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Developing New 2D Materials and Heterostructures for Printed Digital Devices

2D-PRINTABLE - Deliverable report

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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.

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Introduction

As 2D-PRINTABLE reaches its conclusion, it is important to define how project data, research outputs and records will be preserved, maintained, archived or deleted after the end of the funded period. This post-project data management plan builds upon the project's FAIR data commitments, as detailed in D8.3, and sets out the long-term strategy for research, administrative and dissemination data generated during the project.

Data summary

The 2D-PRINTABLE project generated a broad range of research data supporting the discovery, synthesis, processing, characterization and device integration of novel two-dimensional (2D) materials for printed electronics. The data were generated by computational modelling, experimental materials synthesis and exfoliation, advanced characterization techniques, and electronic/optoelectronic device testing. In line with FAIR principles, selected datasets, publications and public project outputs are made available through open repositories, including Zenodo and the Materials Cloud platform.

2D-PRINTABLE generated the following main categories of research data:

Computational and modelling data, including high-throughput density functional theory (DFT) and density functional perturbation theory (DFPT) calculations used for screening and predicting novel 2D materials, electronic structures, band gaps, phonon stability and other material properties. These activities contributed to the identification of dozens of previously unexplored semiconducting 2D materials and further enriched the publicly available MC2D database.

Materials synthesis and processing data, including crystal growth parameters, exfoliation protocols, chemical functionalisation procedures, intercalation and etching methods, ink

formulation parameters, and production records for hundreds of layered bulk materials and more than 40 exfoliated material systems.

Materials characterisation data generated using techniques such as AFM, SEM, TEM, XRD, Raman spectroscopy, UV-Vis spectroscopy, photoluminescence spectroscopy, XPS, TOF-SIMS, DRIFT spectroscopy, GI-XRD, FIB-SEM nanotomography and THz spectroscopy. These datasets were used to assess material morphology, composition, purity, optical and electrical properties, surface chemistry, nanosheet dimensions and network structure.

Device and performance data, including electrical, optical and optoelectronic measurements of printed thin-film transistors (TFTs), capacitors, photodiodes, photovoltaic devices, light-emitting diodes (LEDs), memory devices and simple integrated circuits. The datasets include mobility, conductivity, capacitance, current-voltage characteristics, photoluminescence and electroluminescence measurements, device yield and stability assessments.

Together, these datasets provide a comprehensive resource. The data support scientific publications, technology development and future research activities while enabling reproducibility, reuse and long-term accessibility of non-confidential project results through open-science repositories and databases.

Preservation or deletion of data at project end

The 2D-PRINTABLE project does not personally sensitive research data. However, project administration and management activities have generated personally identifiable information including names, email addresses, signatures, meeting attendance records and contact details of consortium members and stakeholders. At project close, all partners will review such administrative datasets in accordance with GDPR requirements and their institutional policies. Data for which there is no continuing legal, financial, reporting or audit justification will be securely deleted.

Consortium-wide contact lists used solely for project communications will be removed when they are no longer required, anticipated 6 months after the project end. Records associated with grant auditing, financial reporting or contractual obligations will be retained for the mandatory retention periods prescribed by the European Commission and partner institutions before subsequent deletion.

Each consortium partner will remain responsible for managing research data stored on institutional servers, laboratory computers, local repositories and cloud services under their control. Partners will follow their own institutional policies regarding long-term preservation, archiving and deletion.

Internally shared project data stored on consortium SharePoint will be reviewed following project completion. Redundant drafts, duplicate datasets, obsolete working files and superseded versions will be removed where appropriate. Data of continuing scientific, legal or historical value may be retained according to local institutional archiving policies. The SharePoint will be deleted one year after the project end.

Data stored in Repositories

Public datasets, reports, deliverables, publications and other research outputs deposited within the 2D-PRINTABLE Zenodo Community will remain openly accessible after project completion. Zenodo assigns persistent Digital Object Identifiers (DOIs) and provides long-term preservation through the CERN-operated infrastructure. Accordingly, project outputs deposited in Zenodo are expected to remain available for at least twenty years and likely substantially longer. Metadata associated with these records will remain publicly findable, accessible and compatible with general data analysis software.

Partners may additionally archive publications, theses, reports and datasets within institutional repositories such as Trinity College Dublin's TARA repository and equivalent repositories operated by consortium members. Long-term preservation and access conditions for these outputs will be governed by the policies of the respective institutions.

Data stored on the project website

The 2D-PRINTABLE project website will continue to serve as a dissemination resource after project completion for as long as Uniresearch's funding for hosting arrangements permit, likely for three years after the project end with a maximum period of five years.

These data include public deliverables, news articles, communication materials and project information. Prior to website closure, the project coordinator and dissemination team will evaluate the website contents and identify high-value outputs suitable for long-term archiving within Zenodo.

Where feasible, a static export or archive of the website will be preserved to maintain access to significant dissemination materials and public-facing project information.

Preservation of other research outputs

In addition to datasets, 2D-PRINTABLE may generate software, protocols, characterisation methodologies, workflows, materials-processing procedures and other research outputs. Openly released versions of these outputs will remain available through publications and Zenodo records. Physical samples and materials generated during the project will remain under the custodianship of the originating institutions and managed according to local laboratory and institutional policies.

Long-term data stewardship

Responsibility for long-term stewardship of project outputs will transition from the consortium to the institutions and researchers responsible for creating the data. Open research outputs deposited in trusted repositories will remain discoverable through persistent identifiers, standard metadata and repository indexing services. The consortium therefore expects the scientific outputs of 2D-PRINTABLE to remain reusable by researchers, industry, policymakers and other stakeholders well beyond the end of the project.

This post-project management approach ensures that 2D-PRINTABLE continues to comply with Horizon Europe principles on open science, FAIR data and responsible research data stewardship after the conclusion of the project

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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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