Andra Call for Projects
with the support of the
Investments for the Future Programme

DECIMAL

Phenomenological description of corrosion and its impact on the durability of magnesium waste embedded in hydraulic binders

Project supported by Andra under the "Investments for the Future Programme" ("Investissement d'Avenir") - Selected under the Andra Call for Projects: "Optimisation of post-dismantling radioactive waste management", organised in cooperation with the French National Research Agency (ANR).

Duration: 48 months

Project launch: 10/2017

Total project cost: €2.25 million

Sum covered under the Investments for the Future Programme: €540,000

Type of financial support: Subsidy

Locations:
Gif-sur-Yvette, Courbevoie, Paris, Rennes, Bagnols-sur-Cèze

Coordinating body: CEA-Saclay

Partners:

- French Alternative Energies and Atomic Energy Commission. (CEA)
- Institute of Separative Chemistry in Marcoule (ICSM)
- Ecole Nationale Supérieure de Chimie de Paris – Chimie ParisTech (IRCP-ENSCP)
- Institut National des Sciences Appliquées de Rennes (INSA Rennes)
- Orano

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BACKGROUND

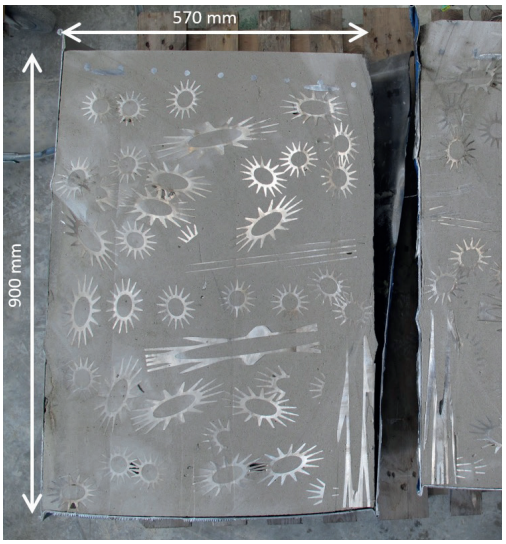
In France, the treatment of spent fuel from gas-cooled (graphite-moderated) reactors has generated radioactive waste, in particular magnesium-alloy cladding in which the nuclear fuel was inserted. This waste will be placed in a steel container and immobilised in a hydraulic binder for disposal. This cementation conditioning process is robust and easy to implement from a technological standpoint, and ensures the confinement of the waste. The reactive nature of magnesium alloys (corrosion leads to the production of hydrogen, a gas which, above a certain quantity, can exhibit a risk of explosion in the presence of oxygen) has led to the development of an innovative (geopolymer) matrix in which the magnesium reactivity is lower than in ordinary cement. This geopolymer matrix is currently being studied to determine its properties and behaviour over time, which is essential data for use with radioactive waste.

Magnesium corrosion is a complex process which can be affected by environmental conditions: composition of the geopolymer with which it is in contact, type of magnesium alloy considered, interactions with other materials, impact of radioactivity, etc.

OBJECTIVES

DECIMAL is a fundamental research project which aims to better understand the behaviour of geopolymer matrices in disposal conditions, and particularly the phenomena occurring at the magnesium/geopolymer interface and the consequences on the integrity/durability of the containers in which the waste will be conditioned. These data will then be used to prepare the conditioning of various magnesium alloys in geopolymer matrices.

▶ Bits of magnesium alloy cladding stored at CEA Marcoule.



▶ Magnesium alloy cladding immobilised in a geopolymer matrix (200 L drum cut top to bottom).

ANDRA
French national radioactive waste management agency

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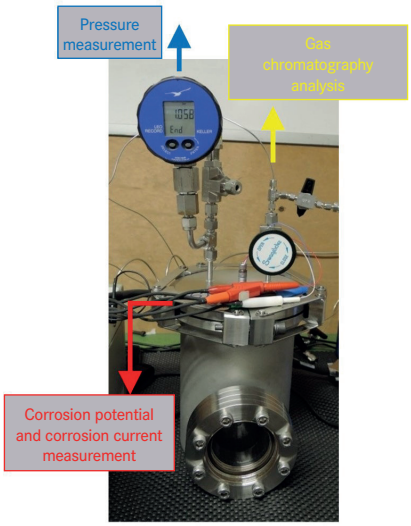
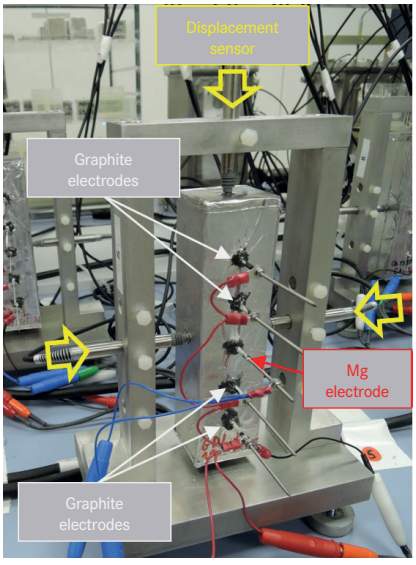


One of the combined electrochemical-gas reactors used in DECIMAL. This experimental device is used to analyse the composition of the (H_2) gas phase throughout the corrosion experiment. Gas production/consumption therefore correlates with the corrosion currents. The goal is to measure magnesium corrosion (electrochemistry) and the associated effective production of hydrogen (gas analysis).



Electrochemical-mechanical measurement portal used in the DECIMAL project. This system can be used for logging the corrosion current of Mg electrodes embedded in a cement matrix (connected to a potentiostat) and the deformations generated on the embedding material by the growth of a layer of corrosion products on the surface of the magnesium (displacement detectors placed on the portal).

PROJECT SEQUENCE

The DECIMAL project will be carried out over four years and involves six research groups. It is based on experimental parametric studies into corrosion and mechanics, and the modelling of the container integrity. The effect of various parameters (chemistry of the environment, type of alloy, irradiation) will be studied through the use of conventional or specific electrochemical techniques associated with gravimetry and microstructural physical and chemical characterisations at various scales. The durability study is a complex task that will take into account the specific characteristics of the geopolymer, waste behaviour and how it changes in interaction with the matrix. Various alloys (Mg-Zr, Mg-Mn) and industrial analogues (Mg-Al), in both pre-oxidised and non-pre-oxidised forms, will be studied to validate the project sequence used.

EXPECTED RESULTS

Innovation

DECIMAL will enable the acquisition of new fundamental data that are currently unknown for magnesium alloy corrosion. The experimental protocols developed for the project will make it possible to take in situ measurements, e.g. real-time measurement of the quantity of hydrogen produced by corrosion, or the quantity of magnesium involved in chemical reactions. An innovative approach will also be implemented with the manufacture of fine geopolymer layers on a Mg-Zr substrate in order to create model materials which could be used for the study of metal/binder interfaces under irradiation.

Impact on radioactive waste management

The nuclear waste consisting of the magnesium alloy fuel cladding used in gas-cooled reactors represents a large quantity of waste, and its conditioning is a challenge for many countries. In France, 1,119 tonnes of radioactive magnesium cladding are in surface storage at CEA Marcoule, and 1,110 tonnes on the Orano La Hague site. Several treatment/conditioning solutions for this waste are currently being studied in order to provide a safe disposal solution. The project will provide essential information for deciding whether or not to embed magnesium waste in a geopolymer matrix, which is the solution currently considered by CEA.