I.FAST

Innovation Fostering in Accelerator Science and Technology

Horizon 2020 Research Infrastructures GA n° 101004730

MILESTONE REPORT

Projects Identification for Development Funding

MILESTONE: MS57

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ABSTRACT

The main focus of Task 12.1 is the development of the applications of particle accelerators, though limited funding is available for detailed study of individual applications. As a result, it is very important that other sources of funding are identified and exploited for this work. The aim here is to collect together initial ideas and be ready for the IFAST Innovation Fund and other European and national funding calls.

Five projects have so far been identified and these are described briefly in this milestone, along with possible partners in the projects.

For more information on IFAST, its partners and contributors please see https://ifast-project.eu/

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Delivery Slip

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Executive summary

This milestone summarise a number of possible projects developed by Task 12.1 that now have potential for commercialisation, but need further funding to deliver that potential. This funding could come from the IFAST Innovation Fund or from other sources.

A short summary of each project is given, along with potential partners, including from industry.

1 Introduction

This milestone describes possible additional projects already identified by Task 12.1 that could be submitted to the IFAST Innovation Funding (IIF) or other sources of funding. The main focus of Task 12.1 is the development of the applications of accelerators, though limited funding is available for actual work. As a result, it is very important that other sources of funding are identified and exploited for this work. The aim here is to collect ideas and be ready for IIF or other calls. No attempt at ranking or selection is performed at this stage, but comments on the possible projects are welcome

Five projects have so far been identified and these are described briefly in Section 2, along with possible partners in the project.

2 Proposed Projects

2.1 Feasibility study of alternative novel materials for electron beam exit windows

Proposed by Frank-Holm Roegner (Fraunhofer FEP)

Other possible partners: HUD, GSI, INCT, RHP

This is a feasibility study of alternative electron exit windows made of thinner material to reduce the necessary electron energy and the energy loss within the window. Two specific examples are considered: a diamond composite layer and graphinated carbon (3D graphene), as studied for ion beams in WP4.

- Commercially used electron exit windows are made from thin titanium foil or aluminum-beryllium-alloy foil partly mechanically stabilized by a copper grid. This construction is limited by the minimal thickness of the metal foils because of the foil rolling technology as well as of the vacuum barrier properties.
- Especially for very low electron energy applications it means that most of the electron energy is trapped by the exit window material. This is wasteful and this energy then needs removal via cooling water.

- To overcome these disadvantages, it is necessary to have an alternative exit window material with the following properties:
  - Less basis weight than the thinnest exit window metal foils
  - High mechanical strength to withstand the atmospheric pressure
  - High transverse thermal conductivity
- This project will explore using two novel materials: diamond like carbon (DLC) and graphinated carbon (GC). In both cases, a very thin layer is coated onto a metal substrate and grid holes are then etched in the metal, so that DLC or GC forms the electron exit window, stabilized by the residual metal grid structure. It is expected that thicknesses <1µm can be achieved, at least for GC.
- Within this project, the feasibility of the manufacturing process as well as the basic properties as an electron exit window will be shown.
- If these are shown to work, it will be become possible to decrease the necessary electron energy for irradiation processes to save energy, shielding effort and simplify infrastructure for very low electron energy applications. Applications such as electron beam welding may become possible in air, rather than vacuum.

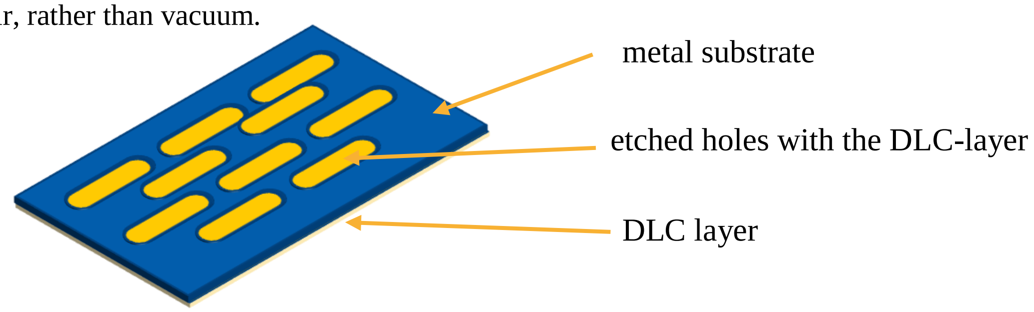

Fig. 1 Schematic of the DLC based electron beam window

- If successful, this window would bring benefits to all applications of electron beams, especially those at low energy.

2.2 USE OF ELECTRON BEAMS TO DESTROY ANTI-MICROBIAL BACTERIA AND GENES AND ANTI-BIOTICS IN SEWAGE SLUDGE TO REDUCE AMR GROWTH

Proposed by Andrzj Chmielewski (INCT)

Other possible partners: Biopolinex, HUD, University of Warsaw

The World Health Organization (WHO) has identified the spread of antibiotic resistance (AMR) as one of the major risks to global public health. This is the ability of micro-organisms to withstand anti-microbial treatments and could have a similar impact to covid, but over a longer timescale. In this project, we plan to demonstrate a technique that could substantially reduce AMR transmission from a very important source: sewage sludge from wastewater treatment plants (WWTP).

The urban water cycle is an important transfer route of AMR into the environment. This is due to the vast quantities of bacteria, other microbes, resistant genes and subclinical levels of antibiotics passing through WWTPs every day. So far, six classes of antibiotics, i.e., β-lactams, sulfonamides, quinolones (fluoroquinolones), tetracyclines, macrolides and others have been detected in the influents and effluents from WWTPs worldwide. It has also been demonstrated that the treatment and disposal of municipal sewage sludge is a source of AMR growth. Although the standard forms of treatment of sludge, such as anaerobic and aerobic digestion, are known to destroy a very large fraction of AMR bacteria and other microorganisms, they do not have much impact the resistant genes. The surviving genes are discharged to multiply in the solid waste from the plant, which is often used as a fertilizer, and can combine with other microorganisms. In addition, some of the antibiotics and their metabolites are deposited in the sludge and survive intact through the treatment chain and are also contained in the solid waste, where they can further promote AMR growth. The AMR microorganisms can then be transported to water courses via leaching and into food crops grown on the land, thus being passed onto humans and animals.

In this project, our goal is to investigate a new and innovative method able to destroy with high efficiency AMR bacteria and genes and antibiotics and their metabolites in sewage sludge. The method is an advanced oxidation technique using energetic electrons. It works by creating large numbers of both oxidising and reducing radicals in water. These can react with a variety of contaminants in the water, either damaging the DNA (in the case of organisms) or creating chemical reactions with the contaminants (in the case of antibiotics). In the laboratory and in pilot studies, this has been shown to be very effective in destroying bacteria and viruses in sewage sludge. Although it is expected that electron beams will have the same impact on AMR micro-organisms and genes, this has not yet been demonstrated experimentally. Studies of damage to antibiotics in water have been done, but this needs to be repeated in the more complex medium of sewage sludge.

Due to the current concerns about AMR growth, there is now discussion of the introduction of new legislation in Europe requiring water companies to deal with this problem. As there is currently no solution to it, a successful demonstration with electron beams could open up very large commercial possibilities.

2.3 Feasibility study of an inverse toroidal electron accelerator (accelerate electrons radially outward) for gas treatment

Proposed by Frank-Holm Roegner (Fraunhofer FEP)

Other possible partners: Ecospray, INCT, RTU

The aim of this project is the further development of a toroidal electron accelerator, but with electron acceleration outwards, for the treatment of flowing gas. It will reduce the cost and installation space required to bring such an accelerator inside a tube and irradiate the annular gap around the accelerator

- Based on FEP's toroidal electron source the radiation principle should be turned around. Instead of the actual radiation of the source surrounding a tube to a radial center point, the new inverse electron source should radiate from the centered electron source radially outward.
- In this case the electron source can be placed into a gas tube to irradiate the gas as a circular ring flow. Unlike the irradiation of a complete pipe cross-section the irradiation of a circular ring needs a lower electron penetration depth at the same gas flow and therewith a lower necessary electron energy.
- At the same time the cost of the electron accelerator will decrease because of the lower acceleration voltage as well as of the smaller design.
- Within the project the basic principle of such an electron source will be demonstrated and the design principles can be tested.

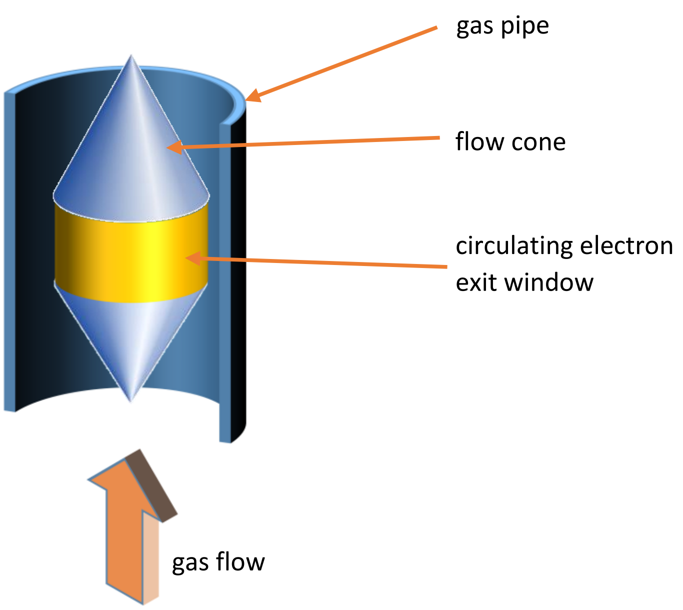

Fig 2: Schematic showing the use of the toroidal accelerator to treat a flowing gas

2.4 THE USE OF ELECTRON BEAMS FOR THE REMOVAL OF MICROPLASTICS FROM SEWAGE SLUDGE

Proposed by Rob Edgecock (HUD)

Other possible partners: INCT, Biopolinex, Veolia

Microplastics (MP), defined as plastic particles <5mm in size, are now found everywhere on Earth. Unlike bulk plastics, they are difficult to detect and difficult to remove from water sources. Although there are limited studies of their health impact, they are known to bio-accumulate, they are sticky and can transport bacteria, parasites, heavy metals, etc and possibly protect these through anaerobic digestion, and some of their additives are known to be toxic. One of the main routes of microplastics into the environment is via sewage sludge and legislation is being discussed in Europe that will reduce the percentage of MPs allowed in sludge that is used as a fertiliser.

An ARIES supported PhD project (thesis currently being examined and publications expected soon) has extensively studied the treatment of a wide range of types of MP in water and in sewage sludge. Although this has not demonstrated the ideal solution of the breakdown of the MPs into harmless products, it has done two things:

1. Shown the removal and destruction of many additives
2. Produced changes in the physical structure that could aid their removal from sludge via standard techniques (see fig. 3)

Measurements on the removal efficiency from sludge after treatment have show significant improvements and will be published soon.

The next step in this work is the demonstration of this technique at a sludge treatment plant and its commercial viability and the aim of this project is to do that. It should be noted that many benefits of treating sewage sludge with electron beams have already been demonstrated and a pilot plant is in operation. The removal of MPs would be an additional benefit.

Fig 3: Five different types of MP from a range of sources in water. Top is before treatment with an electron beam, bottom is afterwards. Note that after treatment almost all the MPs are either floating or have sunk, hence providing routes for removal using standard techniques.

2.5 STUDY OF INNOVATIVE MATERIALS FOR THE STORAGE OF NUCLEAR WASTE WITH A GREATER RESISTANCE TO CORROSION BY WATER CHEMICALLY ACTIVATED BY BETA AND GAMMA RAYS

Proposed by Rob Edgecock (HUD)

Other possible partners: INCT, Sellafield Ltd

It is well-known the nuclear waste material from reactors and other sources will need to be stored in underground repositories for 10s or 100s of thousands of years. A particular concern about such storage is the corrosion of the containers of the waste by water leakage into the repository and from water within the containers. It is also known that this corrosion is likely to be accelerated by radiolysis of the water by beta particles and gamma rays from nuclear decay and there have been a wide range of studies of this effect. In this project, we plan to use the knowledge gained from electron beam studies of waste water and sludge to investigate methods of extending the life of the containers by studying alternative coatings of the containers better able to withstand the impact of the main radicals created in the water.

3 Conclusions

After only 10 months of work, Task 12.1 has already identified a range of projects with a strong potential for commercial exploitation with industrial partners. All of these are aimed at the reduction of waste in the environment and/or increasing the sustainability of accelerators. This work is continuing and other projects may also be developed in time for proposals to the IFAST Innovation Fund. However, the Task will continue to develop new innovation ideas throughout the duration of IFAST and will seek funding both from European and national sources.