D7.3: Prototypes fabrication Transnational Access Provision

WP7 – TA3 – Access to prototype fabrication

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List of abbreviations

FZJ – Forschungszentrum Jülich GmbH

HMU – Hellenic Mediterranean University

JOR – Joanneum Research Forschungsgesellschaft mbH

OBU - Oxford Brookes University

TA – Transnational Access Activities

TA3 – Access to Prototypes Fabrication

TLO – Technical Liaison Office

TUD – Technische Universität Dresden

RISE – Research Institute of Sweden

RTO - Research and Technology Organizations

SME – Small Medium Enterprise

UoA – Units of Access

UNOVA – Instituto de Desenvolvimento de Novas Tecnologias (UNINOVA)

WP – Work package

WUT – Warsaw University of Technology

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1. Executive Summary

The deliverable 7.3 – Prototype fabrication transnational access provision belongs to the Work Package 7 (WP7) titled as TA3 – Access to Prototype fabrication.

The purpose of this report is to provide a comprehensive summary of the proposals related to TA3 which were submitted during the first five calls of EMERGE, i.e., up to December 2023 (M30).

Overall, 53 proposals were submitted on the EMERGE website requesting prototype fabrication access provision (TA3). 24 projects were successfully completed, 3 were rejected, 2 were cancelled and 24 are under evaluation or under implementation. Besides that, 1 additional project was completed for which TA3 access was not originally requested (reassigned).

2. Proposals

2.1 Concluded proposals originally submitted to TA3 access

24 projects were concluded until December 2023.

RISE hosted 9 projects, WUT hosted 5 projects, JOR and TUD hosted 3 projects each, while FZJ and HMU hosted 2 projects each. Table 1 brings the details about each project such as the title, project call and the period of implementation.

Table 1: List of projects concluded for TA3 and concluded by M30.

CALL	ID	Title	HOST Institution(s)	Date
1	**3651**	Screen printing of TiO2 / CeO2 powder mixture for oxygen sensors	WUT	25.10. – 27.10.2022
1	**3662**	Electrochemically exfoliated 2D materials for printed electronics	TUD	27.11. – 10.12.2022
1	**3663**	Xfold TR-FRET slides for high sensitivity and early detection of infectious diseases	JOR	26.01. – 27.01.2023
2	**3845**	Resist-free e-beam lithography for robust nanophotonic and flexible electronic devices in harsh environments	HMU	03.04. – 07.04.2023
2	**3846**	Effect of Electrochromic Pixel Size on Temperature and Humidity Performance	RISE	23.05. – 25.05.2023
3	**3986**	Design concept of a piezoelectric self-adhesive skin patch for wound healing applications	HMU	27.09. – 29.09
3	**4001**	Formulating screen printing ink/paste application for resistive heater application	WUT	01.06. – 30.06.2023

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3	**4008**	Exploiting UV nanoimprinting for introducing micro-structured burst valves in a self-powered microfluidic device for precise liquid volume metering	JOR	01.05. – 14.07.2023
3	**4009**	Screen printing and paste preparation based on Al 1%Si powder for flexible, wearable, self-powered sensor used as human respiration detector	WUT	19.06. – 23.06.2023
3	**4010**	Thin and flexible electrodes for capacitance measurement	WUT	15.06. – 30.06.2023
3	**4011**	Prototype fabrication of screen-printed electrochemical sensors	RISE	28.03. – 21.07-2023
3	**4073**	R2R printing of next generation OPV active layers and HTL	FZJ	03.07. – 07.07.2023
3	**4074**	Controlled doping of the active layer as a way of enhancing performance of organic solar cells	TUD	23.05. – 25.05.2023
3	**4075**	Hybrid organic-inorganic transparent UV photodetector	TUD	18.09. – 22.09.2023
3	**4078**	Stability of OPV-modules operated under indoor conditions	FZJ	01.08. – 04.08.2023
3	**4079**	Textile integrated hybrid printed electronics	RISE	08.06. – 15.06.2023
4	**4625**	Mass production of NFC tags printed on paper with additive techniques and at least 2 years lifetime, easy to recycle.	RISE	06.10. – 24.11.2023
4	**5320**	Photonic sintering of reverse offset printed structures	RISE	21.08. – 12.12.2023
4	**5682**	Evaluation of scalability of 2D printing of magneto-rheological and magneto-electrical composites	RISE	14.09.2023 – 16.11.2023
4	**5814**	Screen-printed structures of alternating TiO2 and CeO2 layers used as an oxygen-sensing materials	RISE	07.08.2023 – 07.12.2023
4	**5821**	Comparison of Material Properties of Electrochemically Printed Structures against Screen and Inkjet printed Structure	RISE	14.07. – 13.10.2023
4	**5825**	Characterization of solution processable nanomaterials for transistor and memristor-based biosensors applications	JOR	06.11. – 09.11.2023
4	**5826**	2D/3D CELL-PILs for tissue engineering	WUT	23.10. – 02.11.2023
4	**5827**	Manufacturing and Characterization of Flexible Thermoelectric Modules and associated electronics through printing techniques	RISE	16.10. – 01.12.2023

In total, 37 users participated in TA3 projects up to December 2023. One project had three participants, eleven projects had two participants, while twelve had only one. Most of the proposals were applied from University Institutes (9), followed by SME (6), RO (5) and Industry (4). Table 2 summarizes the information about users and their home institution for each proposal.

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Table 2: Information about users who carried out concluded projects which were originally submitted for TA3.

CALL	ID	Title	Name	Surname	Research role	Institute / Company	Type
1	**3651**	Screen printing of TiO2 / CeO2 powder mixture for oxygen sensors	Evgenija	Milinković	PhD student	Institute of Chemistry, Technology and Metallurgy, National Institute of the Republic of Serbia	Research organization
			Milija	Sarajlic	Senior scientist	IHTM	Research organization
1	**3662**	Electrochemically exfoliated 2D materials for printed electronics	Bing	Wu	PhD Student	University of chemistry and technology, Prague	University
1	**3663**	Xfold TR-FRET slides for high sensitivity and early detection of infectious diseases	Nagarajan	Subramaniyam	Manager	Xfold Imaging Oy	Small & medium enterprise
2	**3845**	Resist-free e-beam lithography for robust nanophotonic and flexible electronic devices in harsh environments	Angelos	Xomalis	Post-doc	Empa, Swiss Federal Laboratories for Materials Science and Technology	Research organization
			Eleni	Perivolari	Scientist	Empa, Swiss Federal Laboratories for Materials Science and Technology	Research organization
2	**3846**	Effect of Electrochromic Pixel Size on Temperature and Humidity Performance	Elin	Howard	PhD student	Ynvisible GmbH	Industry
			Shekhar	Shinde	Other	Ynvisible GmbH	Industry
3	**3986**	Design concept of a piezoelectric self-adhesive skin patch	Núria	Canal Paulí	Other	Beiersdorf AG	Industry

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		for wound healing applications					
3	**4001**	Formulating screen printing ink/paste application for resistive heater application	Arun Prakash	Aranga Raju	Manager	Levidian Nanosystems Limited	Industry
			Ugo	Sassi	Manager	Levidian Technology	Industry
3	**4008**	Exploiting UV nanoimprinting for introducing micro-structured burst valves in a self-powered microfluidic device for precise liquid volume metering	Dries	Vloemans	Post-doc	KU Leuven - Department of Biosystems - Biosensors Group	University
3	**4009**	Screen printing and paste preparation based on Al 1%Si powder for flexible, wearable, self-powered sensor used as human respiration detector	Marko	Bošković	Scientist	University of Belgrade, Institute of Chemistry, Technology, and Metallurgy, Department of Microelectronic Technologies	University
3	**4010**	Thin and flexible electrodes for capacitance measurement	Kyoko	Jansson	Manager	Innovation Partners (Europe) AB	Small & medium enterprise
3	**4011**	Prototype fabrication of screen-printed electrochemical sensors	Fatima AlZahra'a	Alatraktchi	Manager	PreDiagnose	Small & medium enterprise

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3	**4073**	R2R printing of next generation OPV active layers and HTL	Francois	Grenier	Professor-scientific coordinator	Brilliant Matters Inc.	Industry
			Pierre-Olivier	Morin	Senior scientist	Brilliant Matters Inc.	Industry
			Varun	Vohra	Senior scientist	Brilliant Matters Inc.	Industry
3	**4074**	Controlled doping of the active layer as a way of enhancing performanc e of organic solar cells	Mathias	Nyman	Post-doc	Åbo Akademi University	University
3	**4075**	Hybrid organic-inorganic transparent UV photodetect or	Donato	Spoltore	Professor-scientific coordinator	Università di Parma	University
			Francesco	Mattei	PhD student	Università degli Studi di Parma	University
3	**4078**	Stability of OPV-modules operated under indoor conditions	Katharina	Matura	Degree Student	Linz Institute of Organic Solar Cells	University
			Markus	Scharber	Professor-scientific coordinator	Physical Chemistry, Johannes Kepler University Linz	University
3	**4079**	Textile integrated hybrid printed electronics	Julius Maximilian	Scherf	Scientist	PROFACTO R GmbH	Research organization
			Pavel	Kulha	Senior scientist	PROFACTO R GmbH	Research organization
4	**4625**	Mass production of NFC tags printed on paper with additive techniques and at least 2 years lifetime, easy to recycle.	Ferran	Micaló	Technician	Rotimpres	Small & medium enterprise
			Marc	Vizern	Manager	ROTIMPRES	Small & medium enterprise
4	**5320**	Photonic sintering of reverse offset printed structures	Henrik	Sandberg	Senior scientist	VTT	Research organization
			Kim	Eiroma	Scientist	VTT	Research organization
4	**5682**	Fabrication and	Cristian	Mendes	Post-doc	Fundación BCMaterials-	Research organization

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		electrical characterization on two-dimensional (2D) polymers-based flexible organic electronics				Basque Center for Materials, Applications and Nanostructures	
			Nikola	Perinka	Scientist	Fundación BCMaterials-Basque Center for Materials, Applications and Nanostructures	Research organization
4	**5814**	Screen-printed structures of alternating TiO2 and CeO2 layers used as an oxygen-sensing materials	Jelena	Stevanović	PhD student	Institute of Chemistry, Technology and Metallurgy	University
			Milija	Sarajlic	Senior scientist	IHTM	University
4	**5821**	Comparison of Material Properties of Electrochemically Printed Structures against Screen and Inkjet printed Structure	Jekaterina	Viktorova	Manager	Syenta	Small & medium enterprise
4	**5825**	Characterization of solution processable nanomaterials for transistor and memristor-based biosensors applications	Mattia	Petrelli	Post-doc	Free University of Bozen-Bolzano, Faculty of Engineering	University
4	**5826**	2D/3D CELL-PILs for tissue engineering	Marta	Corvo	Senior scientist	NOVA FCT	University

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4	**5827**	Manufacturing and Characterization of Flexible Thermoelectric Modules and associated electronics through printing techniques	Sajjad	Mahmoudi Nezhad	Senior scientist	ParsNord Thermal Comfort ApS	Small & medium enterprise

In the sections below, one can read the detailed description of projects objectives, requested TA Installations, used TA installations and respective Units of Access (UoA) or hours.

Proposal 3651: Screen printing of TiO2 / CeO2 powder mixture for oxygen sensors (WUT)

Objectives: A systematic analysis of various TiO_2 and CeO_2 powder combinations obtained by using planetary mill was done by the users during a previous research. Afterwards, the powder was used to make a paste which was screen printed to the substrate with interdigitated electrodes. The uniformity and the repeatability of the paste screen-printing was an issue, and the users would like to mitigate by using automated screen-printing process.

Requested TA/installations: TA3.3. Industrial printing / TA2.1 Materials characterization

Used TA/installations: TA3.3. Industrial

Proposal 3662: Electrochemically exfoliated 2D materials for printed electronic (TUD)

Objectives: 3D-printed micro-supercapacitors (MSCs) have become the leading candidates for wearable energy storage devices due to their distinctive characteristics of miniaturization, structural diversity, and integration. The key to achieving customization and improving the performance of 3D-printed MSCs is to investigate the 3D printing technique for various materials and architectures of MSCs. Meanwhile, few-layer phosphorene, a representative 2D nanomaterial, has emerged as a supercapacitor electrode material owing to its large active surface area and a large amount of available space for accumulating electrostatic

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charges. However, due to their high sensitivity to oxygen, few-layered black phosphorus is easily oxidized in ambient conditions, lowering their intrinsic properties, which makes these materials impractical apart from laboratory use in making the ink for 3D printing process. Recently, various functionalization techniques have been employed to overcome the air instability of black phosphorus. In this proposal, a facile and cost-effective method, based on the electrochemical exfoliation of BP and synchronized electrochemical deposition of aluminium oxide will be proposed to passivate exfoliated BP. The prepared BP is expected to exhibit high air stability and then the sample will be applied to a 3D-printed macro-supercapacitor

Requested TA/installations: TA3.2 Functional 2D & 3D printing / TA2.1 Materials characterization

Used TA/installations: TA2.3 (9 UoA) / TA2.4 (2 UoA) / TA2.5 (5 UoA) / TA3.2 (4 UoA)

Proposal 3663: Xfold TR-FRET slides for high sensitivity and early detection of infectious diseases (JOR)

Objectives: The roll-to-roll nanoimprinting of Xfold plasmonic sheet at Joanneum Research, Austria. The master mold sample was designed and fabricated at Xfold, Finland. The structural quality was evaluated during the visit and R2R nanoimprinting was planned.

Requested TA/installations: (P) TA3.1. Device Preparation, (S) TA3.4. Nanoimprinting & laser patterning, (S) TA3.5. Vacuum assisted deposition

Used TA/installations: TA3.4, 30 hours

Proposal 3845: Resist-free e-beam lithography for robust nanophotonic and flexible electronic devices in harsh environments (HMU)

Objectives: The aim of the project is to boost the mechanical properties of flexible photonic and electronic devices. It has been recently shown that by applying nanopatterns one can engineer materials' failure (ACS Applied Nano Materials 6 (5), 3388-3394). While ordinary materials developing cracks homogeneously when strain is applied, nanopatterns ordered in specific shapes (mechanical metasurfaces) drive, control and deflect cracks. Here we aim to produce standard electrodes of printable inks via upscaling methods on flexible substrates. At the next stage, these functional nanoscale thick electrodes will be patterned via resist-free e-beam lithography and high-resolution large-scale UV laser ablation

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(depending on the electrode thickness) to produce mechanical robust nanopatterns that eliminate device's failure upon applied strain.

Requested TA/installations: TA3.2. Functional 2D & 3D printing/ TA4.1. Device metrology & characterization

Used TA/installations: TA3.2, 32 hours; TA4.1, 8 hours.

Proposal 3846: Effect of Electrochromic Pixel Size on Temperature and Humidity Performance (RISE)

Objectives: The overall goal of this experiment was to asses how the pixel size of large area electrochromic influences the behaviour of the devices over a range of environmental conditions (i.e. temperatures and humidities). In particular this study was focused on assessing the switching speed and visual propagation fonts that develop across large area displays. These fronts have a significant contribution to the visual switching in these displays in part because we do not use an underlying conducting electrode (i.e. ITO, FTO, AZO) and instead rely on the low sheet resistance of the chromogenic film (i.e. PEDOT:PSS).

The first portion of the project was dedicated to printing a set of displays that could be used for this experimental work, and then the second portion was dedicated to characterizing these displays after exposure in a climate chamber. We had proposed to characterize the displays in increments of 10 C from -40 C to 80 C, and analyse their performance optically.

Requested TA/installations: TA3.1. Device Preparation / TA4.1. Device metrology & characterization / TA4.2. Validation and standardization.

Used TA/installations: TA3, 20 hours; TA4, 20 hours

Proposal 3986: Design concept of a piezoelectric self-adhesive skin patch for wound healing applications (JOR)

Objectives: The complex process of wound healing depends on the coordinated interaction between various immunological and biological systems, which can be supported and enhanced by technology. Due to the increasing healthcare costs, a rapid aging population (today 1/9 is >60 years old, projected 1/5 by 2050) and the growing incidence of diabetes (today 463 million adults, 700 million by 2045) and obesity in many countries, there is the need to treat acute and severe wounds at an early stage, to prevent them from developing into chronic wounds, which represent a major problem for patients, health care professionals and health care systems. Particularly, electrical stimulation (ES) has been proven to regulate

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cell proliferation and migration, reduce inflammation, and accelerate wound bed closure by mimicking or amplifying the effect of the wound's endogenous electric field. Therefore, the development of a thin, flexible, PENG self-adhesive skin patch for promoting wound healing via ES is of high interest and potential.The objective of this feasibility project is to test if the current PyzoFlex system from JR can be used in this regard, as an energy harvesting source to generate a certain therapeutically relevant voltage/ current via the movement (bending, pressing) of the piezoelectric sensors. The generated voltage would then be directed to wound areas for stimulated wound healing – but this is not a task of the first evaluation phase

Requested TA/installations: TA3.1. Device Preparation

Used TA/installations: TA3 36 hours / TA4 34 hours

Proposal 4001: Formulating screen printing ink/paste application for resistive heater application (WUT)

Objectives: Successful formulation of the Levidian graphene-based screen printable conductive inks.

Optimise the formulation; binder, binder content, graphene loading to achieve decent conductivity on various substrates – paper and foil.

Demonstrate the ink's resistive heater application.

Select one formulation to demonstrate.

- Print simple profile – optimise the printing conditions.
- Measure temperature gains with various voltages
- Measure resistance and change in temperature.
- Determine maximum Wattage for that substrate

Requested TA/installations: TA3.1. Device Preparation / TA2.1. Materials characterization / TA2.2. Chemical & physical techniques

Used TA/installations: TA1.1, 8 hours; TA2, 24 hours; TA3, 16 hours; TA4, 32 hours

Proposal 4008: Exploiting UV nanoimprinting for introducing micro-structured burst valves in a self-powered microfluidic device for precise liquid volume metering (JOR)

Objectives: The general aim of this EMERGE project was to explore roll-to-roll UV-light-assisted nanoimprinting lithography as an alternative manufacturing method to fabricate programmable and functional microfluidic circuits and show its potential for

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upscaling/automating the production of our microfluidic devices on the longer term. More specifically, the research performed within the project could be divided in 4 sub-objectives:

- Characterization of the resolution and accuracy of the imprinted microfluidic circuit with integrated geometric burst valves
- Burst pressure characterization of geometric burst valves with different channel dimensions

Assess the potential of integrating hydrophobic papers in the imprinted microfluidic circuit for introducing hydrophobic stop valves

- Selection of the optimal geometric burst valve combination for robust coordinated liquid manipulation and isolation of a precisely metered liquid volume

Requested TA/installations: TA3.4. Nanoimprinting & laser patterning / TA4.1. Device metrology & characterization

Used TA/installations: TA3.4, 8 hours; TA4.1, 6 hours

Proposal 4009: Screen printing and paste preparation based on Al 1%Si powder for flexible, wearable, self-powered sensor used as human respiration detector

Objectives:

- Fabrication of various pastes for screen printing.
    - Electro-conductive pastes: Graphene nano-tubes, Graphene nano-particles and Graphite with carbon Black.
    - Electro non-conductive pastes: Al with SiO_2, Al, Al with Al_2O_3, Al with MgO, MgO, Al_2O_3, SiO_2.
- Screen printing of non-conductive underlayer and on top of that screen printing of conductive electrodes.
- Measurements of the paste's viscosity.
- Measurements of the screen-printed samples profilometry.

Requested TA/installations: TA2.2. Chemical & physical techniques / TA3.3. Industrial printing / TA4.2. Validation and standardization

Used TA/installations: TA3.3, 12 hours; TA4.2, 8 hours

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Proposal 4010: Thin and flexible electrodes for capacitance measurement (WUT)

Objectives: The development of a non-invasive real-time bladder monitor is based on a Bluetooth Low Energy (BLE) module and capacitive sensors. The prototype device has been validated in the laboratory environment. impedance, and other parameters. For the current prototype measurement, commercially available electrodes for muscle stimulation were used as a proof of concept. However, these electrodes are expensive, large in size, and unsuitable for prolonged usage. To ensure a positive user experience for our all-day use products, a dedicated electrode needs to be developed that is cost-effective and performs well. The primary objective is to print and test dedicated bladder monitor electrodes using printed electronic techniques, specifically screen printing. We will collaborate with our partner, Emerge, who possesses experience in printed biomedical applications, including electrodes, to ensure we meet the technological requirements and limitations. Together, the WUT (Warsaw University of Technology) will develop the initial design, which will consist of multiple layers (conductive layer, isolation layer, etc.) printed on flexible substrates (TPU or PET foil). The electrode layer will be printed using metal-based (silver) and carbon-based paste (graphene and carbon black). A set of 50 printed electrodes will be produced. The WUT equipment will enable us to measure the thickness of the layers (using a profilometer) and the electrical parameters (using a test unit). The electrodes will be measured through cyclic voltammetry (CV), square wave voltammetry (SWV) and electrochemical impedance spectroscopy (EIS) in the FeCNB buffer, which are allowing us to asses of the electric stability in the biomedical application. After the manufacturing and basic testing on the associated Emerge partner side, we will test the application of printed electronic electrodes with a non-invasive realtime bladder monitor.

Requested TA/installations: TA3.1. Device Preparation / TA2.2. Chemical & physical techniques / TA1.1. Device design and architectures

Used TA/installations: TA2.1, 3 hours, TA3.3, 8 hours,

Proposal 4011: Prototype fabrication of screen-printed electrochemical sensors (RISE)

Objectives: Screen-printing electrodes for electrochemical analytical chemistry is a highly emerging field with promising applications, particularly within fast detection of biomarkers for diagnostic purposes. Our sensors have been used to detect cancer biomarkers, bacteria

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and corona virus (references below). However, during electrode production we encounter challenges with prober current yield, reproducibility from sensor to another and sustainable use of resources. Due to these challenges, we lose a lot of electrodes during fabrication, which is both costly and non-sustainable. The output current measured with screen-printed electrodes could be significantly enhanced if the screen-printing process is optimized. Enhanced current yield and reduced noise would also benefit targeted applications by allowing better sensitivity and lower detection limits. Thus, the aim of this project is to 1) optimize the screen-printing process in terms of enhanced reproducibility within a single sheet and from sheet to another, 2) enhanced current yield based on alternative electrode designs and 3) enhanced use of materials and production parameters to achieve a reduction of waste during production. Furthermore, it is an important aim for us to foster Swedish Danish collaborations for future EU calls and long-term partnership.

Requested TA/installations: TA3.2. Functional 2D & 3D printing / TA3.4. Nanoimprinting & laser patterning

Used TA/installations: TA3.3, 40 hours

Proposal 4073 R2R printing of next generation OPV active layers and HTL (FZJ)

Objectives: Enhance Efficiency: Improve the power conversion efficiency (PCE) of commercial OPV modules from the current 5% to greater than 10%.

-Test the Longevity: Extend the lifetimes of OPV modules to more than 10 years, ensuring their durability and reliability in real-world module

-Optimize Processability: Develop a manufacturing process that allows for high-throughput production of large-area solar modules using "green" solvents exclusively, making it environmentally friendly and costeffective.

-Facilitate Industrial Scale-Up: Successfully transfer the newly developed material systems and processes from the laboratory to industrial-scale production, leveraging the expertise of both BM and FZJ in materials and processes, as well as the capabilities of the pilot line at FZJ to evaluate and validate OPV technology under industrial conditions.

These objectives aim to address the challenges outlined in the proposal and contribute to the future commercial viability of OPV technology by improving efficiency, durability, and manufacturability.

Requested TA/installations: TA3.1. Device Preparation

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Used TA/installations: TA3.3, 47 hours

Proposal 4074 Controlled doping of the active layer as a way of enhancing performance of organic solar cells (TUD)

Objectives: The main objective was to moderately dope the active layer of vacuum evaporated organic solar cells, with the aim of improving device performance in device with thick active layers. Computer simulations have shown that, especially in devices with thick active layers, there is an optimum doping concentration where devices performance is maximized. The objectives of this mini project were to dope the active layer of DCV5T-C60 based vacuum evaporated organic solar cells using the p-dopant NDP9, and to characterize the solar cells with JV-characterization, doping-CELIV, EQE and sensitive-EQE. The device manufacturing was slightly delayed due to illness, and the JV-characterization took unexpectedly long due to contact issues. Therefore, some measurements are still to be completed (devices are being shipped to Turku for final measurements).

Requested TA/installations: TA3.1. Device Preparation / TA1.1. Device design and architectures

Used TA/installations: TA3.2, 27 hours; TA4.1, 32 hours

Proposal 4075 Hybrid organic-inorganic transparent UV photodetector (TUD)

Objectives: Fabrication of UV-C photodetectors based on a p/n-Shottky heterojunction between gallium oxide (Ga2O3) and vacuum-evaporated organic small molecules.

Preliminary characterization of the diode's rectifying behaviour by the mean of current-voltage profiling in dark.

Performance optimization by searching for the best doping levels of both the organic and inorganic layers.

Requested TA/installations: TA3.5. Vacuum assisted deposition / TA4.1. Device metrology & characterization

Used TA/installations: TA3.2, 40 hours; TA4.1, 80 hours

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Proposal 4078 Stability of OPV-modules operated under indoor conditions (FZJ)

Objectives Preparation of solar cells (2.5x2.5 cm² substrates with 6 cells á 0.1 cm² active) and modules Module (5x5 cm² substrates and 3x3 cm² active) in four different variations:
Var1: N10 (ZnO) / PM6:Y6:PCBM in chloroform / MoOx / Ag
Var2: N10 (ZnO) / PM6:Y6-C12:PCBM in xylene / MoOx / Ag
Var3: N10 (ZnO) / PM6:Y6 in xylene / MoOx / Ag
Var4: N10 (ZnO) / PM6:Y6:PCBM in xylene + additive / MoOx / Ag
Characterization of cells and modules (J-V curve)
Encapsulation of modules and cells
Requested TA/installations: TA3.1. Device Preparation / TA3.3. Industrial printing
Used TA/installations: TA3.3, 32 hours

Proposal 4079 Textile integrated hybrid printed electronics (RISE)

Objectives: The main objective is to develop a process for bonding of SMD devices on printed interposer realized on textile:
In details:
1. P&P and bonding of SMD components on the rigid interposer using ACF, visual and electrical check of assembled breath rate sensor design
2. Automated P&P and bonding of SMD components on the rigid island using ACA, visual and electrical check of assembled heart rate sensor design
3. Automated P&P and bonding of SMD components on the flexible TPU interposer using ACA, adhesion test, SMD chips used: RFID chip, Accelerometer chip
Requested TA/installations: TA3.1. Device Preparation / TA3.2. Functional 2D & 3D printing
Used TA/installations: TA3.1, 32 hours, TA3.1, 24 hours

Proposal 4625 Mass production of NFC tags printed on paper with additive techniques and at least 2 years lifetime, easy to recycle. (RISE)

Objectives: Screen printing of silver and copper ink on PET and paper substrates for NFC antenna
Pick and place of NFC chip on printed NFC antenna
Ageing test in climate chamber

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Electrical characterization of antenna using VNA

Investigation of functioning of antenna

Requested TA/installations: TA3.3. Industrial printing / TA4.2. Validation and standardization

Used TA/installations: TA1.1, 8 hours, TA3.3, 59 hours; TA4.1, 37 hours

Proposal 5320 Photonic sintering of reverse offset printed structures (RISE)

Objectives: Flexible and printed electronics rely mostly on metal based printing inks for high conductivity circuitry and interconnects. High conductivity and small structures must be printed using micro/nanoparticle inks that require sintering, while flexible substrates typically do not withstand high temperatures. Photonic sintering offers a solution for this sintering process.

An additional objective of the sintering test is to gather information specifically related to the compatibility between the VTT reverse offset printing (ROP) process, its dedicated inks and compatible substrates, and the photonic sintering setup from PulseForge available at RISE. The experiments will include testing the PulseForge system for sintering of ROP printed copper nanoparticle ink on polyimide (PI) and polyethylene terephthalate (PET) substrates, as well as ROP printed silver nanoparticle ink on the aforementioned substrates as reference. If tests are successful, processing parameters which result in a conductive ink layer with minimal damage to the substrate materials will have been found for all material combinations. An additional objective for the tests is to collect background data for further collaboration around the photonic sintering process or for own investment in similar capabilities

Requested TA/installations: TA3.2. Functional 2D & 3D printing / TA4.1. Device metrology & characterization

Used TA/installations: TA3.3 16 hours, TA2.1, 1 hours

Proposal 5682 Evaluation of scalability of 2D printing of magneto-rheological and magneto-electrical composites (RISE)

Objectives: The increasing need of digitalization, including the industry 4.0 and internet of things concepts require introduction of new multifunctional materials for fabrication of low cost and large-scale sensors and actuators. Within such materials are magneto-rheological and magneto-electrical nanocomposites, which will allow a new generation of

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actuators, sensors and energy harvesters, with applications in printed electronics and biomedicine. The functional properties of such composites can be tuned by means of selecting of different types magnetic nanoparticles (varying composition, shape and size), which are dispersed in thermoplastic elastomers. In BCM new composite inks based on different magnetic nanoparticles have already been developed and therefore it would be of high interest to prove their processability and scalability by different printing processes, such a screen printing. Therefore, these inks would be structured in different shapes and size patterns by high throughput and high precision screen printing on different substrates (PET, Kapton, PVDF), using the facilities of RISE such as EKRA E2E2 or DEK Line 1 or 2 printer. Such collaboration could lead to further broader consortia collaborations and create a base for future larger projects with RISE and other EMERGE partners.

Requested TA/installations: TA3.2. Functional 2D & 3D printing / TA4.1. Device metrology & characterization

Used TA/installations: TA1.1, 12 hours; TA3.3 48 hours, TA4.1, 4 hours

Proposal 5814: Screen-printed structures of alternating TiO2 and CeO2 layers used as an oxygen-sensing materials (RISE)

Objectives:

- Screen printing of CeO_2 and TiO_2 strips and stacked layers onto PET and Ceramic substrates for oxygen sensing applications.
- Obtaining the various designs of printed materials, with different geometry within each.
- Investigation of the photonic sintering of printed structures on PET and Ceramic substrates; influence of different sintering parameters will be examined in home institution.
- LASER cutting of alignment frame for ceramic sensor substrates.

Requested TA/installations: TA3.3. Industrial printing / TA2.1. Materials characterization

Used TA/installations: TA1.1, 12 hours; TA3.3 20 hours, TA2.1, 1 hours

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Proposal 5821: Comparison of Material Properties of Electrochemically Printed Structures against Screen and Inkjet printed Structure (RISE)

Objectives:

- Comparison of Syenta's localised electrodeposition technology to existing state of the art
- techniques including screen printing and ink jet printing.
- Comparison of adhesion between technologies
- Comparison of long term sample stability in an environmental chamber.
- Bulk conductivity comparison between nanoparticle inks and Syenta's deposited materials.
- Development of understanding for practical limitations and advantages of each technology.
- Provide education on the current state of the art printed electronics techniques.
- Run a 60 minute interactive presentation for the RISE staff on the Syenta printing method.

Requested TA/installations: TA3.2. Functional 2D & 3D printing / TA4.1. Device metrology & characterization

Used TA/installations: TA1.1, 8 hours; TA3.3 19 hours, TA4.1, 2 hours

Proposal 5825: Characterization of solution processable nanomaterials for transistor and memristor-based biosensors applications (JOR)

Objectives:

The Sensing Technologies Laboratory (Sens Lab) at the Free University of Bozen-Bolzano, Italy, was focused on the development and electrical characterization of biosensors based on spray-coated, solution-processable nanomaterials (e.g., carbon nanotubes (CNTs), poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT). Deep morphological characteristics of the spray-coated nanomaterials were evaluated at Joanneum Research (JOR) facilities in Austria:

- SEM analysis of spray-coated CNTs (different morphologies, e.g., surfactant-based, surfactant-free, acid-treated, and water-treated).
- SEM analysis of spray-coated PEDOT

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- (bare and PVA blend).
- XPS analysis of CNTs, PEDOT, and the gold gate electrode at different functionalization stages (e.g., bare, oxygen plasma treated, aptamer functionalized).

Requested TA/installations: TA3.4. Nanoimprinting & laser patterning, TA4.1. Device metrology & characterization

Used TA/installations: TA3.4, 41 hours

Proposal 5826: 2D/3D CELL-PILs for tissue engineering (WUT)

Objectives:

The aim of this proposal was to develop 2D/3D cellulose-poly(ionic liquid) composites as hydrogels for tissue engineering. The presence of PILs is expected to improve ion transport and provide the stabilization for additional components such as therapeutical agents. Specifically incorporating conductive additives into cellulose composites enhances the regenerative potential of scaffolds. Conductive properties support cell adhesion, proliferation, and differentiation.The specific objectives were:

- To obtain composites from methacrylated gelatine and poly(ionic liquids).
- To tune the ratios and viscosity of the composites to obtain stable inks for 3D printing.
- To print hydrogels from the optimized inks using the Bio X-3D bioprinter.
- To use different ink formulations, introducing cellulose nanofibers.
- To study the influence of methacrylated gelatine analogues in the printability of the inks.
- To obtain freeze-dried scaffolds from the printed substrates.

Requested TA/installations: TA3.3. Industrial printing / TA2.1. Materials characterization

Used TA/installations: TA1.1, 7.5 hours; TA2.2 19 hours, TA3.3, 27 hours

Proposal 5827: Manufacturing and Characterization of Flexible Thermoelectric Modules and associated electronics through printing techniques (RISE)

Objectives:

- Screen printing of silver and copper ink on PET, Kapton, and paper substrates for TEM
- Photonic sintering of copper ink on PET and Paper
- Assembly of TEM module
- Testing functionality of TEM

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Requested TA/installations: TA3.1. Device Preparation / TA4.1 Device metrology & characterization

Used TA/installations: TA1.1, 4 hours; TA3.3 20 hours, TA2.1, 10 hours

2.2 Proposals submitted and currently under evaluation or ongoing

There are currently 24 proposals which were applied during EMERGE 4th and 5th Call, requesting TA3 access provision, and they are all currently under evaluation or ongoing. From RISE 11, FZJ 4, JOR 3, TUD 3, HMU 2 and 1 joint project of FZJ and ICN 2. Table 3 brings information about the proposals which are under evaluation or ongoing.

Table 3: List of proposals submitted for TA3 access to the EMERGE infrastructure in M30 which are under evaluation or ongoing.

CALL	ID	Title	Institution	Pretended Institution(s)
4	**4749**	Patient-specific numerical modelling in palliative solutions for infants with ductal-dependent pulmonary blood flow	Istanbul Medipol University	RISE
4	**4776**	Investigation on Processability of Inkjet Printed E-beam Resists	SUSS MicroTec Netherlands B.V.	JOR
4	**5684**	Printing of electrochemical (bio)sensors using aerosol jet printing techniques	University of Rome "Tor Vergata"	RISE
4	**5811**	Roll-to-roll (R2R) printing of ITO-free, fully solution-processed OPV modules	Ribes Tech	FZJ
4	**5812**	Smart end effectors for next generation sustainable industrial robotic applications	Aarhus University	HMU
4	**5813**	Characterization of enhanced electrochemical sensors	PreDiagnose	RISE
4	**5815**	Functional Ink-Jet Printing of Wireless Energy Systems	Institute of Solid State Physics, University of Latvia	RISE
4	**5819**	R2R printing of Sustainable Semi-transparent Organic Photovoltaic Cells and Modules	University of Rome Tor Vergata	FZJ
4	**5820**	Urban Photovoltaics	Institute of Materials Science of Barcelona (ICMAB-CSIC)	FZJ
4	**5822**	Graphene/Cu2O/Cu heterojunction photodetector on flexible substrate	Democritus University of Thrace	JOR
4	**5823**	Production and Characterization of Azobenzene Polymeric thin Films for the creation of Novel Photonic Devices	NOVA SCHOOL OF SCIENCE AND TECHNOLOGY	FZJ_ICN2

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5	**6198**	Functionalized MXene-based Halide Perovskite Solar Cells for Self-Power Electronics	Institut Català de Nanociència i Nanotechnologia (ICN2)	HMU
5	**6399**	Point-of-care (PoC) Nanoplasmonic biosensor chip integrated microfluidic device for pathogen detection	Xfold Imaging Oy	JOR
5	**6408**	Optimization of hybrid organic-inorganic transparent UV photodetector	Università degli Studi di Parma	TUD
5	**6416**	Mass production of NFC tags printed on paper with additive techniques and at least 2 years lifetime, easy to recycle. Part II.	ROTIMPRES	RISE
5	**6421**	Study of optical reduction of graphene oxide for photonic sensing applications	Indian Institute of Technology Bombay	RISE
5	**6422**	Scalable Fabrication of Printed Stretchable Electronics	University of Coimbra	RISE
5	**6425**	High-energy and long-cycling lithium–sulfur pouch cell using Few-Layer-Graphene coated Aluminium current collector	BeDimensional Spa	TUD
5	**6426**	Correlating processing-morphology-performance of high efficiency organic solar cells (OSCs)	Technion - Israel Institute of Technology	FZJ
5	**6428**	Integration of Flexible Thermoelectric Modules (FTMs) with flexible sensors and electronics	ParsNord Thermal Comfort ApS	RISE
5	**6430**	Prototype fully recyclable screen printed electronics	United Kingdom / Swansea University	RISE
5	**6433**	Characterization and validation of electrochemical electrodes	PreDiagnose	RISE
5	**6434**	Photonic sitering enabling textile integrated electronics	PROFACTOR GmbH	RISE
5	**6441**	Prototype fabrication of interdigitated electrode sensors on flexible papers for structural health monitoring of composites	Wood K plus - Kompetenzzentrum Holz GmbH	TUD

2.3 Proposals submitted to TA3 but reassigned to other TAs

Four proposals were submitted requesting prototypes fabrication transnational access but, after the evaluation from the TLOs, were reassigned to other more suitable TAs. Table 4 summarizes the information about the reassigned projects.

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Table 4: List of proposals submitted for TA3 access to the EMERGE infrastructure from 2021 to 2023 but were approved for other TAs access.

Call / Proposal ID	Proposal title	Home Institution (Country)	Type of Home Institution	EMERGE Institution	Transnational Activities Accessed
3 / 3992	Improving Color Matching between Active and Non-Active Areas of Electrochromic Displays	Ynvisible Gmbh (Germany)	Industry	RISE	TA4.1
4 / 4594	Insertion of ultrathin low-conductivity passivation layers in Perovskite solar cell	Imperial College London (UK)	University	HMU	TA2.1, TA2.2, TA4.1
4 / 4682	Interface engineering in perovskite solar cells based on 2D materials	Imperial College London (UK)	University	HMU	TA2.1, TA2.2, TA4.1
4 / 5816	Integration of ultrasonically exfoliated eco-friendly graphene into perovskite solar cell device fabrication	Oxford Brookes University (UK)	University	HMU	TA2.1, TA2.2

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2.4 Proposals submitted to other TAs but requiring access to TA3 during implementation

From the beginning of EMERGE project to December 2023 (M30), one proposal (5549) was initially submitted to a different TA, but during project execution prototype fabrication activities (TA3) were also included, demonstrating the flexibility of EMERGE partners to adapt to user needs.

Table 5: List of projects originally submitted to other TAs but reassigned to TA3 during project execution

Call / Proposal ID	Proposal title	Home Institution (Country)	Type of Home Institution	EMERGE Institution	Original Transnational Activities requested
4 / 5549	Fabrication and electrical characterization on two-dimensional (2D) polymers-based flexible organic electronics	Fraunhofer IKTS (Germany)	Industry	UNOVA / ALMA	TA2.2, TA4.1

3. Summary of equipments used

A summary of all equipments used during the experiments carried out through material synthesis and characterization access provision up to M30 can be found on Table 6. The data was retrieved from each project timesheet provided by respective EMERGE Institutes TLOs. Further details about the equipments and methologies related to TA3 offered by EMERGE host institutions can be found on deliverable D7.1 – Report of different ink technologies for printing.

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Table 6: List of equipment's used for material synthesis and characterization access provision (TA3) up to M30.

CALL	ID	Title	HOST Institution(s)	EMERGE Equipment
1	3651	Screen printing of TiO2 / CeO2 powder mixture for oxygen sensors	WUT	Aurel C920 Screen Printer, Memmert Chamber Dryer, Bruker DektakXT, Brookfield RS+CPS Rheometer
1	3662	Electrochemically exfoliated 2D materials for printed electronics	TUD	2d Inkjet printing; 3d Printing
1	3663	Xfold TR-FRET slides for high sensitivity and early detection of infectious diseases	JOR	AFM Bruker Dimension, AFM Oxford Instruments, Zeiss Optical Microscope, Keyence Lasercanning Microscope, R2R UV Pilot Line
2	3845	Resist-free e-beam lithography for robust nanophotonic and flexible electronic devices in harsh environments	HMU	Screen printing, slot-die printer, plasma etcher
2	3846	Effect of Electrochromic Pixel Size on Temperature and Humidity Performance	RISE	Screen Printer DEK Line 1, Natgraph oven; TA4: Climate Chamber
3	3986	Design concept of a piezoelectric self-adhesive skin patch for wound healing applications	JOR	Screen Printing, Drying UV oven, Lamination, Poling station
3	4001	Formulating screen printing ink/paste application for resistive heater application	WUT	Screen Printer AUREL C920
3	4008	Exploiting UV nanoimprinting for introducing micro-structured burst valves in a self-powered microfluidic device for precise liquid volume metering	JOR	EVG Mask Aligner 620
3	4009	Exploiting UV nanoimprinting for introducing micro-structured burst valves in a self-powered microfluidic device for precise liquid volume metering	WUT	Screen Printer AUREL C920
3	4010	Thin and flexible electrodes for capacitance measurement	WUT	Screen Printer AUREL C920
3	4011	Prototype fabrication of screen-printed electrochemical sensors	RISE	DEK Line II, DEK Line I, EKRA screen printers, Box oven and Natgraph UV system
3	4073	R2R printing of next generation OPV active layers and HTL	FZJ	R2R Machine, Slot Die, Laser, Backend equipment, Solar Simulator, Dark Lock In Thermography
3	4074	Controlled doping of the active layer as a way of enhancing performance of organic solar cells	TUD	Laser structuring, Lesker PVD system, Cleaning bath
3	4075	Hybrid organic-inorganic transparent UV photodetector	TUD	Thermal vapour deposition tool, Glove box and tools for encpasulation
3	4078	Stability of OPV-modules operated under indoor conditions	FZJ	R2R Machine, Laser, Backend, Doctor Blade, Solar Simulator
3	4079	Textile integrated hybrid printed electronics	RISE	Pick and Place machine (BESI Datacon Eco 2200), Manual device mounting & Microscopy, electrical characterization equipment
4	4625	Mass production of NFC tags printed on paper with additive techniques and at least 2 years lifetime, easy to recycle.	RISE	DEK Line I, Screen Printer, Convection oven, Pick and place machine

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4	**5320**	Photonic sintering of reverse offset printed structures	RISE	Photonic sintering: Ceradrop F-Serie
4	**5682**	Evaluation of scalability of 2D printing of magneto-rheological and magneto-electrical composites	RISE	DEK Line I & II, screen printer, Termax Oven
4	**5814**	Screen-printed structures of alternating TiO2 and CeO2 layers used as an oxygen-sensing materials	RISE	DEK Line II, screen printer
4	**5821**	Comparison of Material Properties of Electrochemically Printed Structures against Screen and Inkjet printed Structure	RISE	DEK Line I & II, screen printer, Dimatix Inkjet printer
4	**5825**	Characterization of solution processable nanomaterials for transistor and memristor-based biosensors applications	JOR	XPS, Scanning Electron Microscope, Spin coater & wet bench
4	**5826**	2D/3D CELL-PILs for tissue engineering	WUT	Celllink BIO X bioprinter
4	**5827**	Manufacturing and Characterization of Flexible Thermoelectric Modules and associated electronics through printing techniques	RISE	DEK Line I, screen printer, Trotec Laser cutter

4. Expected Scientific Impact of Concluded Projects

The completion of the user-projects led to interesting results that are conveniently being used by users to proceed with their research activities, while keeping collaboration with the EMERGE institutions, where these activities were carried out. Relevant information was collected from the “user report” survey that users must complete after conclusion of their TA projects. A brief description of the main achievements obtained during the research activities is provided bellow:

Proposal 3651: Screen printing of TiO_2/ CeO_2 powder mixture for oxygen sensors (WUT)

The main achievements obtained with the research activities developed at WUT are listed below:

- Screen printing TiO_2 and TiO_2/CeO_2 pastes on different substrates.
- Profile measurements for estimate of the layers thickness.
- Viscosity measurements of the pastes that were used for screen printing.

The proposers are working on a publication, where the data obtained during the implementation of the project in WUT will be included and EMERGE project will be acknowledged.

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Proposal 3662: Electrochemically exfoliated 2D materials for printed electronics (TUD)

- Learned how to use the printer to make electrode for electronic device
- Grasped the utilization of 3D printing machine
- Successful obtained the few-layered black phosphorus via the electrochemical exfoliation technique: compare with other exfoliated technique, such as liquid exfoliation and tape exfoliation, the electrochemically exfoliated sample with high-quality of few layers and high yield.
- Prepared the MnO_2 and MnO_2/Ag nano dispersions, the introduction of Ag nanoparticles can impro the electron conductivity of MnO_2
- After the plasma treatment of ITO/PDMS substate, the first try with nano graphene suspension get ideally printed electrodes as we want. However, the other samples don`t work well like graphene suspension.
- The networking brings me some new idea to improve my experiments.

Proposal 3663: Xfold TR-FRET slides for high sensitivity and early detection of infectious diseases (JOR)

I have learned the Roll-to-Roll nanoimprinting technology and its potential application in the photonics industry.
We have performed the atomic force microscopy and scanning electron microscopy experiments to evaluate the Xfold master sample.

Proposal 3845: Resist-free e-beam lithography for robust nanophotonic and flexible electronic devices in harsh environments (HMU)

During our visit, we achieved the deposition of electrodes of different materials on flexible substrates. These are ranging from electrochemically exfoliated graphene and graphene oxide on polyethylene (EEG/PET and GO/PET) to silver nanowires/exfoliated graphene (AgNWs/GEE) and PEDOT/PSS/GO on standard polyimide (PI, kapton tape). Here we explore various printing mechanisms depending on the desired total sample size.

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Proposal 3846: Effect of Electrochromic Pixel Size on Temperature and Humidity Performance (RISE)

The printing an conversion of the test structures was achieved in the first 2-3 days of the project. Overall, the yield was excellent and all of the displays that were printed were able to be used for the testing portion, including the pixels with the smallest dimensions (i.e. a 7-segment display with 1 cm in height).

For the characterization elements we were not able to test at all of the temperatures that we had aimed to test in the project. Instead we decided to a conduct a more thorough characterization at fewer temperatures (0C, 20C 40C and 80C). The initial number of temperature points proposed was likely too ambitious for the amount of time in the project – especially considering that the printing and conversion takes 2-3 days. Overall, we made a judgement call that it would be better to have more thorough data at fewer points than rushing and having less data are more temperature points.

For the larger displays (1 x 5 cm, 1 segment) we collected voltage vs. time plots for a cycle of 6 switches, measuring at 4 different contacts in the display, for 3 replicas. The data presents a very clear potential drop across the working area from the position of the electrical contact. The electrical measurements conducted here mirror the visual propagation front that was recorded in video.

For the smaller displays (1 cm2 and 2 cm2, 7-segment), video footage was collected over the same range of temperatures to monitor the switching speed and bi-stability.

Proposal 3986: Design concept of a piezoelectric self-adhesive skin patch for wound healing applications (JOR)

Four different setups were tested. The PENGs were printed either on medical grade TPU or on PET films, poled and then attached to the inner side of the forearm or to the elbow.

The signals were acquired with a Dewesoft Sirius DAQ system in two different measurement setups via either the CHG or the STG input, both in voltage mode. The STG input has a higher input impedance and thus generated higher signals. This was done with and without ECG electrodes in order to emulate the influence of the skin's impedance as a load. It turned out that walking, pressing with fingers and elbow movement generated voltage signals in the range of 1-4V for the setup without the ECG electrodes, whereby the voltage peaks for the stiff PET substrates are 2-4 times higher than the voltage peaks generated with the softer TPU substrates. This can be understood when taking into account, that stiff yet flexible

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substrates like PET induce more bending in the piezoelectric layer than elastic substrates like TPU. If the ECG electrodes are connected in parallel the signal height is determined by the impedance of the skin (acting as a load via the ECG contacts) which is much lower than that one of the PENG and the DAQ. The generated voltage peaks are in the range of 110-170mV for finger pressing.

Furthermore, the contact resistance of printed silver electrodes to the skin was investigated by impedance measurements with a Novocontrol instrument. As expected, the contact resistance could be strongly decreased (4 orders of magnitude) by using a conductive gel.

Proposal 4001: Formulating screen-printing ink/paste application for resistive heater application (WUT)

Note: Due to the nature of work, Levidian supplied the graphene materials to WUT, and all the experiments were carried out by WUT staff. Levidian did not visit WUT during the project and all project updates was carried out over Teams call.

Achievements

- Two different formulations based on various binder system achieved- type L and M.
- Obtained 18%-20% graphene loading on both binder systems – type L paste which had good
- conductivity was chosen for the heater application.
- Simple square profile was printed on paper and foil – 2 layers ~10 µm thick.
- o Foil – 450 Ohm/sq
- o Paper – 350 Ohm/sq
- Demonstration heating element reached more than 120 oC without any degradation. Beyond 5W, the substrates were damaged.

Proposal 4008: Exploiting UV nanoimprinting for introducing micro-structured burst valves in a self-powered microfluidic device for precise liquid volume metering (JOR)

Characterization of imprinting resolution and accuracy

A Keyence confocal microscope was used to scan the microfluidic channels with integrated geometric burst valves of different channel dimensions (125 – 25 µm width) in 3D. From these 3D images all information about the imprinted microchannel shape,

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resolution (height and width), accuracy (height and width) and roughness can be extracted. Furthermore, the presence of particular imprint artefacts such as air bubbles can be determined. During the research visit itself, no image analysis was performed yet but this will be done afterwards.

Burst pressure characterization

The pressure measurements, using the Fluigent pressure pumps, showed a strong relationship between the width of the geometric burst valve and achieved burst pressure. In particular, significantly different burst pressures ranging between 390±63 Pa (125 µm) and 3140±356 Pa (25 µm) were determined for distilled water as liquid matrix.

Paper integration for hydrophobic stop valve

Hydrophobic pre-cut (3x3 mm² squares, 115 µm thickness) Whatman grade 50 papers were successfully integrated and sealed within the microfluidic circuit without creating bonding issues (when positioned and properly aligned in the imprinted region). Again pressure measurement were preformed to determine the burst pressure of these hydrophobic stop valves. Unfortunately, no sufficiently high burst pressures (max 4000 Pa) could be achieved because the occurrence of liquid leakage around the papers. To overcome this, very tight fitting of the papers inside the fluidic circuit is required what might be very challenging to achieve. The introduction of 3D geometric restriction (both in width as height) would be an interesting alternative method as this does not requires the integration of small papers.

Burst valve selection for coordinated liquid manipulation

We showed the possibility to combine multiple of the developed geometric restriction to manipulate liquids in a coordinated manner and isolate precisely metered liquid volumes. The system was proven to be robust up to flow rates of 80 µL/min (using distilled water as liquid matrix) for all tested valve combinations except the 100-50 µm one.

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Proposal 4009: Screen printing and paste preparation based on Al 1%Si powder for flexible, wearable, self-powered sensor used as human respiration detector

1. Fabrication of various pastes for screen printing.
   Electro-conductive pastes: Graphene nano-tubes, Graphene nano-particles and Graphite with Carbon Black.
   Electro non-conductive pastes: Al with SiO_2, Al, Al with Al_2O_3, Al with MgO, MgO, Al_2O_3, SiO_2.
2. Screen printing of non-conductive underlayer and on top of that screen printing of conductive electrodes.
3. Measurements of the paste's viscosity.
4. Measurements of the screen-printed samples profilometry.

Proposal 4010: Thin and flexible electrodes for capacitance measurement (WUT)

Due to the lack of firm adhesion of commercially available simple electrodes to the abdomen, their angle can change with even small movements of the user, and they are significantly affected by accumulated sweat. Custom electrodes designed for stimulation purposes can also heat up when worn for extended periods. This can lead to interference from different layers of tissues and disturbances in the capacitance value and correlation of impedance and voltage signals. The project has identified limitations in the current performance of these electrodes.

Printed electronics methods offer a low-cost and effective means of producing user-friendly electrodes. With a thickness of approximately one hundred micrometers, these electrodes will be almost imperceptible during all-day use.

The bio degradable materials, thin layer construction, exact size and optimal placement will reduce unexpected affects by skin, moisture and heating. We will conduct performing test in the laboratory setting and a small number of field test

Proposal 4011: Prototype fabrication of screen-printed electrochemical sensors (RISE)

We have managed to successfully print a new design of electrodes with enhanced current yield and less loss of sensors per sheet. By comparing the sensor performance from sheet to another, we can also confirm that the current variance is negligible and thus we are able

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to produce reliable and reproducible sensors despite batch variation. We also managed to experiment with electroplating with gold nanoparticles.

Proposal 4073: R2R printing of next generation OPV active layers and HTL (FZJ)

The main achievement of this project is that it proved that BM material (Active layer and HTL) can be printed in commercial OPV module and implemented using eco-friendly manufacturing processes using "green" solvents. This has been made possible by leveraging knowhow from HQP and the pilot line at FZJ. Efficiency and stability have not reached the expected value due to technical difficulties and lack of time

Addressing efficiency gaps and leveraging the joint expertise of BM and FZJ, this project has positioned PTQ10:Y6C12 as a competitive, commercially viable OPV blend with potential for industrial-scale adoption.

Proposal 4074: Controlled doping of the active layer as a way of enhancing performance of organic solar cells (TUD)

We successfully doped the active layers using NDP9, and we could demonstrate a drastic effect on device performance. However, in terms of optimizing the power conversion efficiency the resulting doping concentrations were simply too high. The reason is mainly due to the material choices we made; it turned out that choosing NDP9 as the dopant was a mistake.

Due to lack of time, we were not able to conduct all measurements during the visit. These measurements are currently being completed. Based on the outcome of these measurements, a follow-up visit will be planned and applied for through the EMERGE-infrastructure.

Proposal 4075: Hybrid organic-inorganic transparent UV photodetector (TUD)

Obtained indications about the possibly more suitable doping levels of both the organic and inorganic materials by the observation of the fabricated device’s different performances, even at a preliminary stage.

Observed how to further increase the success chances of the fabrication and encapsulation process.

Received confirmation of the stencil mask alignment process reliability.

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Proposal 4078: Stability of OPV-modules operated under indoor conditions (FZJ)

Gathering knowledge and experience in processing of solar cells as well as modules. Testing different active layer compositions, whereby Var2 showed promising results in comparison to chloroform based systems.

Proposal 4079: Textile integrated hybrid printed electronics (RISE)

In total 11 samples were assembled (the plan of 20 samples was not reached due to problems in delivery of components sent prior to PRO visit at RISE)
In details:
1. SOIC16 packages were assembled on rigid printed islands using AnisoMat FCP film. The connection of all pins to the printed track was checked by digital multimeter, all resistances were below 2 Ohms. Two samples of the breath rate sensors were completed.
2. Optical Sensor from ROHM Semiconductors was assembled on rigid printed islands using AnisoMat FCP film and ACA paste. In total 3 sensors were completed, functional check will be done at PRO since it needs a programming step which was not possible at RISE. Due to type of the SMD package with cavities around the contact pads, troubles in electrical connections can be expected (see description in chapter 3).
3. Optical sensor from ROHM semiconductors was assembled on flexible TPU interposer using AnisoMat FCP. On sample was realized and further adhesion testing will be concluded at PRO.
4. RFID chip from NXP was assembled on PET flexible foil using both ACA and ACF, in total 3 realized, finctionality will be checked at PRO, since a special reader is needed

Proposal 4625: Mass production of NFC tags printed on paper with additive techniques and at least 2 years lifetime, easy to recycle. (RISE)

- Screen printing of silver and cooper inks was carried out on PET and paper substrates.
- Manual and automatic pick and place of NFC chip was carried out.
- Ageing of fabricated NFC antenna was carried out in climate chamber.
- Testing of electrical functionality of antennae were carried out using network analyser

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Proposal 5320: Photonic sintering of reverse offset printed structures (RISE)

Practical experience in using the PulseForge tool, integrated into a Ceradrop inkjet printing system, was gained, as well as an understanding of the critical factors/parameters contributing to the photonic sintering process.

It was found that the copper ink requires a high voltage pulse with minimal pulse length for sintering the copper layer without causing damage to the substrate. This was successfully achieved with copper printed on PI substrate, which has a significantly higher Tg than PET. Process parameters for sintering copper on PET could not be optimized within the available time frame of the tests, despite applying various micropulsing parameter variations, which were expected to aid in fine tuning the applied energy. All tested sintering conditions resulted in either ablation of the printed ink (high energy), or non-conducting copper patterns which remained intact, while already causing melting of the PET substrate (low energy).

For ROP printed silver ink, process parameters were obtained for sintering the ink on both PI and PET substrates. On PET substrate however, minor melting of the substrate was observed, indicating a need for further optimization.

Sheet resistances of < 1 Ohm/square were measured for both copper on PI and silver on PI and PET.

Proposal 5682: Evaluation of scalability of 2D printing of magneto-rheological and magneto-electrical composites (RISE)

Different compositions of magneto-electrical and magneto-rheological composite materials have been printed by means of screen-printing technique. The inks were based on water-, solvent- and UV curable-based polymers. All the inks were printed on flexible substrates (PET and Kapton) and cured in thermal oven/conveyer curing system or UV conveyer curing system. Some of the magneto-electrical materials were also printed with PEDOT:PSS electrodes to be layer polarized and measure the magneto-electric response by applying bias. In some cases, the number the printed active layers has been varied as well to evaluate the influence of the thickness on the functional properties. Last but not least, some composites printed on Kapton substrate will be later evaluated by means thermal treatment or photonic curing.

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Proposal 5814: Screen-printed structures of alternating TiO2 and CeO2 layers used as an oxygen-sensing materials (RISE)

- Screen printing of CeO_2 and TiO_2 on commercial Dropsense ceramic substrates with pre-patterned gold IDE electrodes and platinum heater.
- Both inks were printed, either in the form of the stripes next to each other OR one over the other using Horizon DEK II screen printer.
- Four layers of each ink were printed to obtain thicker films.
- Thickness of two layer TiO_2 was found to be approximately 1.5um.
- The sensors were heated at 120 Deg C before printing each subsequent layer for oxygen sensing application.
- As an exploratory activity, some sensors were investigated for photonic sintering using Ceradrop – Pulseforge photonic sintering system. Several pulse patterns and pulse energies were investigated.
- One of the sensors was tested after photonic sintering for desired conductivity, mimicking the actual measurement protocol used by users in home labs. The resistance was found to be around 30 to 40MOhm while platinum heater was sourced with 8V, approx. 0.7A current.
- LASER cutting of hard cardboard frame was carried out to align the DropSense sensors on printing board, allowing well aligned printing patterns.
- Further investigation of oxygen sensing capability, chemical properties and morphological information, of printed sensors and printed+photonically sintered sensors will be carried out by users in their home lab.

Proposal 5821: Comparison of Material Properties of Electrochemically Printed Structures against Screen and Inkjet printed Structure (RISE)

- Hands on, demonstration and training on screen printing DEK Horizon equipment was carried out
- Screen printing of different pitch and design features was carried out on PET substrate. A silver nanoparticle ink was used, and the screen design was EMERGE-P5821, which had previously been used by Syenta to print samples. This was quite successful and together we printed over 25 PET sheets

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- Syenta provided sample of same design for resistivity measurements, peel testing and conditioning in climate chamber
- The samples spent 32 hours located in a climate chamber and were exposed to the following conditions.
  16 hours – 85% RH 35 deg C; 16 hours – 30% RH 60 deg C
  After the 32 hour exposure period had finished, some visible discolouration was noticeable. Some parts of the copper had changed from bronze/copper to a dark blue/green. Resistivity measurements were taken before and after using a multimeter, and also 4 point probe (only after exposure). Resistance measurements were inconclusive since the impact of the ITO conductivity was unclear
- Peel testing revealed that there was a significant discrepancy between the adhesion strength of the electro deposited copper ink and the screen-printed silver ink. The silver ink showed 100% adhesion after peeling, however for the Syenta sample only approximately 10% of the copper remained.
- Demonstration and training on Diamatix printer to print copper and/or silver ink was carried out. Features with pitch similar to those printed with screen printing and with Syenta printer were investigated. Performance of the Diamatix appeared poor
- Finally, the Syenta staff provided a presentation to the RISE staff on the fundamentals of the electro chemical printing process. This presentation was well attended with 10-15 staff and generated a lot of interest and questions

Proposal 5825: Characterization of solution processable nanomaterials for transistor and memristor-based biosensors applications (JOR)

- Morphological characterization of CNT and PEDOT films spray-coated at Senslab.
- Validation of gold electrode aptamer biofunctionalization.
- Networking with JOR colleagues for future collaborations.
- Exchange of knowledge related to films deposition and characterization techniques.

Proposal 5826: 2D/3D CELL-PILs for tissue engineering (WUT)

The studies allowed us to obtain stable inks with adequate viscosity for 3D printing. The tuning of the printing parameters enabled the 3D printing of hydrogels from alginate, methacrylated gelatine, methacrylated gelatine, and cellulose nanofibers inks. These inks

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were studied in the absence and presence of PILs, and also a methacrylated mucin. Several cross-linking agents and methods were used. Finally, the hydrogels were freeze-dried to obtain the respective scaffolds.

Proposal 5827: Manufacturing and Characterization of Flexible Thermoelectric Modules and associated electronics through printing techniques (RISE)

- Screen-printing of silver and cooper inks was carried out on PET, Kapton and paper substrates.
- Need of creating holes using laser cutting was found, hence laser cutter was used in project.
- Manual pick and place of Pellets was carried out.
- Since copper ink was not conductive after oven sintering, photonic sintering was investigated.
- Testing of electrical functionality of TEM were carried out.
- Mechanical strength of the TEMs were examined.

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