Eliminating Gate-Voltage Hysteresis in Suspended Single-Wall Carbon Nanotube Field-Effect Transistors

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Single-Wall Carbon Nanotubes (SWCNTs) have an immense potential to revolutionized modern day electronics and optoelectronics due to their unique optical and electronic properties. Particularly, semiconducting SWCNTs have a direct band-gap, allowing one to take advantage of both optical and electronic properties in a device. One such device is the SWCNT field-effect transistor (FET). However, SWCNT FETs exhibit gate-voltage induced hysteresis and time-dependent behavior. This hysteresis, likely caused by atmospheric and environmental effects, prevents one from truly ascertaining the gate-dependence on multiple properties of the device. In this study, we fabricated suspended SWCNT FET devices, performed photoluminescence excitation (PLE) spectroscopy, as well as creating a vacuum box (through modification of an optical microscopy cryostat) in order to measure the pressure-dependence of hysteresis of chirality-assigned SWCNTs. We observed an elimination of hysteresis in both current vs. gate-voltage and PL vs gate-voltage in low-pressure environment. Finally, we also observed a gradual recovery of hysteresis after exposing the low-pressure samples to air. By developing an easy to use and reproducible method of eliminating gate-induced hysteresis, we anticipate that these results can help us better explore crucial optoelectronic properties of SWCNT devices.

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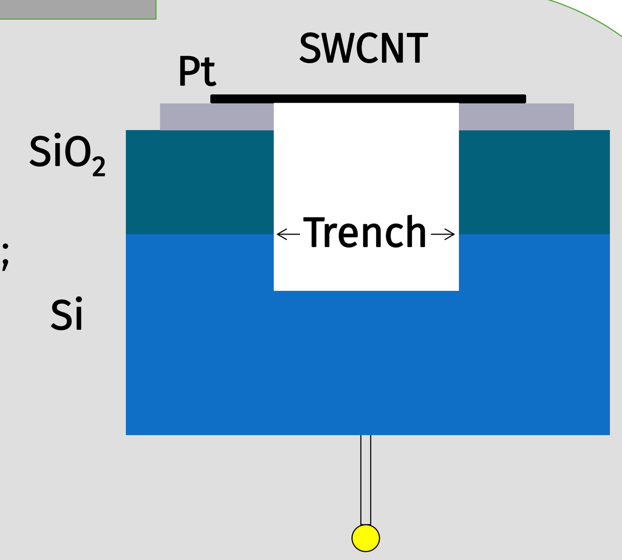
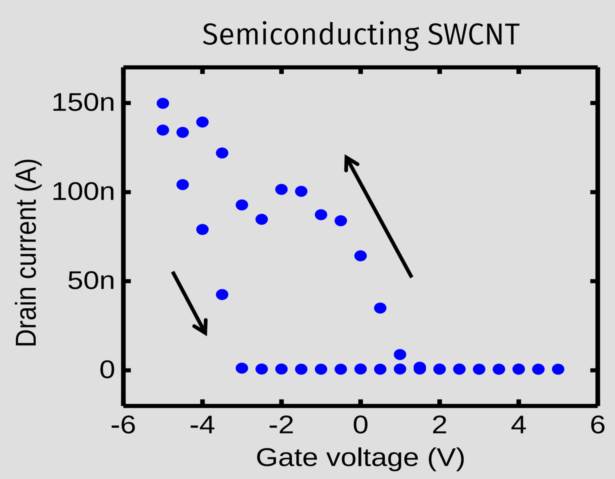
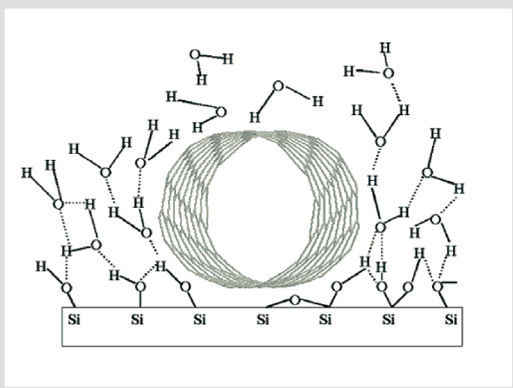
Background

- SWCNTs have small dimension and direct band gap: potential application in optoelectronics
- FET devices take advantage of these properties; trench architecture allows for large PL
- Si back gate allows for electrostatic doping of charge carriers







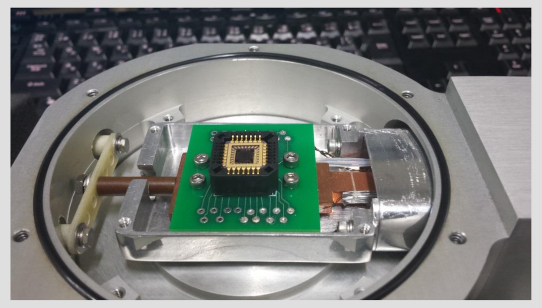
Reference 1

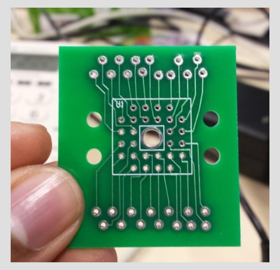
- Despite the potential, SWCNT FET devices have gate-voltage hysteresis
- Prevents understanding true gate-dependence of various properties
- Likely caused by atmospheric effects, water, or O_2 adsorbed charge traps

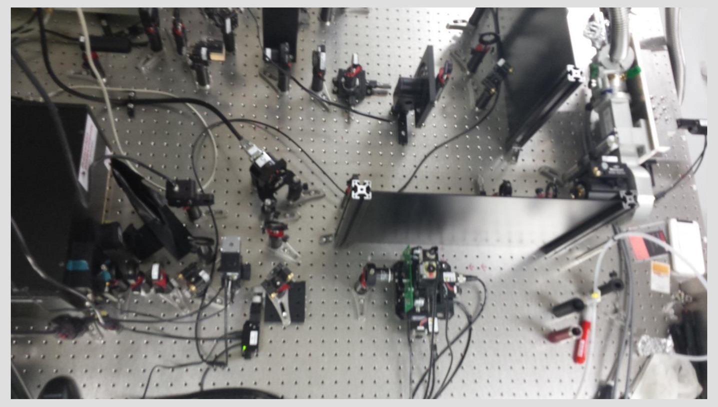
Objective: Eliminate gate-voltage hysteresis in SWCNT FET devices and ascertain the conditions for doing so.

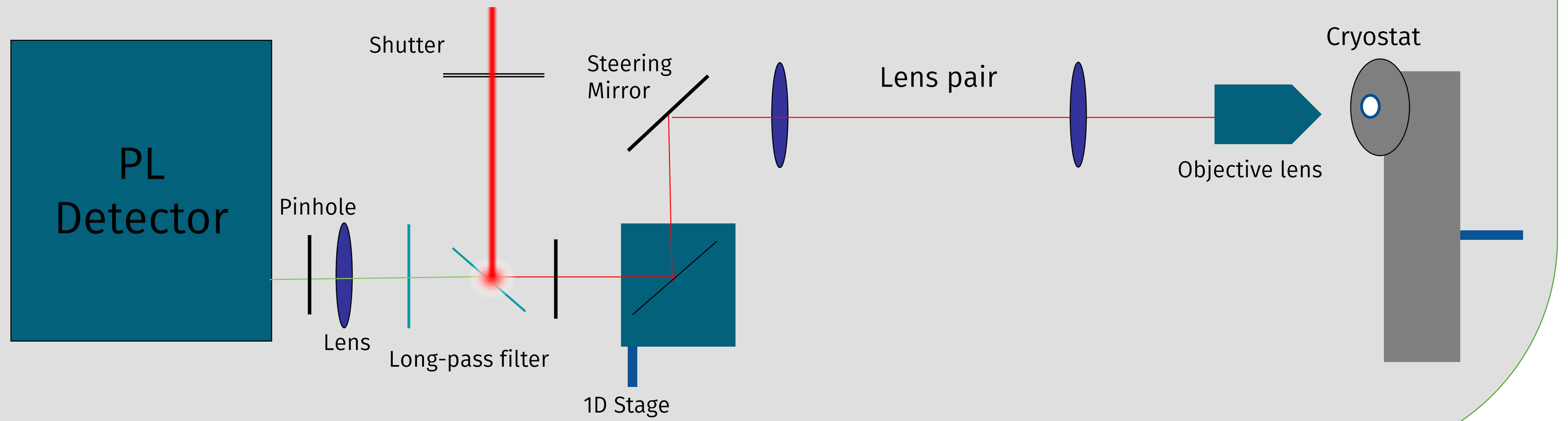
Setup

- Constructed Vacuum Box (Cryostat)
- Photoluminescence (PL) excitation and emission
- Steering Mirror and Path Switch

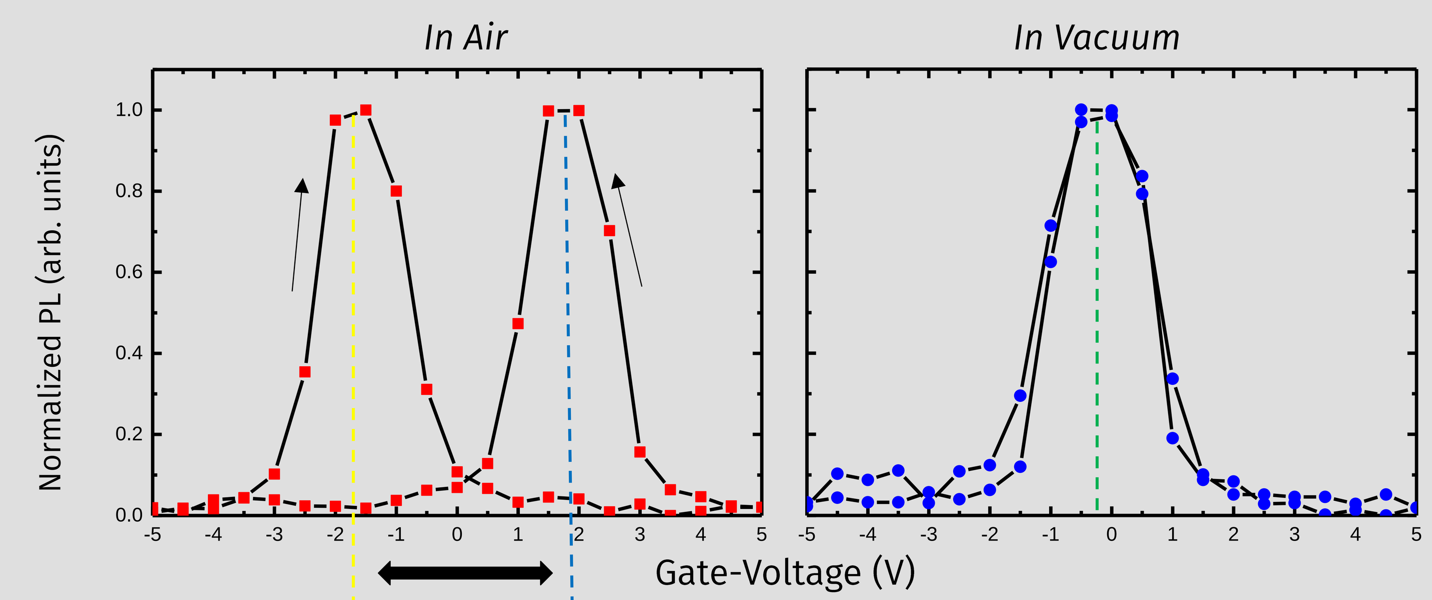






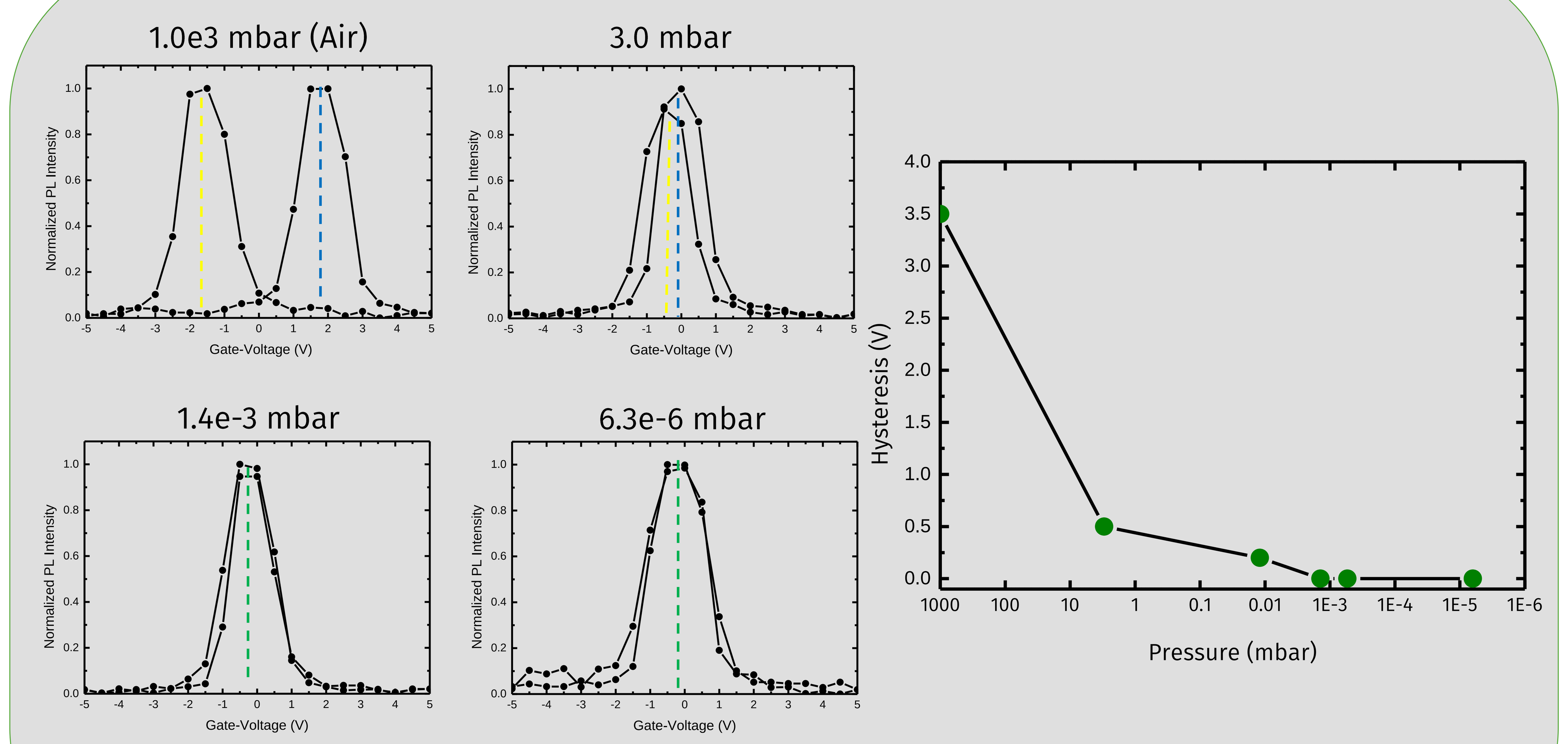


Photoluminescence vs. Gate-Voltage



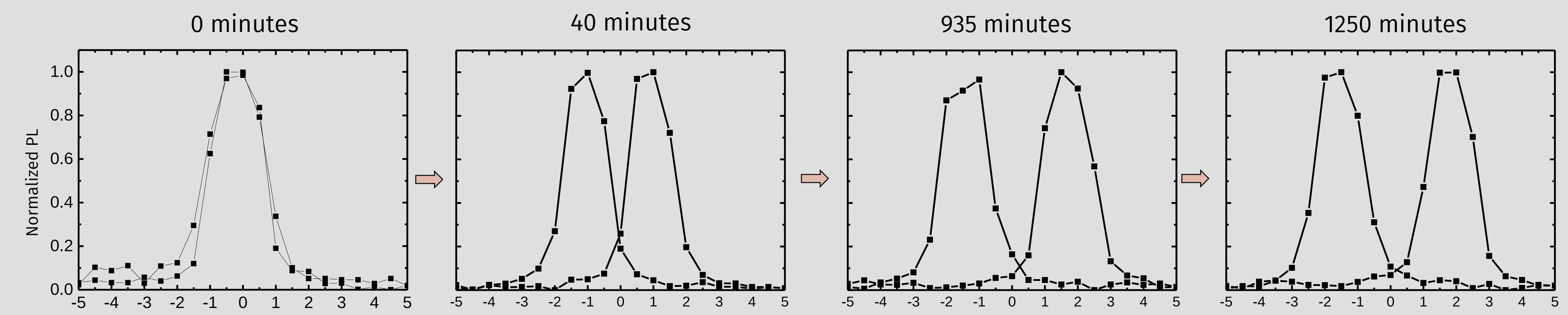
- In air: clear hysteresis defined by two distinct peaks and quenching values
- In vacuum, PL quenches normally; all measurements done on (9,7) SWCNT

Pressure Dependence of Hysteresis



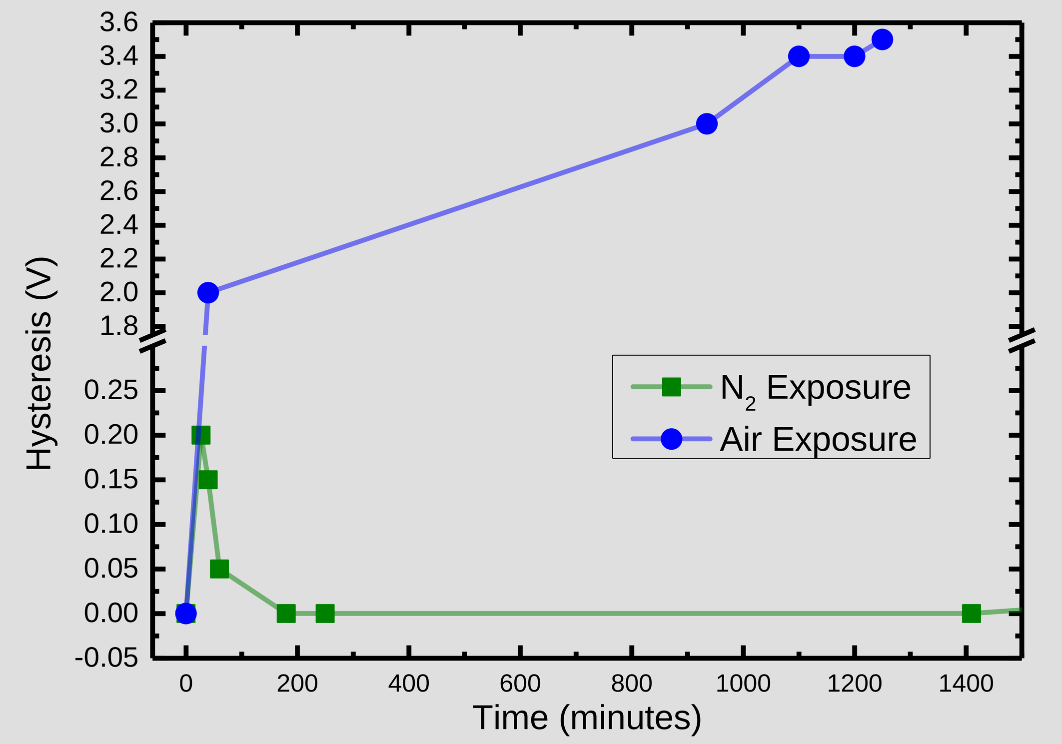
- In situ pressure dependence measurements done with Turbopump

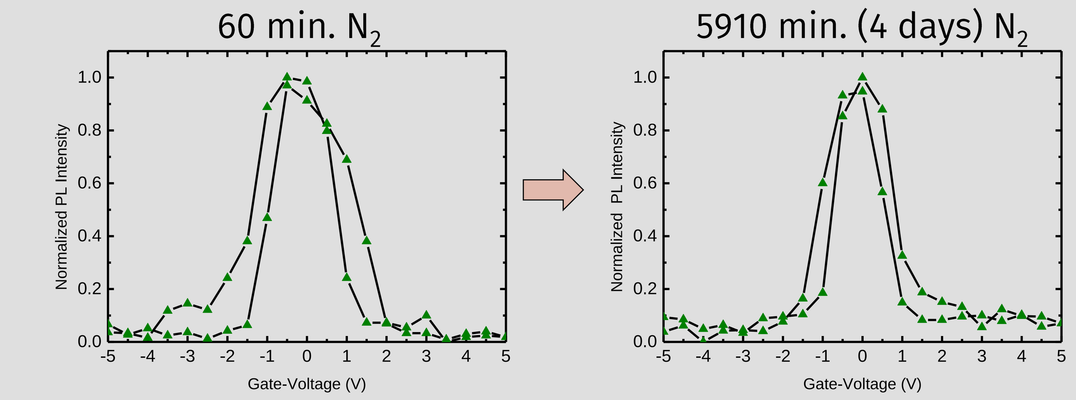
Air Recovery Time Dependence



- Hysteresis recovers after exposure to air; we observe clear increase over time

Environment Effects





Conclusions

- Clear elimination of hysteresis in PLV in the new vacuum box setup
- Isolated cause of hysteresis to adsorbed atmospheric molecules, e.g. water

What's next?

- New gate-voltage dependence measurements
- Possible giant band gap renormalization

References

1. Kim *et al.* Nano Lett. 3, **193** (2003)
2. Yasukochi *et al.* PRB 84, **121409**(R) (2011).

Acknowledgements

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