The Joint Programme on Nuclear Materials of the European Energy Research Alliance (EERA-JPNM) – Coordinating GenIV reactor materials research for a low-carbon Europe

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Abstract

The Joint Programme on Nuclear Materials (JPNM, www.eera-jpnm.eu) was created in 2010 as part of the European Energy Research Alliance (EERA, www.eera-set.eu) to coordinate European research on GenIV reactor materials. The reason for the focus on GenIV materials is the pivotal importance of materials in view of safety and sustainability of nuclear energy, as well as innovation in the energy field in general. Some of the conditions expected in GenIV reactors are common to both, current nuclear systems and fusion, as well as non-nuclear high energy efficiency systems. The large overlap between the topics addressed in the SMINS workshop and those in the focus of the EERA JPNM is the reason of the co-sponsorship, via the MatISSE project, together with NEA-OECD.

In this paper the goals, grand challenges, research agenda , projects, structure and strategy of the EERA JPNM are briefly presented, with a view to promoting international cooperation on GenIV reactor materials.

Introduction: sustainable nuclear energy

The goal of sustainability is common to all low-carbon energy sources. Generation IV (Gen IV) fission reactors, along with the necessary fuel cycle facilities, are the nuclear energy way towards sustainability. Sustainable nuclear energy systems allow the nuclear fuel cycle to be closed and the energy output from available resources to be substantially increased, while reducing the quantity and improving the management of high level radioactive waste through transmutation processes. The Sustainable Nuclear Energy Technology Platform (SNETP) [1] envisions accordingly that the European nuclear industry will continue to deliver safe low-carbon nuclear energy for the present and the coming centuries, with a commitment towards even higher safety standards, efficiency and sustainability. Building GenIV fast reactors and systems is part of this vision and commitment. The sodium fast reactor (SFR) is the most mature technology of this type; lead cooled fast reactors (LFR) are considered the next technology, while gas cooled fast reactors (GFR) are a longer term alternative. Correspondingly, three prototypes are planned to be built in Europe, under the coordination of the European Sustainable Nuclear Industrial Initiative (ESNII [2]), namely ASTRID as SFR, ALFRED as LFR and ALLEGRO as GFR. Moreover, a multipurpose irradiation facilitycalled MYRRHA, with fast spectrum and based on the accelerator-driven system concept, that could be used to burn also nuclear wastes containing significant quantities of minor actinides is included in the ESNII roadmap, as well.

However, the operating conditions envisaged for these systems are demanding and will impact on the performance of nuclear structural and fuel materials. The performance of these materials is therefore an essential point to make GenIV reactors a reality. The safety and the feasibility of GenIV nuclear system concepts and their optimization will indeed depend crucially on the capability of the chosen materials to withstand the expected extreme operating conditions, characterised by high temperature, prolonged irradiation, and chemically aggressive environments. Materials with the required properties must therefore be selected or developed, properly qualified, and their behaviour in operation fully understood. This is the central topic of the SMINS workshop and is also the focus of the Joint Programme on Nuclear Materials (JPNM) of the European Energy Research Alliance (EERA). For this reason, the EERA JPNM signed a Memorandum of Understanding with OECD-NEA to be formally co-organiser of this Workshop.

EERA and the JPNM

The international non-profit association EERA AISBL (*Association Internationale Sans But Lucratif*) was created on April 8th, 2014 by the 15 organizations which were members of the Executive Committee of the pre-existing alliance, EERA. It gathers now 176 European public research centres and universities, the research work of which is coordinated for a low-carbon energy Europe. The EERA is one of the cornerstones of the European Strategic Energy Technology Plan (SET-Plan [3]).

The EERA association has two main governing bodies, the General Assembly and the Executive Committee: the latter is composed by the representatives of the 15 major organisations in the Alliance. The research activities of the EERA are organised in 17 Joint Programmes (JP), each devoted to a specific energy technology or energy issue (see EERA website for the complete JP list [4]). The JPNM is the only one dealing with nuclear activities. Nuclear energy is indeed fully recognized by the SET-plan as a low-carbon energy source. The reason for the focus on materials is the pivotal importance that they have in view of safety and sustainability of nuclear energy, as well as innovation in the energy field in general. In particular, some of the conditions expected in GenIV

reactors are common to both current nuclear systems and fusion, as well as non-nuclear high energy efficiency systems.

JPNM objectives and challenges

The objective of the EERA JP on Nuclear Materials is to improve safety and sustainability of nuclear energy by focusing on materials aspects. This has two implications:

1. Better knowledge of materials behaviour under operating conditions, seeking predictive capability, to select the most suited materials and define safe design rules, especially allowing for radiation and temperature effects, while caring for compatibility with coolants.
2. Development of innovative materials with superior capabilities, either through suitable processing methods applied to existing materials or adoption of new types of materials, in terms of resistance to high temperature, irradiation and aggressive environments.

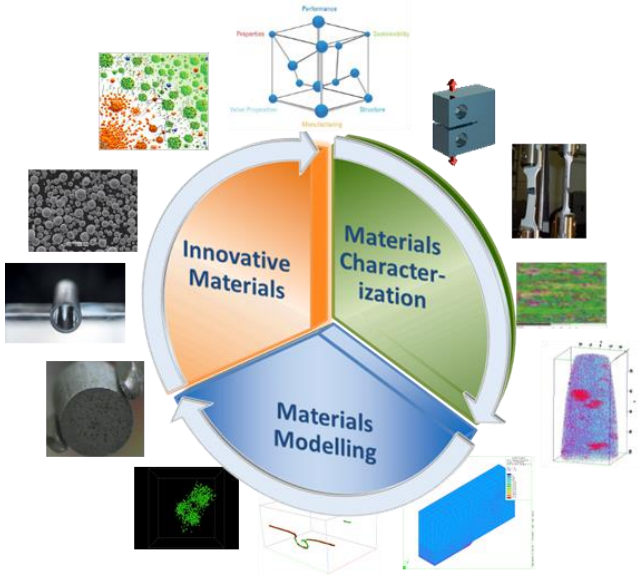
The three grand challenges correspondingly identified in the JPNM Vision Paper [5] are:

- Grand Challenge 1: Elaboration of design rules, assessment and test procedures for the expected operating conditions and the structural and fuel materials envisaged. This involves deployment of infrastructures for exposure to ageing and for testing of materials, and for production of data and knowledge, which is currently limited.

- Grand Challenge 2: Development of physical models coupled to advanced microstructural characterization to achieve high-level understanding and predictive capability: an essential asset, given the scarcity of experimental data and the difficulty and cost of obtaining them.

- Grand Challenge 3: Development of innovative structural and fuel materials with superior thermo-mechanical properties and radiation-resistance or, in general, of nuclear-relevance, in partnership with industry.

Figure 1: Research approach adopted in the EERA JPNM, consistently with the Grand Challenges

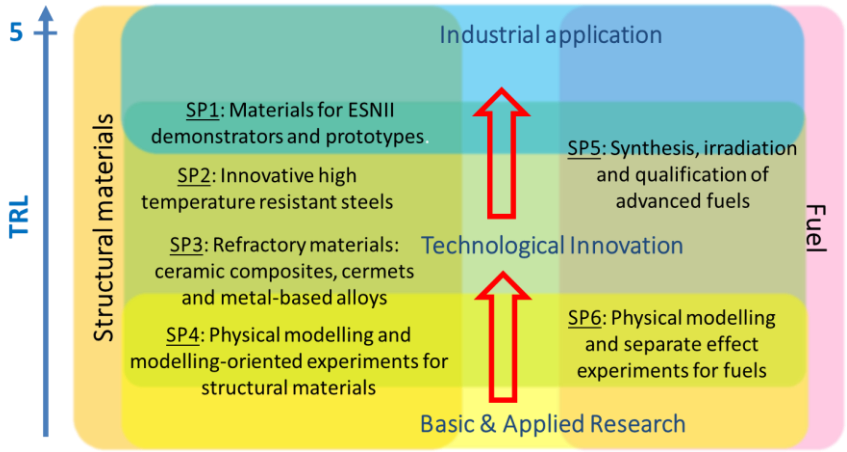


The research approach is correspondingly based on a virtuous circle that includes materials characterization and qualification, modelling and development of innovative materials (or innovative fabrication processes), as illustrated in Fig. 1. A Strategic Research Agenda that defines the direction of the JPNM research over the next decade, with focus on the next five years, is currently being prepared.

Structure and functioning of the JPNM

Consistently with the above challenges, the EERA JPNM is currently structured in six sub-programmes: four on structural materials and two on fuel. They cover for both classes of materials the full spectrum of activities: from fundamental research on the physical mechanisms responsible for degradation effects, to the pre-normative research that feeds the design codes used by the designers, passing through the development of new materials or new processes for their fabrication that improve their properties, as illustrated in Fig. 2. The Technological Readiness Level of all remains below 5 (lower than the industrial use) within the mandate of JPNM.

Figure 2: Subprogrammes of the JPNM



The coordinators of the six subprogrammes, together with the general coordinator, his/her deputy and a member in charge for cross-cutting issues, form the **Management Board** of the JPNM. The appointment of a member in charge for cross-cutting issues testifies of the high importance ascribed to finding commonalities with other nuclear and also non-nuclear energy technologies.

There are currently 48 organisations in total that contribute to the JPNM, of which 17 are full members and are represented in the **Steering Committee**, to which the Management Board has to respond. Overall these organisations commit more than ~200 PY/Y, based on what they declared. The countries represented are 17.

The community of organisations involved in the EERA JPNM disposes altogether of a wide range of infrastructures and facilities of relevance for research on nuclear materials: irradiation devices (materials testing reactors –MTRs–, ion accelerators, …); loops and autoclaves for the exposure of materials to aggressive fluids (including in-pile loops, i.e. loops inside MTRs); hot cells for the manipulation of radioactive materials; hot and cold laboratories for mechanical and microstructural

characterisation under a variety of conditions; workshops for the fabrication of specimens, including miniaturized specimens; and different advanced techniques for microstructural examination.

The JPNM has three instruments of implementation, namely:

- **Joint Technical Teams (JTT)**: These correspond to the scientific community involved in each SP, that meets regularly (at least annually) in targeted workshops or other meetings to monitor and share results and discuss collaboration. JTTs may flexibly involve the whole SP, be transversal to SPs, or correspond to the subset of a SP. JTTs exist permanently, although the members may be changing, and constitute the core of the human resources of the JP.
- **Task Forces (TF)**: These are groups of experts specifically appointed to provide specific answers to questions that can be of scientific/technical nature or of coordination/funding instrument kind, and are expected to finally deliver a report on it. It is supposed to be in charge for a limited amount of time, generally ~1 year.
- **Pilot Projects (PP)**: These are small projects (~2-3 M€ max. of value) focused on precise topics that result from the convergence of research interests and lines of several organisations from different Member States (MS). The typical duration is expected to be 3-4 years. They are the main instrument for the alignment of research actions between different organisations and MS, constitute the research portfolio of the JPNM.

The research performed by the JPNM is detailed in the Description of Work (DoW) of the JP, which is an official EERA document. This document for the JPNM has been recently updated for the period 2016-2020, having now closed the DoW 2011-2015. The new DoW has been largely defined via an internal PP call, that took place in 2015, as a result of which 23 PP have been launched, corresponding to a value of ~50 M€ of research. At least another PP call is expected before 2020. The finances are expected to come from a coordinated use of institutional funding; however, in order to try to get some support also from the European Commission, proposals to Euratom are prepared based on the content of the PP portfolio.

Instrumental to bridge between the first and second five-year period of the JPNM, to partially support its coordination and to partially fund its research activities, is the combination of coordination and support action (CSA) and collaborative project (CP) included in the FP7 project MatISSE (Materials' Innovations for a Safe and Sustainable nuclear in Europe [6]). However, this is not the only project under the umbrella of the JPNM. The JPNM aims indeed at acting as *envelope* for several European and national projects. Among the past ones, the FP7 projects GETMAT [7] and MATTER [8] should be mentioned: the public deliverables of both these projects are available through the website of the EERA JPNM [9]. It is expected that new H2020 projects will enter the JPNM envelope.

Dissemination of the results of the work performed within the JPNM is essential for the impact of the JP and therefore also for its visibility. For this purpose, the JPNM website [10], which is also of help for the JPNM management, is a continually evolving fundamental instrument. For example, a repository of publications in green open access has been opened on it, to be progressively enriched with the articles published as outcome of the JPNM research activities [11].

Added value of the JPNM

The added value of the creation of the JPNM can be summarised in 10 points:

1. The JP creates a community where researchers can recognise themselves and find a framework to leverage their ideas and initiatives through trans-border collaboration;
2. The JP centralises the collection and dissemination of data, results, information on events, within the community;
3. The JP takes care for the needs of the scientific community as a whole and promotes it in the outside world;
4. The JP strives to coordinate national and European project proposals based on joint prioritization and medium-term planning;
5. The JP optimises the use of funding resources for targeted priorities, by focusing institutional, national and European funds towards common goals;
6. The JP benefits from previous project results on which it builds future ones, maintaining stable research lines;
7. The JP may receive recognition of excellence by MS and EC, leading in the medium-to-long term to dedicated support (condition: credibility);
8. The JP acts as single interlocutor and entry point for exchange and collaboration with all stake-holders: EC and MS, industry, and other platforms, including international organisations such as the GenIV International Forum (GIF), the International Atomic Energy Agency (IAEA), and of course the NEA-OECD itself;
9. The JP promotes cross-fertilisation with other energy technologies and maintains the recognition of nuclear energy as low-carbon technology;
10. The JP may potentially coordinate the organisation of irradiation campaigns, making best and most affordable use possible of existing facilities, while bridging between fission and fusion.

Conclusive remarks

The EERA JPNM coordinates research activities in Europe on materials for GenIV reactors (mainly ESNII systems) to reduce fragmentation and achieve higher impact, by pursuing:

- Alignment of national programmes
- Blending of institutional, national and European funding
- Research activities that cover the full spectrum, from basic research to support to reactor systems, for both structural materials and fuel

The MatISSE FP7 project provides currently support to many of these activities.

The EERA JPNM has a vocation towards openness and international cooperation: collaborators from inside and outside Europe are very welcome!

References

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