

Applications of MoS₂ as a Two-Dimensional Materials Beyond Graphene

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April 21, 2015

Overview

Origins and Discovery of Graphene

MoS₂ and TMDs as Materials Beyond Graphene

Properties of MoS₂

Synthesis of MoS₂

Applications of MoS₂ in FETs

Outlook & Conclusion

Search for new Materials

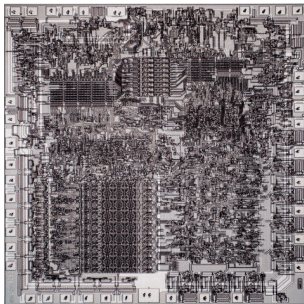


Figure: The Intel 8080 introduced in 1974 consisted of approximately 5,000 transistors

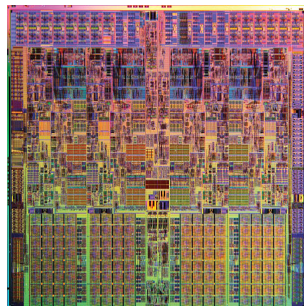


Figure: The Intel Core i7 in 2008 consisted of approximately 731 million transistors

[Grifantini, 2008]

Discovery of Graphene

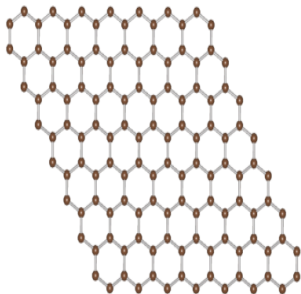
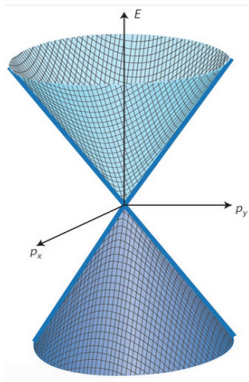


Figure: [Riken, 2012]

- 1985 suggestion of 1-D structure of carbon
- Several theoretical studies on formation of single layer of graphite
- 2004 Geim et al. isolate single layer of carbon atoms

Properties of Graphene



- Band Gap
- Mobility
- Young's Modulus
- Drawbacks
- 'Relativistic' properties

Figure: Electronic band structure of graphene [Fuhrer, 2010].

MoS₂

Transition Metal Dichalcogenides (TMDs)

- Renewed research in the last decade
- Intrinsic semiconductor
- Metal atom M
 - Mo, W, Nb, Re, Ni, or V
- 2 chalcogenide atoms X₂
 - S, Se, Te

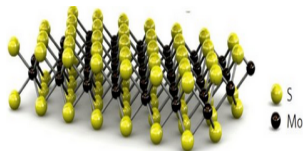


Figure: Bulk MoS₂ crystal [Wang, 2012].

Properties of MoS₂

- Monolayer MoS₂
 - Direct Band Gap 1.8 eV
 - Young's Modulus 270 GPa
- Bulk MoS₂
 - Indirect Band Gap 1.3 eV
 - Young's Modulus 240 eV

Micromechanical Exfoliation of MoS₂



Figure: Bulk MoS₂ crystal [Wang, 2012].

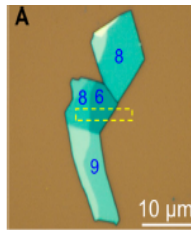


Figure: Image of MoS₂ [Li, 2014].

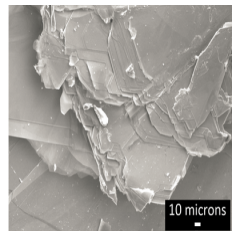


Figure: Example of layering in MoS₂ flakes [Radisavljevic, 2011].

MoS₂ in FETs

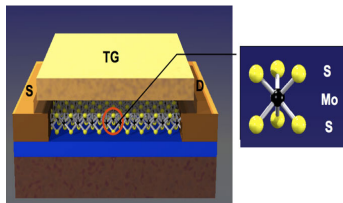


Figure: Schematic of FET with monolayer MoS₂.

- High on/off ratio
- Mobility of monolayer MoS₂ at room temperature
 $\sim 0.1 - 10.0 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1}$
- Mobility of bulk MoS₂
 $\sim 100 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1}$.

MoS₂ in FETs Continued

- Increased mobility with use of HfO₂ dielectric
- Mobility increased to $\sim 200 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$
- Drawbacks & problems still remain

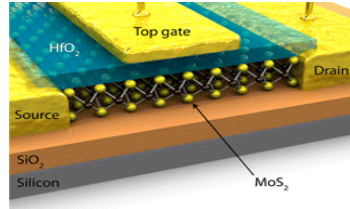


Figure: Detailed schematic of MoS₂ FET

Outlook and Conclusion

- Improving mobility in MoS₂ FETs
- Other materials

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Single-Layer MoS₂ transistors

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