Enhancing the Quality of Transferred MoS_2 Thin Films Through Annealing

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Abstract

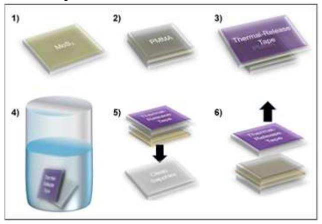
Molybdenum Disulfide (MoS_2) is a promising 2D semiconductor for electronics, optoelectronics, and related applications. Unlike many semiconductors that lose their functional properties at atomic thicknesses, MoS_2 maintains its intrinsic semiconducting behavior down to the monolayer limit. MoS_2 cannot be grown on the desired device substrates, so it requires transfer off the growth substrate. This study utilizes a polymer-assisted transfer method which avoids major mechanical and etching damage but leaves polymer residue which damages film quality. To remove polymer residue and improve film quality, we investigated the effect of annealing on polymer-transferred MoS_2 films. After acetone cleaning and an anneal at 300 °C for 10 min at 10 Torr, no significant PMMA residue or mechanical damage were left behind. Partially coalesced films retained less PMMA after acetone cleaning. Future studies will explore high vacuum annealing with surface temperature monitoring capabilities.

Objective

- To reduce the PMMA residue left on transferred MoS_2 films through annealing
- To evaluate the mechanical damage of the film during transfer and cleaning through AFM and SEM analysis
- To investigate the changes in Raman and Photoluminescent (PL) spectra of transferred MoS_2 films

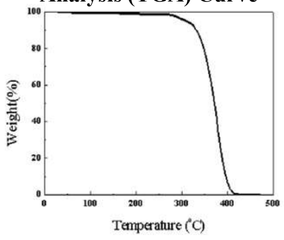
Methods

Polymer-Assisted Transfer



- A PMMA transfer method is utilized
- Post-transfer the film is soaked and sonicated in hot acetone
- Films are annealed at 300, 330, 360, and 400 °C

PMMA Thermogravimetric Analysis (TGA) Curve



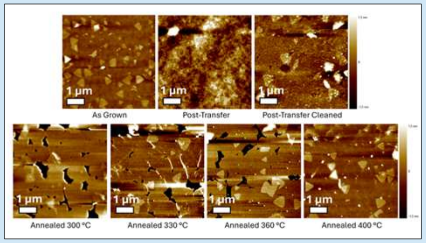
Bellan, Chandar & SUGUMARAN, Dr. SATHISH & Sengoden, R.. (2013). Spin Coated Nano Scale PMMA Films for Organic Thin Film Transistors. Physics Procedia. 49. 145–157. 10.1016/j.phpro.2013.10.021.

- TGA curve suggests this temperature range will degrade PMMA
- Anneals are performed at 10 torr for 10 min with a 30 °C/min ramp rate under argon flow ~180 sccm on the Rosie system

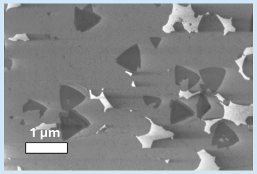
Results

Annealing Removes PMMA Residue (AFM)

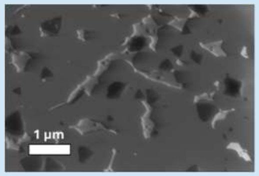
- Transfer leaves PMMA residue visible in AFM scans
- Acetone cleaning reduces PMMA residue
- Annealing at 300-400 °C further reduces PMMA residue
- Post-annealing surface morphology is largely preserved



300 °C Anneal Reduces More PMMA (SEM)

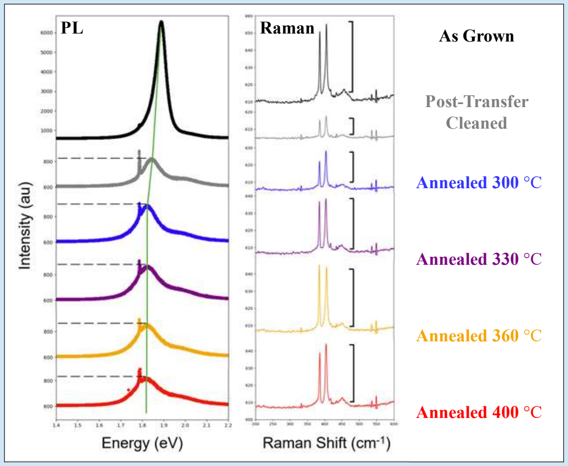


Sample annealed at 300 °C



Sample annealed at 400 °C

Annealing Shifts Raman/PL Spectra

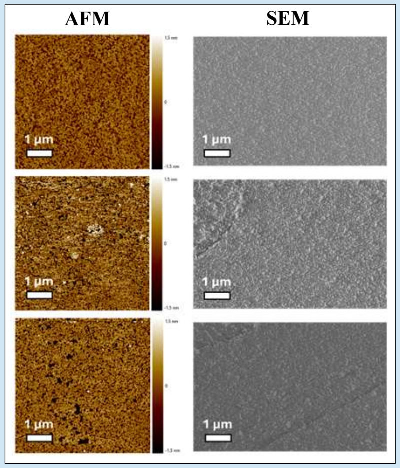


Partially Coalesced Films Behave Differently

As Grown
- As grown film is partially coalesced
- Exposed sapphire patches are small

Post-Transfer Cleaned
- Low PMMA residue post-cleaning
- Exposed sapphire patches are larger

Annealed 330 °C
- Minimal changes post-annealing
- Slight mechanical damage



Why does acetone cleaning work better on partially coalesced films?

Conclusion

- Polymer-assisted transfer leaves PMMA residue that degrades MoS_2 film quality
- Topological and optical data confirm annealing as a key step to restore post-transfer MoS_2 quality
- Partially coalesced films show better cleaning efficiency of PMMA residue

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