Research Proposal

Design and Fabrication of High-Performance Flexible Thin-Film Transistors Using 2D Semiconducting Materials

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1. Introduction and Background

With the rising demand for wearable technology, foldable displays, and implantable sensors, flexible electronics have become a frontier in applied physics and materials science. Traditional silicon-based electronics, while high-performing, are rigid and incompatible with flexible substrates. Two-dimensional (2D) materials such as MoS_2 and WS_2 offer tunable band gaps, high carrier mobility, and mechanical flexibility, making them ideal candidates for next-generation flexible thin-film transistors (TFTs).

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2. Research Problem

Current flexible electronic devices face trade-offs between flexibility, performance, and scalability. Challenges include poor charge transport at interfaces, instability under bending conditions, and difficulty in low-temperature deposition processes compatible with flexible substrates. There is a need for an optimized fabrication process and device architecture that maintains high electronic performance under mechanical strain.

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3. Objectives

- To synthesize and characterize 2D semiconducting materials for use in flexible TFTs.
- To develop a low-temperature fabrication process suitable for plastic substrates.
- To evaluate the electrical and mechanical performance of fabricated TFTs under various strain conditions.

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4. Methodology

Material Synthesis and Characterization:

- Synthesize monolayer and few-layer MoS_2 via chemical vapor deposition (CVD).
- Use Raman spectroscopy, AFM, and TEM to analyze material quality and thickness.

Device Fabrication:

- Fabricate bottom-gate, top-contact TFTs on flexible substrates (e.g., PET or PI) using inkjet printing or transfer methods.
- Deposit source, drain, and gate electrodes using silver nanoparticle ink or sputtering under low-temperature conditions ($<150°C$).

Performance Testing:

- Measure device characteristics (I-V, mobility, on/off ratio) using a semiconductor parameter analyzer.
- Perform bending tests to evaluate performance degradation under different radii of curvature and cycles of mechanical stress.

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5. Expected Outcomes

- A scalable process for integrating 2D semiconductors into flexible electronics.
- TFTs with carrier mobility >10 $cm^2/V \cdot s$ and stable performance under >1,000 bending cycles.
- A published framework for optimizing materials and device architecture for next-generation wearable electronics.

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6. References

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2. Kim, D. H., et al. (2009). Stretchable and foldable silicon integrated circuits. *Science*.
3. Wang, C., et al. (2018). Advanced materials for printed electronics. *Nature Reviews Materials*.

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