D7.5 1. Prototypes fabrication using cellulose as substrate and device/ system component

WP7 TA3: Access to prototype fabrication

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List of abbreviations

ALMA – AlmaScience
FZJ-HPG – Forschungszentrum Jülich GmbH
JOR – Joanneum Research Forschungsgesellschaft mbH
RISE – Research Institutes of Sweden AB
R2R – Roll-to-roll
TA – Transnational activity
TUD-IAPP – Technische Universität Dresden / Dresden Integrated Centre for Applied Physics and Photonic Materials
TUD-FM – Technische Universität Dresden / Molecular Functional Material
UNOVA – Instituto de Desenvolvimento de Novas Tecnologías
UV – Ultra-violet
WUT – Warsaw University of Technology / Centre for Advanced Materials and Technologies

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1. Executive Summary

Within the scope of WP7 (Access to prototype fabrication), four installations are offered to potential external users with well-equipped infrastructures and experts for developing prototypes. The installations provide access to state-of-the-art fabrication techniques such as R2R printing, nanoimprinting, laser patterning, vacuum-assisted deposition, and functional 2D/3D printing.

All the partners involved in WP7 have provided a detailed list of the equipment available for the different installations, which can be consulted on the project website (https://emerge-infrastructure.eu/transnational-access-activity/ta3-prototype-fabrication/). The information is categorised under five sub-classes of the TA:

- TA3.1. Device Preparation
- TA3.2. Functional 2D & 3D printing
- TA3.3. Industrial printing
- TA3.4. Nanoimprinting & laser patterning
- TA3.5. Vacuum-assisted deposition,

Seven partners are involved in the WP7, leveraging the following processes and technologies:

- ALMA offers services related to the design and processing of foils and the tailoring and modification of paper as a substrate material. The infrastructure provided by this partner is equipped with lab-scale and small pilot equipment capable of manufacturing and customising paper hand sheets (sheet former, automatic film applicators, screen printing, flexographic printing, slot die).
- FZJ-HPG grants access to three head roll-to-roll lines for coating solar modules (R2R-Coating-Line). This coating line is fitted with three individual coating stations, allowing a variety of coating or printing heads at variable widths up to 300 mm. For pre-printing trials, FZJ-HPG offers an equipped lab with inkjet, slot-die, and meniscus coating, allowing to perform tests on sheet-to-sheet machines to validate results before moving processes on the roll-to-roll printing machinery.
- In WP7 JOR provides access to techniques and equipment such as R2R-pilot lines with gravure printing, slot die coating screen printing, inkjet printing, Aerosol jet

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printing, and hot embossing. In terms of micro/nanopatterning. Additionally, at JOR, it is possible to develop projects using UV-nanoimprinting, maskless greyscale laser lithography for patterning on 2D and 3D curved surfaces, and cleanroom with photolithography, e-beam lithography and reactive ion etching.

- RISE owns a printing laboratory with tools for research, development and pilot-production of printed and organic electronics. The TA3 users can benefit from semi-automated or fully automated sheet-based flatbed screen printing tools equipped with dryers (hot-air, IR and UV-curing). The screen-printing tools that meet the industry standards and enable pilot production. They also facilitate the transfer of technology to commercial manufacturers.
- TUD-IAPP has expertise in vacuum and solution film growth, thin films and device prototypes. In the frame of WP7, the infrastructure offered by TUD-IAPP includes deposition and structuring techniques, such as vacuum evaporation, electron-beam evaporation, atomic layer deposition, organic vapour jet printing, inkjet printing, spray coating, mask-less photolithography, and high-resolution photolithography with mask aligner.
- In the TUD-FM laboratories, the users will benefit from staff and equipment for ink preparation, printing and optimisation of the printing process, device design and production. For these activities, TUD-FM gives access to a viscometer, tensiometer, sonicator, dissolver glovebox, inkjet printer machine equipped with 32 nozzles, and doctor blade.
- WUT via CEZAMAT offers cutting-edge facilities for developing and testing functional materials for application in large-scale printing techniques. The equipment provided by this centre includes testing machines to scale up from laboratory materials to large-scale manufacturing, semi-automatic screen-printing machines, in-line furnace and curing chambers, and materials deposition with printing techniques and coating.

2. Description

From the 63 proposals submitted to the 4 calls already launched and closed, just one of the user projects selected was developed under the TA3 umbrella during the reported period using cellulose substrates. The work developed by the partners included the selection,

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production, or modification of the substrates, characterisation of cellulose substrates, and fabrication of electronic devices.

In the following sections, the projects developed in the frame of TA3 will be briefly presented. D7.5 is a public document; thus, some technical details will be omitted not to compromise any confidential matters and confidentially agreements.

2.1. Project: Fabrication and electrical characterisation on two-dimensional (2D) polymers-based flexible organic electronics

The project "*Fabrication and electrical characterisation on two-dimensional (2D) polymers-based flexible organic electronics*" was hosted by UNOVA and ALMA. Bowen Zhang, a PhD candidate developing his work at Fraunhofer Institute-IKTS in Germany, submitted the proposal during the 4th open call.

This project aimed to fabricate and characterise flexible devices, activities aligned with TA3 and TA4, using highly crystalline 2D polymers synthesised by the surfactant-monolayer-assisted interfacial synthesis (SMAIS) as semiconductors. Due to the project's goals, the TA3 activities were conducted under the supervision of a researcher from AlmaScience, while the TA4 was under the responsibility of UNOVA.

During the week that the user was in AlmaScience installation, he was involved in discussions with both teams to define strategies for the project, as well as in the process of paper substrates selection, preparation of the substrate, deposition of electrodes, transference of the 2D polymers onto the paper substrate, and device fabrication (field-effect transistors). For this work, two paper substrates were used: a commercial one used as the gate dielectric in several publications [1, 2, 3, 4], and a second one prepared by the AlmaScience team, which is also used for activities developed in the joint research activity 1 (WP9 - Research on hybrid printing setups with quantitative in-line measurement methods for high precision fabrication of bio-nano systems).

[1] https://onlinelibrary.wiley.com/doi/full/10.1002/aelm.201800423
[2] https://iopscience.iop.org/article/10.1088/0957-4484/25/9/094007/meta
[3] https://www.sciencedirect.com/science/article/pii/S2352940718302749
[4] https://onlinelibrary.wiley.com/doi/abs/10.1002/adma.201102232

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The commercial paper consists of a 75 µm thick entangled fibre matrix with an average width of 10 µm and an RMS roughness of 6.4 µm. The paper was selected since it was observed from previous works its ability to withstand extreme conditions, namely temperature and vacuum. The wettability and resistance to water and acetone were also tested during the project's persecution since the polymer's transfer process onto the paper substrates involved two steps using solvents where the substrates needed to remain for 10-15 minutes. The commercial paper endured the entire fabrication process that involved two metal depositions, one water-assisted transfer, a washing step with acetone, and several drying times.

Despite the rough and irregular surface, the transfer and adhesion of the polymer and metal layers were good, and the layers were continuous, ensuring the possibility of percolation between source and drain contacts. Moreover, it was observed that water-assisted transfer and acetone washing did not affect the dielectric properties of the paper.

The paper made by AlmaScience consists of a 95 µm substrate with a matrix made with bleached eucalyptus kraft pulp without fillers and additives. The roughness of this paper is ≈4 µm, determined by 3D profilometry.

During the week the project was developed, it was impossible to test this substrate as gate dielectric. Still, the user received the paper with the gate electrode deposited to conclude the transfer process and the fabrication of the device.

The UNOVA team characterised the devices (TA4) in close collaboration with AlmaScience.

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Figure 1 - Photo of UNOVA and AlmaScience staff with Bowen Zhang (EMERGE infrastructure user).

3. Final Remarks

So far, only one project involving customized cellulose substrates has been completed. Since this deliverable is a public one, no more information can be disclosed on the architecture and results obtained. More details will be provided in the project report to be presented to the European Commission. Nevertheless, it was already agreed that the collaboration between AlmaScience and the user will continue offsite to improve the results obtained.

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