Impact of Transfer Methods on 2D Semiconductor Device Performance

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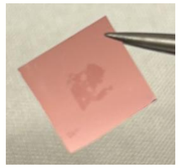
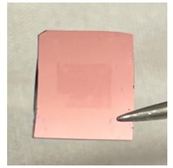
1. Abstract

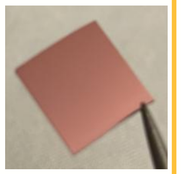
Transferring 2D semiconductor films from their native growth substrates to target substrates is a critical step in 2D electronics, as it directly impacts material integrity and interface quality. This project shows how different transfer techniques affect the quality of WSe_2, focusing on contamination, defect formation, and material degradation, with characterization (Raman and AFM) used to evaluate film quality. These observations were used to assess how transfer-induced changes in material properties relate to device performance. The results indicate that quasi-dry methods produce more consistent transfers with less damage, while wet and dry transfers are more inconsistent across various samples and parameters.

2. Procedure

1. Pre-transfer characterization using Raman and AFM to establish baseline material quality
2. Transfers applied:
Quasi-Dry on Sample A: TRT-assisted stamping with minimal liquid use to reduce chemical damage
Wet to Quasi-Dry on Sample B: wet transfer with PMMA+DI water delamination (fail), to quasi-dry with thicker PMMA and lamination
Dry on Sample C: PDMS/PVA stamping with KOH (degraded film)
3. Post-transfer characterization to evaluate transfer quality and film continuity

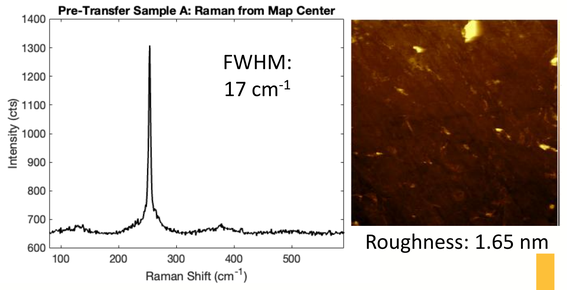

Sample A Target Substrate (Post transfer)


Sample B Target Substrate (Post transfer)


Sample C Target Substrate (Post transfer)

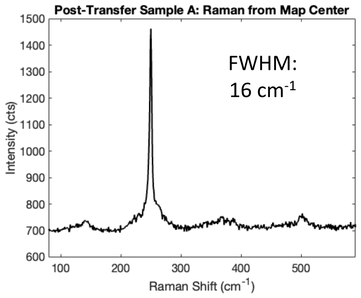
3. Results

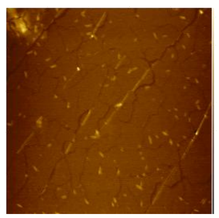
Quasi-Dry (Success)



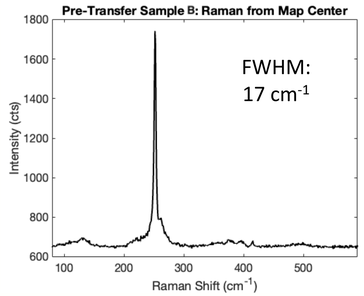
Roughness: 1.65 nm

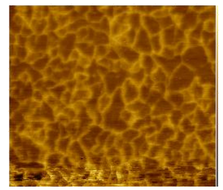
Above: Strong Raman peak and uniform film surface
Below: Raman preserved and AFM shows uniformity



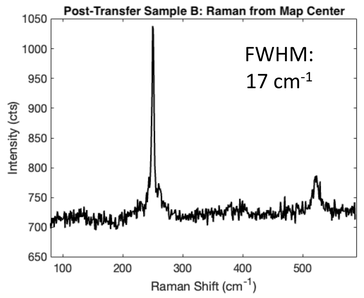

Roughness: 2.04 nm

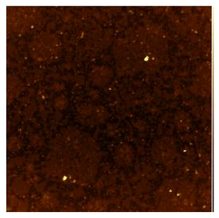
Wet (Fail), switched to Quasi-Dry (Success)



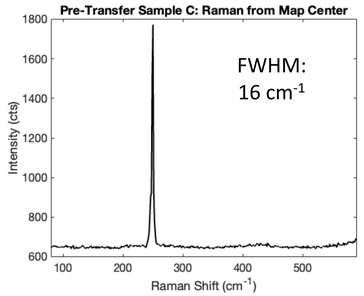

Roughness: 1.21 nm

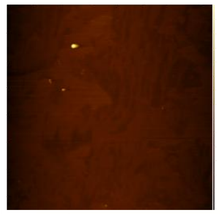
Above: Strong Raman peak and uniform film surface
Slightly reduced Raman and cracked/rougher surface
(not a uniform transfer)



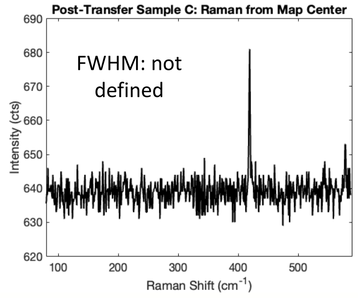

Roughness: 1.79 nm

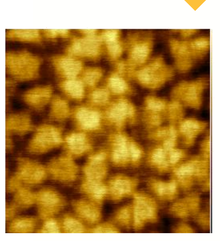
Dry (Fail), removed film from substrate




Roughness: 9.80 nm

Above: Strong Raman peak and consistent morphology
Below: Noisy Raman signal and disrupted surface (film loss)




Roughness: 0.42 nm

4. Challenges

- Dry transfer (Sample C) failed due to KOH etching which "shredded" the WSe_2 film (Figure a)

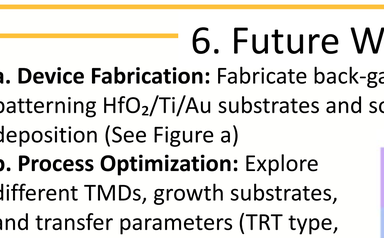


Figure a

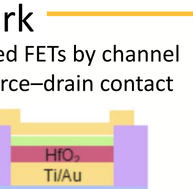


Figure b

- PVA-based pickup in the dry transfer did not successfully adhere to or lift the film (Figure b)
- Wet transfer on Sample B failed to pick up the film, resulting in no transfer
- Results highlight the sensitivity of WSe_2 to processing conditions and the difficulty of consistent transfer

5. Conclusion

a. Transfers: The quasi-dry transfer on Sample A produced the best results, since it preserved film continuity with minimal defects. The dry method (C) did not work and "shredded" the film.
b. Devices Performance: Cracks and bubbles degrade charge transport, making unreliable transfer methods unsuitable for devices. The improved film quality from quasi-dry transfers suggests better device performance.

6. Future Work

a. Device Fabrication: Fabricate back-gated FETs by channel patterning HfO_2/Ti/Au substrates and source–drain contact deposition (See Figure a)
b. Process Optimization: Explore different TMDs, growth substrates, and transfer parameters (TRT type, PMMA thickness) to improve transfer reliability and reduce defects

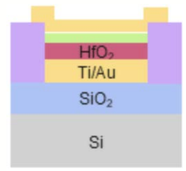


Figure a

Acknowledgements:
Firstly, I would like to thank Professor Sanchez for his guidance and support throughout this entire project. I am also very appreciative of Anna Bethke for her help and mentorship during the experimental work. Additionally, I would like to acknowledge Melike Erdi for her help and support during this research. I would also like to thank Aixin Zhang for his help in giving me valuable feedback on my poster.

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