

Editorial

Special Issue: 2D Layered Nanomaterials and Heterostructures for Electronics, Optoelectronics, and Sensing

Filippo Giannazzo ^{1,*} , Federica Bondino ² , Luca Seravalli ³  and Simonpietro Agnello ⁴ 

¹ Consiglio Nazionale della Ricerche (CNR), Istituto per la Microelettronica e Microsistemi (IMM), Strada VIII, 5, 95121 Catania, Italy

² Consiglio Nazionale delle Ricerche (CNR), Istituto Officina dei Materiali (IOM), Area Science Park, S.S. 14 Km. 163, 5, Basovizza, 34149 Trieste, Italy; bondino@iom.cnr.it

³ Consiglio Nazionale delle Ricerche (CNR), Istituto dei Materiali per l'Elettronica ed il Magnetismo (IMEM), Parco Area delle Scienze 37/a, 43124 Parma, Italy; luca.seravalli@imem.cnr.it

⁴ Department of Physics and Chemistry Emilio Segré, University of Palermo, Via Archirafi 36, 90143 Palermo, Italy; simonpietro.agnello@unipa.it

* Correspondence: filippo.giannazzo@imm.cnr.it

Since the first report in 2004 on the electronic properties of graphene exfoliated from graphite [1], the research on two-dimensional materials (2DMs) has grown steadily. To date, hundreds of 2DMs have been investigated experimentally, whereas a database of up to 6000 monolayer structures has recently been compiled through computational studies [2]. Interestingly, the 2DM family covers the entire range of electronic properties, from semimetallic graphene and semiconducting transition metal dichalcogenides (TMDs) to insulating hexagonal boron nitride. Furthermore, van der Waals (vdW) heterostructures with engineered bandgaps have been realized by stacking different layers [3], enabling the demonstration of novel device concepts for electronics/optoelectronic, sensing, quantum, and energy applications.

In this context, this Special Issue, entitled “2D Layered Nanomaterials and Heterostructures for Electronics, Optoelectronics and Sensing”, features insightful contributions on the scalable growth of 2DMs, fabrication approaches of vdW heterostructures, advanced characterization methods (optical, vibrational, chemical, electrical), and the theoretical modeling of these heterostructures. Furthermore, it aims to address challenges involved in 2DM integration and device fabrication.

Specifically, the Special Issue includes 10 high-quality, original research papers covering the following topics:

- i. Scalable synthesis of molybdenum disulfide (MoS_2) through an advanced chemical vapor deposition (CVD) approach based on liquid Mo precursors [4], as well as by pulsed laser deposition (PLD) on substrates of interest for microelectronics (sapphire, gallium nitride) [5];
- ii. First-principles calculations of electronic and optical properties of graphene, borophene, and boron carbide 2D heterostructures [6];
- iii. Advanced optical and electronic transport characterization of novel vdW heterostructures ($\text{Ta}_2\text{NiS}_5/\text{CrOCl}$) [7];
- iv. Electronic and optoelectronic devices based on 2DM heterostructures, i.e., novel 2D field effect transistors with a tungsten diselenide (WSe_2) channel and multi-layer palladium diselenide (PdSe_2) vdW contacts [8]; bipolar transistors based on a $\text{MoS}_2/\text{WSe}_2/\text{MoS}_2$ heterostructure [9]; photo-transistors and self-powered photodetectors based on graphene/Si [10]; NiO/graphene/Si junctions [11]; photovoltaic devices [12]; and biosensors based on $\text{MoS}_2/\text{WTe}_2$ Schottky barriers [13].



Received: 20 May 2025

Accepted: 28 May 2025

Published: 2 June 2025

Citation: Giannazzo, F.; Bondino, F.; Seravalli, L.; Agnello, S. Special Issue: 2D Layered Nanomaterials and Heterostructures for Electronics, Optoelectronics, and Sensing. *Nanomaterials* **2025**, *15*, 851. <https://doi.org/10.3390/nano15110851>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

This Special Issue spotlights relevant examples of ongoing research directions in the continuously expanding field of 2D materials and aims to serve as inspiration for researchers working in these areas.

Acknowledgments: The Guest Editors of this Special Issue acknowledge the support of European Union (NextGeneration EU), through the MUR-PRIN2022 project “2DIntegratE” (2022RHRZN2).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Novoselov, K.S.; Geim, A.K.; Morozov, S.V.; Jiang, D.E.; Zhang, Y.; Dubonos, S.V.; Grigorieva, I.V.; Firsov, A.A. Electric field effect in atomically thin carbon films. *Science* **2004**, *306*, 666. [[CrossRef](#)] [[PubMed](#)]
2. Zhou, J.; Shen, L.; Costa, M.D.; Persson, K.A.; Ong, S.P.; Huck, P.; Lu, Y.; Ma, X.; Chen, Y.; Tang, H.; et al. DMatPedia, an open computational database of two-dimensional materials from top-down and bottom-up approaches. *Sci. Data* **2019**, *6*, 86. [[CrossRef](#)] [[PubMed](#)]
3. Geim, K.; Grigorieva, I.V. Van der Waals heterostructures. *Nature* **2013**, *499*, 419. [[CrossRef](#)] [[PubMed](#)]
4. Esposito, F.; Bosi, M.; Attolini, G.; Rossi, F.; Fornari, R.; Fabbri, F.; Seravalli, L. Influence of the Carrier Gas Flow in the CVD Synthesis of 2-Dimensional MoS₂ Based on the Spin-Coating of Liquid Molybdenum Precursors. *Nanomaterials* **2024**, *14*, 1749. [[CrossRef](#)]
5. Španková, M.; Chromik, Š.; Dobročka, E.; Slušná, L.P.; Talacko, M.; Gregor, M.; Pécz, B.; Koos, A.; Greco, G.; Panasci, S.E.; et al. Large-Area MoS₂ Films Grown on Sapphire and GaN Substrates by Pulsed Laser Deposition. *Nanomaterials* **2023**, *13*, 2837. [[CrossRef](#)]
6. Niu, L.; Conquest, O.J.; Verdi, C.; Stampfl, C. Electronic and Optical Properties of 2D Heterostructure Bilayers of Graphene, Borophene and 2D Boron Carbides from First Principles. *Nanomaterials* **2024**, *14*, 1659. [[CrossRef](#)] [[PubMed](#)]
7. Su, Y.; Chen, P.; Xu, X.; Zhang, Y.; Cai, W.; Peng, G.; Zhang, X.; Deng, C. Symmetry-Engineering-Induced In-Plane Polarization Enhancement in Ta₂NiS₅/CrOCl van der Waals Heterostructure. *Nanomaterials* **2023**, *13*, 3050. [[CrossRef](#)] [[PubMed](#)]
8. Murastov, G.; Aslam, M.A.; Leitner, S.; Tkachuk, V.; Plutnarová, I.; Pavlica, E.; Rodriguez, R.D.; Sofer, Z.; Matković, A. Multi-Layer Palladium Diselenide as a Contact Material for Two-Dimensional Tungsten Diselenide Field-Effect Transistors. *Nanomaterials* **2024**, *14*, 481. [[CrossRef](#)]
9. Yan, Z.; Xu, N.; Deng, S. AC Characteristics of van der Waals Bipolar Junction Transistors Using an MoS₂/WSe₂/MoS₂ Heterostructure. *Nanomaterials* **2024**, *14*, 851. [[CrossRef](#)] [[PubMed](#)]
10. Strobel, C.; Chavarin, C.A.; Knaut, M.; Albert, M.; Heinzig, A.; Gummadi, L.; Wenger, C.; Mikolajick, T. p-Type Schottky Contacts for Graphene Adjustable-Barrier Phototransistors. *Nanomaterials* **2024**, *14*, 1140. [[CrossRef](#)] [[PubMed](#)]
11. Pandit, B.; Parida, B.; Jang, H.-S.; Heo, K. Self-Powered Broadband Photodetector Based on NiO/Si Heterojunction Incorporating Graphene Transparent Conducting Layer. *Nanomaterials* **2024**, *14*, 551. [[CrossRef](#)] [[PubMed](#)]
12. Rajpar, H.; Bashir, M.B.A.; Salih, E.Y.; Ahmed, E.M. Fabrication and Enhanced Performance Evaluation of TiO₂@Zn/Al-LDH for DSSC Application: The Influence of Post-Processing Temperature. *Nanomaterials* **2024**, *14*, 920. [[CrossRef](#)] [[PubMed](#)]
13. Zhang, X.; Chen, S.; Ma, H.; Sun, T.; Cui, X.; Huo, P.; Man, B.; Yang, C. Asymmetric Schottky Barrier-Generated MoS₂/WTe₂ FET Biosensor Based on a Rectified Signal. *Nanomaterials* **2024**, *14*, 226. [[CrossRef](#)] [[PubMed](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.