Summary of the IP4Plasma project results

Description of the project context and the main objectives.

Atmospheric pressure plasma technologies have great innovation potential for surface engineering of materials. They are environmentally friendly, solvent-free technologies which make use of the special chemical and physical properties of reactive species generated in an electrical gas discharge: e.g. ions, electrons, radicals, photons or excited states of molecules and atoms. Most atmospheric pressure plasma technologies are closely related to industrial corona technology, which is widely used for adhesion promotion of materials before printing, gluing, laminating or coating. Compared to corona technology, atmospheric pressure plasma coating technologies offer a wider range of capabilities for more advanced surface engineering. However, they have by far not yet reached the same level of industrial use because of higher equipment and running operating costs.

The aim of IP4Plasma project was to bridge the gap between IPR protected laboratory-scale innovations in the field of atmospheric pressure plasma assisted chemical vapour deposition (AP-PA-CVD) technology and its industrial implementation for advanced surface treatment and nano-scale coating of materials. This will be done by demonstrating the suitability of the technology for existing and new industrial applications in the medical products and diagnostics sector.

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Figure 1: Plasma afterglow

Medical applications were chosen for the demonstrations due to their high added value and their need for incorporating new chemical functionalities in surface treatments, using cost-effective manufacturing methods. The demonstrators include the production of a quicker and cheaper rapid tuberculosis and HIV tests, manufacturing of advanced wound dressings with antibacterial properties and improved sealing method for medical packaging

A mobile pilot scale plasma treatment system was designed and built based on existing experience and IPR protected know-how, and subsequently validated in end user production facilities.

A description of the work performed since the beginning of the project and the main results achieved so far.

A new mobile plasma treatment system was designed based on the knowledge of VITO, IST, IMA and SOFTAL Corona & Plasma GbmH, with better reliability and maintainability and reduced operational costs, making it better suited for industrial production. The scalability of the equipment for different production systems is ensured by modular design. During the project four plasma systems were built, with widths ranging from 200mm to 1200 mm, and used in the industrial demonstrations.

One of the reactors was delivered to Tosama d.o.o., a Slovenian manufacturer of medical textiles and hygienic products, for industrial demonstration in their wound dressing manufacturing line. Three different precursors were tested, and all show the ability to inhibit the growth of S. aureus and C. albicans. Considering the health and safety aspects of the precursors it was concluded that chitosan, as well-known biocompatible polymer has the highest potential for medical/wound dressing application. The treatments were shown to be stable over time and survive the relevant sterilization procedures.

At Tosama, demonstrations for sealing of medical packaging was also carried out. Optimization of the plasma treatment process for medical paper and foil for medical packaging was carried out, showing that the sealing properties can be effectively controlled with plasma treatments.

The development for the rapid tuberculosis tests were carried out by Lionex GmbH and Fraunhofer IST. The new quantitative test based on the plasma treatment methods is called LIODROP®; a patent for that has been applied by LIONEX.

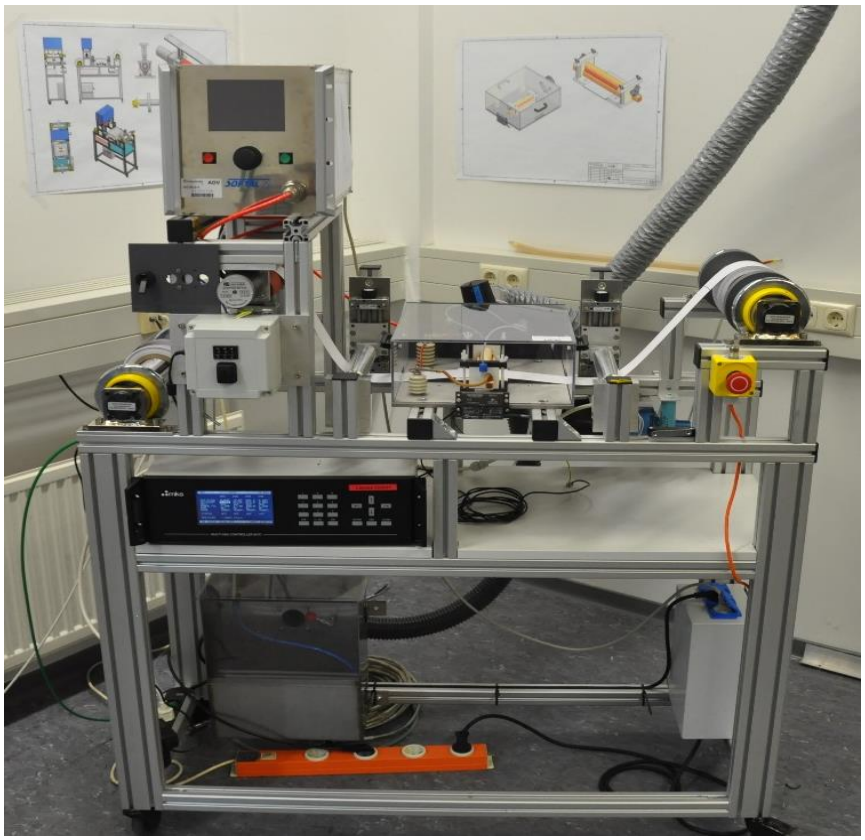

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Figure 2: Roll to roll system for manufacturing Lionex TB-test

+ control
TMB acetate based

+ control
TMB citrate based

- control
TMB citrate based

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Figure 3: LIODrop-Ip4 Plasma TB test

The sensitivity of the plasma coated tests is at least ten times more sensitive than the standard lateral flow tests which are currently in use. The stability of plasma treated tests were analyzed by real time stability tests and accelerated stability tests, showing that at after six-month storage, the coating is stable at 2-8°C under dry conditions.

LIONEX and Fraunhofer IST also developed an HIV detection test using the LIODROP® test platform. The results show that using the antibodies developed, detection of HIV is possible.

Fraunhofer IST developed and realized new coatings with aldehyde functional groups as basis for the tuberculosis and HIV tests. An evaluation for a quantification method for the amount of functional groups, achieved on the surface, was carried out. Herewith the density of functional groups can be proofed for quality assurance.

The largest 1200mm wide reactor was installed at the premises of SOFTAL Corona & Plasma GmbH and used for testing other applications besides the demonstrators and verifying the scalability of the processes. The homogeneity of precursor deposition on several substrates and precursors was proven for the whole 1200mm width. For example, the new plasma system shows significant UV ink adhesion improvement on polyester films compared to earlier plasma treatment methods, such as ALDYNETM.

In addition, surface potential measurement method for on-line monitoring of the efficiency and uniformity of plasma treatments has been developed. Trials were conducted at the industrial roll-to-roll demonstrations to verify that this online monitoring method can detect the nano-size coatings deposited by plasma treatments.

Life cycle assessment and life cycle cost analysis of the applications were performed, showing that there are no specific issues seen in various environmental indicators when compared to the selected baseline products.

Market and valorisation studies for the wound dressing and diagnostics applications were conducted, along with market analysis for the equipment sales. The market potential of new application areas, including e.g. water filtration membranes was studied and new contacts to potential users initiated. IPR analysis was conducted and the IPR situation monitored continuously by the partners, showing that there is freedom to operate.

An online training course on the new plasma equipment and its use was designed and implemented, to provide information about the possibilities of the plasma treatments to companies interested in new surface treatment methods and to give more in-depth information on the use of the new equipment. The course is available at http://moodle.ip4plasma.eu/ .

Expected final results and their potential impacts and use (including socio-economic impact and the wider societal implications of the project so far).

Tuberculosis has become a global disease and is very common in resource poor, high burden countries of Asia, Africa and Eastern Europe. TB affects over 9 million people a year, and it kills 1.7 million people every year despite that there is a cure. Most people

who are exposed to TB never develop symptoms, because the bacteria can live in an inactive form in the body. About 5% of the infected individuals develop TB, a majority being children.

Thus, there is a global need for cost-effective test with better sensitivity and specificity for the control of this major human disease. The tuberculosis test developed in IP4Plasma project by Lionex GmbH - based on the coating methods patented by VITO and Fraunhofer IST - answers this need. It

- allows a diagnosis within minutes instead of traditional tests which take days
- is highly sensitive (>75% for TB positive cases detected) and specific (>99%)
- is inexpensive : the costs/test has been pushed down with the cost-effective roll-to-roll plasma treatment and the novel LIODROP test cassette to approx. 1 € (endemic countries) and 5 € (Western Europe)
- can be carried out without any test installation and is easy to use also in field conditions.

Using the same method as for the tuberculosis test also a rapid test for HIV diagnostics was developed.

The cheaper and faster diagnostics test developed for TB and HIV will enable screening of much larger population with the same amount of resources, leading to broader and very likely also earlier detection of patients which can subsequently receive medical treated. This might drastically improve the life quality and life expectancy of the patients as well as prevent further spreading by active prevention measure. Indirectly, this will also improve the socio-economic fabric of societies which currently suffer from high TB/HIV infection rates. HIV diagnostics may also be used to screen blood and/or serum donations to blood banks for HIV infections. This not only reduces costs but also increases safety for people who need blood or serum donation.

For advanced wound dressings and medical packaging costs savings and new functionalities are expected due to the use of plasma technologies. Ageing population and the increasing incidence of diseases such as diabetes create more demand for advanced and more effective wound treatment, particularly antibacterial wound dressings. Over the last decade demand of advanced dressings has increased considerably due to higher adoption of interactive/bioactive and antimicrobial dressings.

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Figure 4: Plasma installation on Tosama production line

The demonstrations done in IP4Plasma show that it is possible to develop antibacterial and antifungal wound dressings using plasma deposition.

In the IP4Plasma project, major steps forward were taken in the development of AP-PACVD, a technology previously only in research use is now matured to be used in industrial environment. The technology advanced in both technology readiness as well as manufacturing readiness. The project brought new knowledge, new contacts, potential for new cooperation and business opportunities for all partners. The project significantly contributed to the establishment of one start-up company (APEMCO) and indirectly to a second one (FUNCOATS) which are based on VITO's technology. Additionally, two start-ups or spinoffs are being planned to utilize the project results.

The project is estimated to have an impact on business growth and additional privately and publicly funded projects for the partners. Especially the adhesion improvements of materials sensitive to high energy plasma could open up new research and business opportunities.

Based on the market studies, there is a great market potential for all chosen applications. Potential impact of LIONEX's rapid TB-tests are huge both in sense of social and medical aspects as well as commercial aspects.