Ph.D Offer

IMMOBILISATION OF VOLATILE WASTE FROM NUCLEAR ENERGY IN HIGH-PRESSURE MATERIALS: EXPERIMENTAL APPROACH ON GLASS AND GLASS-CERAMICS

Keywords:

Volatile nuclear waste – Glass and glass-ceramics – high-pressure

Description:

France's energy independence is based on the use of nuclear energy. Although this source of energy has the advantage of being continuous, its life cycle leads to the production of radioactive waste that is dangerous for people and needs to be incorporated into immobilisation matrices that remain stable over geological time in natural environment. In the nuclear energy cycle, the management of final waste is an essential stage. Some volatile radioisotopes (^{36}Cl, ^{79}Se, ^{129}I) have no suitable solution for immobilisation. Until now, the management of ^{129}I has involved release and dilution in seawater. Our knowledge of systems under extreme conditions in Earth Sciences and inorganic chemistry in Materials Sciences has enabled us to develop a protocol for immobilising these elements in matrices (glass and glass-ceramics) synthesised under high-pressure conditions.

Validation of these matrices for storage in the natural environment involves three prerequisites: 1) significant incorporation of these radioisotopes, 2) good chemical durability and 3) high mechanical strength. While we have made considerable progress in recent years in optimising the incorporation of volatile nuclear waste and the associated chemical durability, little is known about their mechanical strength. The link between the three aspects also remains to be established. Meeting these objectives requires a multi-scale experimental approach: from the study of the atomic scale to macroscopic properties. This laboratory approach is essential if we are to establish the compositions of specific matrices for the long-term immobilisation of these radioisotopes in the natural environment and thus perpetuate the use of nuclear energy in conditions that are viable for society and the environment.

Context: This thesis is part of our ongoing projects aimed at proposing remediation solutions for waste from the nuclear energy industry. Synthesis under high-pressure conditions is an innovative and original approach that is not often used in Materials Sciences and which is destined to become more widespread, particularly for the immobilisation of volatile nuclear waste. The experimental conditions addressed are industrially feasible. To date, scientific studies into the formulation of radioisotope immobilisation matrices have focused mainly on iodine, with very little research on chlorine and selenium. Studies have focused mainly on the dissolution mechanisms of these elements and their effects on the structure of the matrix, but little or no attention has been paid to their impact on mechanical strength properties. The link between the two remains to be determined. While glass is the material of choice for the incorporation of nuclear waste in France, glass-ceramics represent a serious alternative due to their increased mechanical strength. However, little or no research has been done into the immobilisation of ^{36}Cl, ^{79}Se and ^{129}I.

The aim of this thesis is to study changes in the physico-chemical properties of glasses and glass-ceramics doped with volatile pollutants (i.e. ^{36}Cl, ^{79}Se and ^{129}I) synthesised under high-pressure conditions. The three main objectives of this thesis work are to evaluate 1) the mechanical strength properties, 2) the chemical durability of the matrices produced and 3) to establish the link between the first two.

This thesis will be based on an experimental approach to synthesise under extreme conditions (high-pressure) glassy materials at first and glass-ceramics in a later stage. The materials thus produced will be studied from three angles: 1) characterisation of the atomic structures, 2) study of the mechanical strength of the synthesised materials and 3) modelling of the physical properties as a function of the structure on an atomic scale. The first two will be carried out jointly (2 years) and the third at the end of the first two (1 year).

Student profile: The candidate will have a Master's degree or equivalent in Earth and Planetary Sciences or Materials Sciences, in line with the themes of the 3MG doctoral school. He/she will have in-depth knowledge of glass and/or glass-ceramic materials, and of experimental techniques such as high-temperature and/or high-pressure syntheses. A good understanding of the structure of glassy materials at the atomic scale and their physical properties will be a plus.

The candidate should be proficient in a range of analytical techniques including: solid state NMR, XPS, XRD, Raman, AFM and Indentation, SEM. Theoretical and practical knowledge of these techniques will be appreciated.

The candidate should be able to synthesise information and be enthusiastic about laboratory work. In addition, good communication skills within a research team are expected in both French and English.

Work environment:

The Ph.D work will be conducted in both LPG and IMN laboratories in Nantes. The combination in between the two units is a strength owing to the combined and complementary proficiencies. The recruited candidate will have access to large experimental facilities for the synthesis of materials at high-temperature and high-pressure. The use of the PLASSMAT platform will insure the full characterization of the samples.

Funding:

The funding will be obtained from Pôle Sciences et Technologies, Région Pays de la Loire, and Nantes Université. ~2130€ gross/month starting on the 01/10/2024.

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Application:

The candidate should provide a detailed CV, including two references, a motivation letter, a summary of the Master's thesis topic (1 page max), and grades and ranking in Master 1 and 2.