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# **Developing New 2D Materials and Heterostructures for Printed Digital Devices**



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## **2D-PRINTABLE - Deliverable report**

### **D8.4 – CSA activities under Graphene Flagship**



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#### Project Scientific Abstract

The 2D-PRINTABLE project aims to integrate sustainable large-scale liquid exfoliation techniques with theoretical modelling to efficiently produce a wide range of new 2D materials (2DMs), including conducting, semiconducting, and insulating nanosheets. The focus includes developing the printing and liquid phase deposition methods required to fabricate networks and multicomponent heterostructures, featuring layer-by-layer assembly of nanometer-thick 2DMs into ordered multilayers. The goal is to optimize these printed networks and heterostructures for digital systems, unlocking new properties and functionalities. The project also seeks to demonstrate various printed digital devices, including proof-of-principle, first-time demonstration of all-printed, all-nanosheet, heterostack light-emitting diodes (LEDs). In conclusion, 2D-PRINTABLE will prove 2D materials to be an indispensable material class in the field of printed electronics, capable of producing far-beyond-state-of-the-art devices that can act as a platform for the next generation of printed digital applications.

## Summary

This report summarizes the collaborative and coordination activities carried out by the 2D-PRINTABLE consortium within the wider Graphene Flagship initiative.

As an active member of the European 2D materials community, the project contributed to a broad range of GrapheneEU CSA activities, including dissemination and project management working groups, joint scientific collaborations, workshops, networking events, roadmap discussions, and initiatives related to standardisation, industrialisation, dissemination, and exploitation.

Throughout the reporting period, the consortium engaged with numerous Graphene Flagship-related projects, including ARMS, GIANCIE, GRAPHERGIA, SAFARI, 2D-PL, 2DSPIN-TECH, 2D ENGINE, and MUNASET. These collaborations supported scientific exchange, strengthened cross-project synergies, and reinforced integration within the European 2D materials ecosystem.

In parallel, 2D-PRINTABLE partners contributed to wider community-building and innovation-oriented activities through participation in Graphene Week events, standardisation committees, and interactions with industrial and policy stakeholders. Collectively, these activities demonstrate the consortium's strong commitment to collaboration, knowledge sharing, and maximizing the long-term impact of project results beyond the project lifetime.

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# 1 Introduction

## 1.1 Background

2D-PRINTABLE aims to develop scalable and sustainable production and printing approaches for 2D materials and heterostructures for digital electronics applications. The project focuses on integrating liquid exfoliation techniques with advanced printing and deposition methods to enable the fabrication of high-performance printed electronic devices.

As part of the wider European 2D materials landscape, 2D-PRINTABLE actively contributes to the collaborative ecosystem established through the Graphene Flagship and associated GrapheneEU coordination and support activities.

The GrapheneEU CSA initiative facilitates collaboration among projects working in the field of graphene and related 2D materials by promoting knowledge exchange, dissemination coordination, standardisation activities, industrial engagement, and scientific networking.

## 1.2 Purpose of this report

The purpose of this report is to document the CSA-related collaborative activities undertaken by the 2D-PRINTABLE consortium and to highlight the project's contribution to the wider Graphene Flagship ecosystem.

The report demonstrates:

- Active participation in GrapheneEU coordination activities;
- Scientific and technical collaborations with related projects;
- Joint dissemination, networking, and workshop activities;
- Contributions to roadmap, industrialisation, and exploitation discussions;
- The broader impact of cross-project synergies on the European 2D materials ecosystem.

## 2 Participation in GrapheneEU Coordination Activities

Throughout the reporting period, 2D-PRINTABLE partners actively participated in numerous coordination activities organised under the GrapheneEU CSA framework. These activities supported alignment across projects, facilitated exchange of best practices, and strengthened collaboration within the wider Graphene Flagship ecosystem.

### 2.1 Dissemination Working Groups

Consortium partners regularly participated in dissemination working group meetings organised by GrapheneEU. These meetings focused on communication and dissemination coordination across projects, sharing of outreach activities, planning of joint initiatives, and exchange of best practices related to communication, dissemination, and exploitation (CDE).

Representatives from UNR contributed actively to these meetings by presenting updates on ongoing and planned dissemination activities within 2D-PRINTABLE and participating in broader discussions related to outreach and visibility strategies across the Graphene Flagship ecosystem.

Participation included multiple dissemination working group meetings throughout 2024, 2025, and 2026.

Key activities included:

- Sharing of planned dissemination activities
- Contribution to joint social media campaigns
- Graphene Week dissemination impact updates
- (Joint) Promotion of symposium activities
- Contributions to Graphene Flagship Annual Reports 2023, 2024, 2025

### 2.2 Project Management and Coordination Meetings

2D-PRINTABLE coordinator TCD and partner UNR participated actively in project management and coordination meetings organised through GrapheneEU. These meetings provided a platform for exchange of management practices, reporting approaches, consortium coordination strategies, and updates on ongoing Flagship-related activities.

Project management activities also included participation in data management, financial and technical reporting training sessions organised under the CSA framework.

Key activities included:

- CSA Coordinators Meetings - Ongoing
- CSA Project Managers Meetings - multiple meetings delivered
- Project Managers Working Group - Ongoing
- Training on Financial Reporting – completed
- Training on Technical Reporting - completed
- Workshop on Research Data Management - completed

## 2.3 Standardisation and Industrialisation Activities

Several 2D-PRINTABLE partners played active representative roles within the wider Graphene Flagship ecosystem, contributing to standardisation, innovation, and roadmap-oriented activities coordinated through the GrapheneEU CSA framework.

- TUD acted as the project representative for innovation activities, contributing to discussions related to technology transfer, innovation pathways, and the long-term impact and exploitation potential of graphene and related 2D material technologies. Through these activities, the project supported broader efforts to strengthen connections between research, industrial uptake, and future commercial applications.
- UniBwM served as the project representative for standardisation activities and participated in the Graphene Flagship Standardisation Committee. These activities focused on supporting harmonisation efforts, promoting best practices, and contributing to discussions related to future standards and methodologies for graphene and 2D materials technologies.
- BeD represented the project in roadmap-related activities involving multiple Graphene Flagship projects and industrial stakeholders. These discussions addressed future research directions, market opportunities, industrial needs, and application roadmaps for advanced 2D materials and printable electronics technologies.

Together, these representative roles strengthened the visibility and integration of 2D-PRINTABLE within the Graphene Flagship ecosystem and enabled the consortium to contribute actively to shaping future research, innovation, and industrialisation strategies in the field of graphene and related materials.

## 3 Graphene Week and Community Contributions

2D-PRINTABLE partners contributed extensively to Graphene Week and related community activities. The consortium played an active role through keynote talks, invited presentations, poster contributions, session chairing, dissemination coordination activities, and participation in networking and ecosystem-building discussions. Participation in Graphene Week enabled the consortium to showcase project progress, strengthen collaborations with related initiatives, and engage with researchers, industry stakeholders, and policymakers working in the field of graphene and related 2D materials.

### 3.1 Graphene Week 2024

Graphene Week 2024 marked a particularly important milestone for the 2D-PRINTABLE consortium, with a strong project presence throughout the event. As Europe's leading event dedicated to graphene and related 2D materials, Graphene Week provided a valuable platform for showcasing project achievements, strengthening collaborations, and engaging with the wider research and innovation community.

A significant contribution to the success of the event was made by project partner VSCHT, which played a key organisational role in supporting the programme and coordination of Graphene Week 2024. 2D-PRINTABLE coordinator TCD was a keynote speaker. In addition, consortium partners from BeD, UKa, TUD, and UniBw M actively contributed to the scientific and innovation-focused programme by presenting and discussing recent advances and developments from the project.

The event enabled the consortium to strengthen connections with key stakeholders across the European 2D materials ecosystem and facilitated discussions on future collaborations, dissemination activities, and exploitation opportunities.

As in previous editions, the Innovation Forum represented a central component of the event, featuring dedicated sessions on roadmapping, standardisation, industrialisation, and real-world implementation of 2D materials technologies. These discussions brought together researchers, start-ups, industrial leaders, and established companies to address both the opportunities and challenges associated with the commercialisation of graphene and related materials.

Participation in these activities further reinforced the consortium's engagement with innovation-oriented discussions and strengthened the positioning of 2D-PRINTABLE within the broader European graphene and 2D materials community.

## 3.2 Graphene Week 2025

At Graphene Week 2025, 2D-PRINTABLE partners expanded their engagement through participation in scientific sessions, project management discussions, dissemination activities, and networking events.

Partner BeD contributed to the event organisation and chaired several sessions focused on commercialisation and innovation, including discussions on raising capital for commercialisation, commercialisation pitches, and pathways from fundamental research to innovative applications. These activities contributed to strengthening dialogue between academia, industry, and innovation stakeholders.

Partner TUD delivered a keynote presentation during a plenary session, while VSCHT and TUD participated as invited speakers, highlighting advances in 2D materials research and related applications. In addition, consortium members participated in project management and dissemination working group meetings during the event, sharing updates on communication and dissemination activities, discussing the impact of Graphene Week participation, and promoting upcoming project initiatives, including the 2D-PRINTABLE symposium planned for March 2026.

Overall, participation in Graphene Week activities throughout the project significantly strengthened the visibility, integration, and collaborative engagement of 2D-PRINTABLE within the European 2D materials ecosystem.

## 3.3 Joint dissemination and community engagement

2D-PRINTABLE partners also contributed to dissemination-oriented discussions and project coordination activities during Graphene Week events, including participating in joint promotion campaigns. These interactions facilitated exchange of experiences across projects and supported alignment of communication and dissemination strategies.

2D-PRINTABLE will also have a strong presence at the next Graphene Week 2026 event, with multiple partners (TCD, Uka, BeD, UniBw M, VSCHT) joining the conference and presenting the latest project results.

## 4 Joint Scientific and Technical Collaborations

The 2D-PRINTABLE consortium established numerous scientific and technical collaborations with other projects within the Graphene Flagship ecosystem.

These activities contributed to strengthening scientific exchange, facilitating access to complementary expertise, and supporting the joint advancement of 2D material technologies.

### 4.1 Joint publications

Several consortium partners engaged in collaborative publication activities with researchers from other Graphene Flagship projects.

These collaborations resulted in joint manuscripts, scientific discussions, and co-authored publications covering a broad range of topics related to 2D materials processing, sensing, exfoliation techniques, and device applications.

| Project partner | Collaboration     | Activity                                                                                                                                               |
|-----------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>TUD</b>      | Jena, 2D-SPINTECH | Joint ACS Nano publication “Solution-Processable Electronic-Grade 2D WTe <sub>2</sub> Enabled by Synergistic Dual Ammonium Intercalation” DOI: 10.1021 |
| <b>UniBW M</b>  | AMO GmbH, 2D-PL   | Joint manuscript                                                                                                                                       |
| <b>BeD</b>      | GIANCE            | Manuscript collaboration                                                                                                                               |
| <b>UniBW M</b>  | TUD, GrapheneEU   | Joint publication “Towards wafer-scale 2D material sensors” DOI: 10.1088/2053-1583/adac73                                                              |

### 4.2 Technical collaboration and sample exchange

Technical cooperation activities included sample exchange, crystal growth collaboration, discussions on material characterisation, and collaborative development of 2D material systems.

These activities facilitated access to complementary infrastructure and expertise across projects and supported joint technical progress.

Examples included:

- VSCHT – Collaboration on crystal growth of 2D magnets with 2DSPIN-TECH;
- TCD - Sample exchange discussions for 3D imaging with GRAPHERGIA;
- VSCHT - Collaborative work with 2D-PL;
- BeD - Material exchange activities with GIANCE supporting imaging and characterisation studies.

## 5 Joint Scientific and Technical Collaborations

2D-PRINTABLE partners participated in and co-organised numerous workshops, networking events, and collaborative scientific sessions throughout the project duration.

These activities contributed significantly to projects integration within the flagship and facilitated scientific exchange between projects, researchers, industry stakeholders, and policy actors.

### 5.1 Joint workshops and scientific sessions

The consortium explored and organised several collaborative workshop activities with projects including ARMS, GIANCCE, GRAPHERGIA, and other Graphene Flagship initiatives.

Key activities included:

- Joint workshop discussions with ARMS in January 2025;
- Collaborative meeting with GRAPHERGIA in December 2024;
- Joint workshop with GIANCCE in January 2025;
- Organisation of a dedicated scientific session focused on printable electronics during the E-MRS event in May 2025

At each event, the projects had the opportunity to present their respective results and discuss collaboration possibilities.

### 5.2 Korean Flagship Presentation Activities

Following the long-established collaboration between the Graphene Flagship and the Korean Graphene Society, 2D PRINTABLE hosted the bilateral Workshop 9th EU-Korea workshop on graphene and 2D materials in May 2025 at the University of Strasbourg. The main aim of the meeting has been the discussion and exchange of ideas and best practices on current and emerging topics associated with the 2D materials synthesis and production, multiscale studies of their physical and chemical properties, as well as application development and commercialization for graphene and related 2D materials in (opto)electronics, energy and composites. The workshop was instrumental to explore and promote new collaborative research opportunities between Korean and European researchers in the field of 2D materials. Multiple EU projects have participated, including:

- ARMS;
- SAFARI;
- GIANCCE;
- GRAPHERGIA;
- 2D-PL;
- 2DNEURALVISION.

Overall, the discussions demonstrated the consortium's commitment to strengthening international collaboration and expanding the visibility of European 2D materials activities.

The consortium also supported networking and matchmaking activities involving industrial and innovation stakeholders.

Examples included introductions between industrial actors, discussions related to commercial collaboration, and exchange of contacts supporting future innovation activities.

These interactions strengthened links between research organisations, industrial stakeholders, and commercialisation actors.

### 5.3 2D-PRINTABLE & HYPERSONIC Symposium 2026

On 31 March 2026, the 2D-PRINTABLE & HYPERSONIC Symposium was held in Dublin, Ireland, bringing together researchers, industry representatives, and policymakers to discuss the future of printable 2D materials for digital electronics. The event provided a valuable platform for scientific exchange and collaboration across the European 2D materials community.

Co-organised by the two projects, the symposium featured invited speakers connected to the Graphene Flagship ecosystem, SAFARI, ARMS, and the Innovative Advanced Materials Initiative (IAM-I). Their presentations highlighted recent developments, emerging technologies, and future challenges in the field of 2D material-based electronics.

Project partners also presented recent research results and technological advances, while the event fostered discussions on future collaborations, innovation opportunities, and application pathways. The symposium concluded with a panel discussion involving representatives from industry and innovation support organisations, including Enterprise Ireland, focusing on commercialisation and market uptake of 2D material technologies.

The symposium strengthened collaboration across projects within the Graphene Flagship ecosystem and contributed to the broader objectives of GrapheneEU by promoting knowledge exchange, cross-project synergies, and stronger connections between research, innovation, and industrial stakeholders in the field of 2D materials.

### 5.4 Roadmap, Innovation, and Industrialisation Activities

Beyond scientific collaboration, 2D-PRINTABLE partners contributed actively to innovation-oriented and industrialisation-focused discussions across the Graphene Flagship ecosystem.

Several consortium partners participated in roadmap-related discussions involving multiple Graphene Flagship projects and stakeholders.

These activities included meetings and exchanges related to:

- Technology translation;
- Future industrial applications;
- Market opportunities;

- Research priorities;
- Ecosystem alignment.

Projects involved in roadmap discussions included:

- ARMS
- SAFARI;
- GIANCIE;
- GRAPHERGIA;
- 2D-PL;
- 2DNEURALVISION;
- 2D-SPINTECH;
- Next-2DIGITS;
- MUNASET;
- GATEPOST;
- 2D-ENGINE.

Industrial stakeholders engaged through these activities included companies and organisations involved in advanced materials, semiconductor technologies, automotive applications, and innovation support, such as Volkswagen, BENEQ, and CROSSFIRE.

These discussions contributed to strengthening understanding of industrial needs and future commercial opportunities for printable and flexible electronics based on 2D materials.

The activities also supported broader discussions on exploitation pathways, commercialisation strategies, and long-term sustainability of research outcomes.

## 6 Impact of CSA Activities

The CSA activities undertaken during the reporting period generated significant scientific, innovation, dissemination, and ecosystem-level impact for the 2D-PRINTABLE project and the wider Graphene Flagship community.

### 6.1 Scientific impact

Cross-project scientific collaboration enabled:

- Exchange of complementary expertise;
- Joint publications and manuscripts;
- Access to materials and characterisation capabilities;
- Development of new collaborative research opportunities;
- Increased visibility of project results.

These activities strengthened the scientific integration of 2D-PRINTABLE within the European 2D materials research landscape.

### 6.2 Innovation and Exploitation impact

Participation in roadmap activities, industrialisation discussions, and commercialisation-oriented events supported:

- Identification of future application pathways;
- Exchange with industrial stakeholders;
- Strengthening of exploitation strategies;
- Increased awareness of market and innovation opportunities.

The consortium's engagement in innovation-oriented discussions also contributed to bridging the gap between scientific research and industrial uptake.

### 6.3 Dissemination and Community impact

Dissemination and networking activities increased the visibility of 2D-PRINTABLE across the wider Graphene Flagship ecosystem and promoted stronger integration between projects.

The consortium's active contribution to dissemination working groups, workshops, and Graphene Week activities supported:

- Knowledge exchange;
- Coordination of dissemination efforts;
- Community-building;
- Networking opportunities for researchers;
- Strengthening of collaborative relationships.

## 6.4 Contribution to the European 2D materials community

Through active engagement across scientific, dissemination, innovation, and industrialisation activities, 2D-PRINTABLE contributed to reinforcing the collaborative nature of the European 2D materials ecosystem.

The project supported the broader objectives of the Graphene Flagship by promoting synergies across projects, encouraging interdisciplinary collaboration, and contributing to the long-term sustainability and impact of European research and innovation activities in graphene and related materials.

## 7 Conclusion and Recommendation

The CSA activities carried out during the reporting period significantly strengthened the integration of 2D-PRINTABLE within the Graphene Flagship ecosystem.

Through active participation in dissemination working groups, project management networks, scientific collaborations, roadmap activities, and community events, the consortium contributed to reinforcing collaboration and knowledge exchange across the European 2D materials landscape.

The project established valuable scientific and innovation-oriented links with numerous related initiatives, supporting joint publications, technical collaboration, dissemination activities, industrial engagement, and exploration of future application pathways.

As the project enters its final phase, these collaborative activities continue to support exploitation planning, ecosystem integration, and long-term sustainability of project outcomes beyond the project lifetime.

The consortium remains committed to fostering collaboration across the Graphene Flagship community and contributing to the advancement of printable and flexible electronics based on 2D materials.

## 8 Deviations from Annex 1

There are no deviations from the description of this deliverable as given in Annex I of the Grant Agreement.

## 9 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

### Project partners:

| # | Partner short name | Partner Full Name                                                                                                                                         |
|---|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | TCD                | TCD THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD, OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN |
| 2 | UNISTRA            | UNIVERSITE DE STRASBOURG                                                                                                                                  |
| 3 | UKa                | UNIVERSITAET KASSEL                                                                                                                                       |
| 4 | BED                | BEDIMENSIONAL SPA                                                                                                                                         |
| 5 | TUD                | TECHNISCHE UNIVERSITAET DRESDEN                                                                                                                           |
| 6 | VSCHT              | VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE                                                                                                               |
| 7 | UNR                | UNIRESEARCH BV                                                                                                                                            |
| 8 | UniBw M            | UNIVERSITAET DER BUNDESWEHR MUENCHEN                                                                                                                      |
| 9 | EPFL               | ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE                                                                                                                  |

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