2.1.8. EDF-2022-RA-ENERENV-CUW: Sustainable components for underwater applications

Budget

The Union is considering a contribution of up to EUR 20 000 000 for this topic under the call EDF-2022-RA

Number of actions to be funded: Up to one action may be funded for this topic

Objectives

Piezoelectric materials used for military applications, especially in underwater acoustics, are to a very large extent based on ceramics, more specifically, on lead titano-zirconate Pb1- xZrxTiO3 (PZT). Civilian and military users now face challenges with European regulations regarding lead and its derivatives identified in the Candidate List of the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation from 2012, with the risk of its inclusion in the Annex XIV (substances under authorization) in the coming years. This is a concern for sonar systems used in underwater applications utilising piezoelectric ceramics. In addition to the REACH regulations, other global regulations, such as the Restriction of Hazardous Substances (RoHS) or Waste Electrical and Electronic Equipment (WEEE), require the elimination of lead and its salts from consumer goods and industrial devices. These constraints and regulations stimulate the need for an increased technological and industrial maturity of piezoelectric material alternatives to PZT. As an example, the recent update of the European RoHS directive has precluded the use of PZT ceramics from July 2021 for civil applications.

General objective

The general objective is to replace existing PZT based ceramics with alternative technologies, such as lead-free piezoelectric materials (aspiring to have no reduction in performance levels with even the potential for a gain), which will be suitable for military underwater applications, including the most demanding, which is a passive hydrophone and active transducer for sonar and underwater communications. The overarching goal is to have the emergence of at least one European lead-free piezoceramic supply chain, which will soon be mandatory with regarding the European REACH regulations. The patenting of new formulations and processes would be of use for sonar applications.

PZT ceramics are used in most acoustic sensors for underwater military applications: hydrophones, sonobuoys, dipping sonars, variable depth and hull mounted sonars, torpedoes, towed arrays. With the launch of major fleet renewal programs, which are currently entering the implementation phase, the R&D of the naval sector has the challenge to control the environmental impact and the safety of ships, while preserving acoustic performance.

Since the renewal of scientific work on the replacement of PZT, started around 2000, considerable research has been conducted in studying substitution ceramics, with promising results. Research on demonstrators integrating lead-free piezoelectric ceramics and crystals based on BT10, KNN11, KN12, BCTZ13 has been published in scientific literature. However, gathering all the properties of PZT materials to alternative lead-free piezo-electric materials has never been done, and this is the reason academic research is still extremely active in this sector. In addition, reproducibility and process up-scale raise numerous issues.

Apart from military sectors, civilian markets are very broad and extend to several domains (non-destructive control sensors, medical echography apparatus, automotive, printing, energy harvesting). Even if civilian markets are very broad and potentially less demanding in terms of physical and piezoelectric properties than military domains, very few lead-free piezoelectric materials are proposed at industrial level and their physical and piezoelectric properties are very far from PZT. This means that mastering the production of advanced and high performance lead-free piezoelectric materials at an industrial level remains challenging. For the time being, no lead-free solutions exist that facilitate the high level of performance required by military underwater applications.

Specific objective

The specific challenge is thus to advance the state-of-the-art in the research of, and innovation in, new high performance lead-free piezoelectric materials for military underwater sensors applications to replace PZT, with a view to future phases of development and industrialization, leading to the prospective establishment of at least one European supply chain in this domain.

New materials can also provide the opportunity to generate additional benefits, for example, enlarging the operational frequency bandwidth of sensors or source generators, improving duty cycle limitations or reducing the sensor size. These opportunities can upgrade the performance of the sensors and should hence be considered in the evaluation of materials and processes to be studied.

Scope and types of activities

Scope

The proposals should carry out research actions for the development of advanced lead-free piezoelectric materials with physical and piezoelectric properties, enabling the substitution of PZT in military underwater applications. These research actions may be extended to disruptive ceramic technology processes, such as 3D printing, and material engineering to enhance current piezoelectric properties. Moreover, increasing the technological maturity of lead-free piezoelectric materials for PZT substitutions in military underwater applications, and assessing these new materials for military underwater applications on representative test transducers could also be considered. Furthermore, increasing the manufacturing readiness level of promising lead-free piezoelectric materials and enabling one or more European industrial suppliers of lead-free piezoelectric materials for sonar transducers is a benefit of research activities in this area. In addition, the proposal must pay particular attention to potential synergies and complementarity to other ongoing R&D projects at national, multinational and on-going dual-use initiatives at European Union level, to avoid unnecessary duplication.

Types of activities

The following types of activities are eligible for this topic:

	Types of activities (art 10(3) EDF Regulation)	**Eligible?**
(a)	Activities that aim to create, underpin and improve knowledge, products and technologies, including disruptive technologies, which can achieve significant effects in the area of defence (**generating knowledge**)	Yes (mandatory)

(b)	Activities that aim to increase interoperability and resilience, including secured production and exchange of data, to master critical defence technologies, to strengthen the security of supply or to enable the effective exploitation of results for defence products and technologies (**integrating knowledge**)	Yes (mandatory)
(c)	**Studies**, such as feasibility studies to explore the feasibility of new or upgraded products, technologies, processes, services and solutions	Yes (optional)
(d)	**Design** of a defence product, tangible or intangible component or technology as well as the definition of the technical specifications on which such design has been developed, including partial tests for risk reduction in an industrial or representative environment	Yes (optional)
(e)	System prototyping of a defence product, tangible or intangible component or technology (**prototype**)	No
(f)	**Testing** of a defence product, tangible or intangible component or technology	No
(g)	**Qualification** of a defence product, tangible or intangible component or technology	No
(h)	**Certification** of a defence product, tangible or intangible component or technology	No
(i)	Development of technologies or assets **increasing efficiency** across the life cycle of defence products and technologies	No

The proposals must cover the following activities:

- Generating knowledge, with in particular:
    - The review of the scientific and industrial state-of-the-art lead-free piezoelectric materials and innovative synthesis processes
    - The identification of the relevant materials and processes
    - The identification of manufacturing technologies for lead-free piezoelectric materials
    - The review of the available operational specifications
    - The definition of a roadmap for materials and processes development
- Integrating knowledge, with in particular:
    - The identification and assessment of EU industrial suppliers for the production of lead-free piezoelectric materials, including technology transfer.

In addition, proposals may address:

- Studies, with in particular:
    - The formulation, synthesis, physical and structural characterization, piezoelectric characterization of new composition of lead-free piezoelectric material.

- The study of innovative process alternatives to current ceramic machining and advanced sintering processes.

- Design, with in particular:

  - The material specifications and advanced material characterization (piezoelectric tensor measurement) at sample and transducer levels.
  - The integration of parameters in transducer modelling, fabrication of representative transducer, which should be partially tested in real environmental conditions (e.g., assessment of linearity response with respect to stress and temperature, pressure and temperature cycling, endurance tests).

Functional requirements

The research to be conducted should meet the following functional requirements:

- Replace PZT by lead-free suitable piezoelectric materials and assess their performance level, aspiring to have no loss in performance or even a potential gain, against the following (not exhaustive):

  - For Active transducers: maximal Source Level, matched electrical bandwidth, power density, efficiency, and more generally for high drive, temperature, stress and electric field handling, duty cycle, power linearity
  - For Passive transducers: signal to noise ratio, stress handling (depth rating/for deep-sea applications), frequency bandwidth, and sensitivity.

- The choice of lead-free piezoelectric materials may differ depending on military underwater applications (passive or active transducers), and different use cases should be addressed. For both use cases (active, passive), the loss, or gain, versus actual PZT transducers will be addressed through a redesign phase of equivalent lead-free transducers. These lead-free transducers shall undergo a series of pre-qualification tests (not exhaustive):

  - Functional evaluation: source level, signal to noise ratio, sensitivity, frequency bandwidth, directivity, efficiency, linearity with power, endurance test
  - Environmental evaluation: pressure and temperature cycling, vibrations, shocks.

Expected impact

The research should contribute to:

- reduction in pollution, which is a part of the European Green Deal,
- Strong technological differentiators compared to non-European sonar suppliers,
- Emergence of one or more European supply chains,
- Patenting of new formulations and processes,
- Compliance with REACH regulations on hazardous substances and obsolescence anticipation,
- Sustainability components for underwater applications