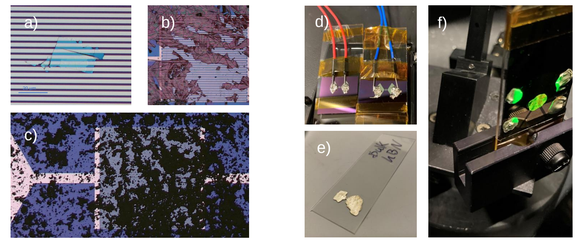


Testing Devices and Setup

- Initial measurements use CdSe nanocrystals, a well-studied and readily available photoactive material.
- As applied bias increases, three features absorption spectrum features (at approximately 590 nm and 510 nm, and a tail from shorter wavelengths) become recognizable in order of increasing energy. Each measurement shows fingerprints of three excitonic transitions.

Photocurrent, absorption, and photoluminescence excitation (PLE) spectra of CdSe nanocrystal films. The photocurrent is normalized to the illumination intensity. The color gradient in the photocurrent spectra indicates the voltage applied across the 10μm gap.

Images of Devices



a) h-BN flake in 2μm electrodes. b) CdSe film on 10μm electrodes. c) Drop-cast film of 1μm h-BN flakes.

d) Assembled devices. e) Bulk h-BN is attached to the setup with silver paste. f) Device in the setup.

Next Steps

- Increase flake coverage
- Modify annealing conditions to activate emitters and improve contact
- Use alternative light source to increase power – currently the limiting factor
- Probe time domain behavior and fit current decay to a model
- Take data at low temperature
- Apply additional preamp before the lock-in
- Further optimize device w.r.t. electrical noise

Acknowledgements & References

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