

4.1 Final publishable summary report

Executive summary

The EU FP7 ICT Call 1 Coordination Action “Manufacturing and Production Equipment and Systems for Polymer and Printed Electronics” (Acronym: PRODI, Grant Agreement number: 215426) has provided a **structured forum** for European printing, coating, laser, 'advanced processing' machinery manufacturers, production line integrators, and process measurement and automation industry to work together **in improving European excellence and competitiveness in roll-to-roll (R2R) Polymer and Printed Electronics machinery and automation**. The project has worked closely together with three other projects in the same area, namely the Quadriga projects: PolyNet (NoE), PolyMap (SA), and OPERA (CA).

The emerging technologies of printed and large area electronics enable huge variety of applications with increasing complexity of devices and systems. This development sets forth new requirements for high volume, cost-effective production as well as control systems in order to preserve high quality along with rational production methods. European printing and automation industry has been very strong in traditional printing, and it is important that the technical excellence can be maintained and improved also in R2R polymer and printed electronics. It requires good co-operation between the industry and research organisations, a common **vision**, and a strong effort on **training and distribution of information**. The project has involved a wide network of participants to joint networking and educational activities, and provided them with appropriate tools to meet the needs of the future. The amount of individual events has also been impressive.

The project tasks included collecting and refining requirements for organic and large area electronics R2R printing machinery, the on-line measurement methods and automation solutions in view of some of the most important applications. The two requirements documents have been published as the project deliverables for the whole OLAE community. The actual documents are available both on PRODI project website and in OE-A wiki database.

The requirement documents were used as a starting point in the creation of the vision for the future. The vision paper, which is the main deliverable of the PRODI project, is a very comprehensive presentation of the roll-to-roll manufacturing technologies, trends and future visions. The document has been disseminated widely and well received among the organic and large-area electronics community.

The main contributors in the PRODI consortium have been the 6 leading R2R organic and printed electronics research and development organisations in Europe, also having good global scientific and industrial contacts. In order to ensure that the industrial perspective is taken into account, the contributors selected and invited a high quality Industrial Advisory Board (IAB) to review the results and give guidance to the project consortium. The IAB consisted of selected group of leading companies in the areas of printing machinery technologies (such as gravure, screen, offset, flexo, inkjet, etc.), coating, laser, embossing/imprinting, measurement and process automation, as well as production line integration. The Associate Network (AN) was also established, consisting of actors interested in monitoring the development of R2R polymer and printed electronics. Companies have been

able to freely join the AN, which is actually a common network for all the Quadriga projects. The close collaboration with the Quadriga projects has been essential in disseminating the results and making the best overall impact.

Additional information about the consortium, the IAM and AN networks, as well as the deliverables of the project can be obtained from the project website, which is going to be maintained also after the project:

www.project-prodi.eu

The main PRODI deliverables are also accessible through the wiki database of Organic Electronics Association (OE-A). The address of the wiki database is:

www.oe-a-wiki.org

The existence of such a comprehensive database and active usage of it are evidences of the success of the Quadriga projects in creating an active OLAE community consisting of industrial and academic members. Project PRODI has played an important role in providing valuable content to this ecosystem.

Summary description of project context and objectives

The project PRODI, “Manufacturing and Production Equipment and Systems for Polymer and Printed Electronics” was intended to provide a benchmarking and educational forum for European printing, coating, laser, 'advanced processing' machinery manufacturers, production line integrators, and process measurement and automation industry to work together in improving European competitiveness in roll-to-roll (R2R) Polymer and Printed Electronics machinery and automation.

The disruptive technologies of printed and large area electronics enable a variety of complex applications of devices and systems. This development creates new requirements for high volume, cost-effective production as well as on-line measurement and control systems. European printing and automation industry has had a good global position in traditional printing, and it is of vital importance that the technical excellence can be maintained and improved also in R2R polymer and printed electronics.

The program was structured into work packages. The objective of the first WP involved **generating and collecting the essential requirements for the manufacturing machinery, measurement and process automation** of the new R2R printed electronics. The first task of the work was the definition of the relevant processes, and refining the list of parameters that form the basis of the actual requirements. The data set was assessed with reference to selected example applications, namely organic photovoltaic, electrochromic display, and organic TFT.

The set of requirements for machinery were accompanied by the requirements for measurement and automation for the same applications, and used in creating a future vision of success for the industry.

The vision has been made for longer term usage, but it also addresses the short term detailed items. The focus has been in Europe and the data was gathered mostly from the European industry and research community, but the worldwide aspects have been taken into the account in the work. The usage of a formal QFD method in consolidating and analysing the requirements improved the quality of the work considerably.

The deliverables of the first WP included specific requirements for R2R manufacturing equipment, measurement instruments and automation systems, and contribution to the consolidated vision for the future. The whole work package was aimed to reinforce Europe's leading role in this rapidly developing technology domain, thus enabling traditional industry to create new market possibilities and new manufacturing paradigms. The two documents have been widely disseminated, and they are also available through the wiki database supported by OE-A.

The second work package dealt with **education and training**. It was intended mostly to the representatives of the industrial network, but also to the scientific community. The tasks consisted mostly of conducting workshops, annual intensive courses and seminars according to the joint event calendar. There was an impressive amount of individual events organised within the PRODI framework.

The deliverables in the WP, mostly the events themselves, were important support measures for organic and large area electronics, as emphasized in the objective of the EC work

programme call. The target audience for the training and education included especially **manufacturers of the printing and manufacturing machinery, and measurement and automation system vendors**. The objective was to help the leading companies in the areas of traditional printing machinery and automation to get enough information to be able to drive the change of the machinery and automation development paradigm caused by the new R2R polymer and printed electronics manufacturing technologies.

The third work package concentrated on **building and maintaining the associate network** of industrial and other partners interested in monitoring the development of R2R polymer and printed electronics manufacturing machinery and production lines. The tasks included selecting, inviting and nominating the Industrial Advisory Board, and building the Associate Network together with the OLAE community. The rest of the work in this work package included refining and distributing the information to the community on a regular basis in the form of newsletters and various events. The deliverables included reports on the success in generating a well-functioning networking, and information dissemination.

Description of the main S&T results/foregrounds

The project was very successful in achieving the intended results and creating the planned deliverables. By nature of CSA activities the results are mostly documents, reports, events and dissemination activities, so no specific intellectual property was created in PRODI project. The most important results were the two reports on requirements for machinery and measurement systems, and the R2R vision for the future.

The PRODI project deliverable D1.2 defined a set of roll-to-roll (R2R) manufacturing equipment requirements for three selected end applications in the field of printed and organic electronics. The requirements were focused on three end applications including: organic solar cells (OSCs), electrochromic displays (ECDs) and organic thin-film transistors (OTFTs). The selection of the three end applications was based on their high relevance for the printed and organic electronics industry and the need for removing their roll-to-roll manufacturing challenges. The consortium's approach was validated by the Industrial Advisory Board (IAB) of PRODI before the actual implementation.

The requirements definition work was performed by identifying critical customer attributes per application and creating specific linkages between customer attributes, application design parameters and manufacturing equipment requirements. The three devices and their manufacturing processes were analysed layer by layer. While doing so, the key technological challenges and solutions to these were identified. Also state-of-the-art technical parameters were specified for each process sequence in order to offer a baseline for the future-oriented target values.

The work was supported by a Quality Function Deployment (QFD) method, which was used to identify critical customer attributes and create specific linkages between customer attributes and design parameters at application and manufacturing process level. A logical analysis approach also provided a well-organized structure for the present report. The information is an outcome of an extensive literature review and the survey targeted at leading companies and R&D organisation in the field of printed and organic electronics in EU.

The requirements document can be downloaded at the following network location:

<http://www.project-prodi.eu/networkmember/index.html>

The PRODI project deliverable D1.4 provided an overview of defining roll-to-roll (R2R) requirements for measurement instruments and automation systems. Analogous to the deliverable report of roll-to-roll (R2R) manufacturing equipment requirements, the measurement requirements report was focused on three end applications including: organic solar cells (OSCs), electrochromic displays (ECDs) and organic thin-film transistors (OTFTs).

First, the relevant parameters for measurement and automation were identified from the study on the requirements for manufacturing equipment. From these parameters the following main parameters for the abovementioned applications were identified:

- Overlay and registration,
- Layer uniformity,
- Pattern quality,
- Product functionality.

The requirements for measurement and automation solutions for these parameters were quantified and, if not quantifiable, explained and discussed. The report shows also an overview of the currently available measurement and automation solutions to ensure that the requirements for these parameters are met.

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The main objective of the project PRODI was to address the requirements and future visions of roll-to-roll manufacturing of organic and large area electronics (OLAE), especially from the machinery and measurement system perspective, to help the European industry to enhance their competitiveness. The work has been summarized in the project deliverable D1.6, the vision document. The approach described in the beginning of the report was rather pragmatic: the experts collected first the preliminary input from the industrial representatives, and then applied the data to three most suitable applications they also had the best practical experience about. The analysis of the three applications was performed systematically using, for example, the quality functions deployment (QFD) method.

The latter part of the vision document addressed the state of the art and future vision of roll to roll manufacturing equipment and on-line measurement systems, respectively. The approach was widened beyond the three applications addressed previously for the maximum coverage, and benefit of the stakeholders. Different characteristics were extensively analysed, and the individual results summarized. The overall vision was then elaborated as the conclusions. Because of the nature of the vision document, no exact timelines were presented, but rather most probable future scenarios and their implications.

The vision paper serves the best as a strategic planning tool for the industry and the research community to find out the gaps between the state of the art and the future targets. It will also help in finding the areas of biggest impact in steering the future research and development activities. One important objective is also to exchange the information between the machine

manufacturers and the measurement and automation providers to help in understanding the factors that will be the most critical in improving the yield and quality of OLAE roll to roll manufacturing. The more the machine and automation industry collaborate, the more competitive will Europe be in transforming the traditional industry to the printed intelligence.

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The training and educational content of the project was comprehensive and well received by the OLAE community. The Industrial Advisory Board was a good way to have fruitful dialogue between the research community and the industry, and the Associated Network was an effective vehicle to disseminate the technical information and create common spirit. The collaboration between the Quadriga projects strengthened the position of the whole community and boosted the joint activity level.

Potential impact of the project, the main dissemination activities and exploitation of results

The project has had a wide impact to the Organic and Large Area Electronics community by educating the key stakeholders and providing them with a set of documents that can be used in defining the future development directions for products and systems. Since organic electronics will increasingly be used in a large variety of applications, the trends of the industry will have an impact to the whole society. The examples include consumer goods, packaging industry, construction business, personal health diagnostics, etc.

The list of dissemination activities already during and immediately after the project is impressive including 32 individual briefings, workshops and conferences, but the main deliverables have also been published on the project website and the wiki database created by PolyMap, one of the Quadriga projects. Organic Electronics Association (OE-A) currently plays a key role in the continuity of the industrial collaboration after the PRODI project by maintaining the wiki database containing the deliverables and lots of other documents. The download rates of the documents have been high, over 500 downloads. It is even possible to publish the vision document also as a printed volume for wider audience and prolonged attention.

The address of the project public website

The PRODI project has had the following logo and website address throughout its duration:



www.project-prodi.eu

The main point of contact regarding the project has been the project coordinator:

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