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Electron Microscopy Analyses of Samples Devoted to the Study of the Nuclear Reactor Severe Accident

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Safety of the light water nuclear power plants (Generation II. and III.) has gained great importance since the end of 70th of last century. Highly levelled nuclear event on the INES scale [1] is commonly called the "Nuclear reactor severe accident" and can be defined as: "An accident, which exceeds the design bases of the reactor sufficiently to cause failure of structures, materials, systems, etc. Core cooling cannot be properly assured by normal means."[2] If the reactor vessel load melts, a complex melt pool is formed. This lava like melt is called "corium" and consists mainly from UO_2, ZrO_2, iron and iron oxides. Hypothetically, corium could interact with water (in the reactor vessel or in the cavity under the vessel) and concrete (if it penetrates through the vessel) forming the containment structures. Therefore, a deep knowledge of behaviour of mentioned materials at high temperature is needed, namely features in the liquid state (miscibility gap phenomena; viscosity, etc.) and solidification paths as well.

Presented paper is focused on the interaction of molten corium and the coolant (light water in PWR and BWR). Generally, this phenomenon is called molten fuel – coolant interaction (FCI). FCI could be described in four main stages: i) Premixing – melt pouring into the water and coarse fragmentation; ii) Triggering - external or internal coincidence causing fine fragmentation; iii) Propagation – movement of the fine fragmentation wave through the premixed volume; iv) Expansion – transfer of thermal energy to the work of steam causing a pressure rise-up.

In this contribution we present analyses of two different kinds of samples: i) non-radioactive materials simulating corium; ii) radioactive corium simulant (UO_2-ZrO_2 mixture). Work with non-radioactive materials include experiments with molten tin were performed in the MISTEE facility situated in KTH, Stockholm, Sweden [3] and experiments with Al_2O_3-Fe thermite mixture in the PREMIX facility situated at FZK Karlsruhe, Germany [4]. The experiments using radioactive UO_2-ZrO_2 mixture were performed in the KROTOS facility located at CEA Cadarache, France [5]. All the samples were analyzed by means of solid-state chemistry and physics (SEM/EDS, OM, TG, DRX etc.)

Main focus of our work is to describe the possible chemical reaction between melt and water that can affect the FCI progress. For example, the melt oxidation can affect the mainly its properties at the melt – water interface (surface tension, melting point etc.) governing the fine fragmentation in the propagation stage of FCI, another important connected with melt oxidation (and water thermolysis) is hydrogen generation. It is believed that presence of non-condensable gases inhibits the probability of steam explosion (fine fragmentation) occurrence. Figure 1. shows optical (1.A) and SEM (1.B) micrographs of tin debris coming from MISTEE facility. Figure presents morphology of Al_2O_3-Fe debris coming from the PREMIX facility. Differences among above mentioned materials will be discussed, for example surface oxidation of tin debris was detected, on the other hand, alumina-iron mixture can absorb water vapour forming oxo-hydroxides and finally UO_2-ZrO_2 mixture was oxidized by water vapour forming $U_xZr_{1-x}O_{2+y}$ solid solution.

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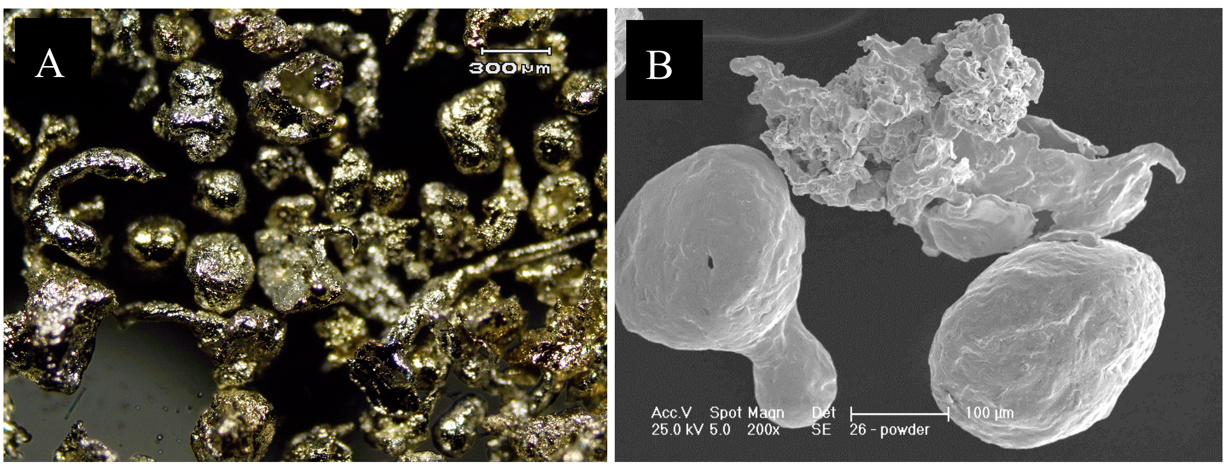

FIG. 1. Optical (A) and SEM (B) micrographs of tin debris coming from MISTEE experiments.

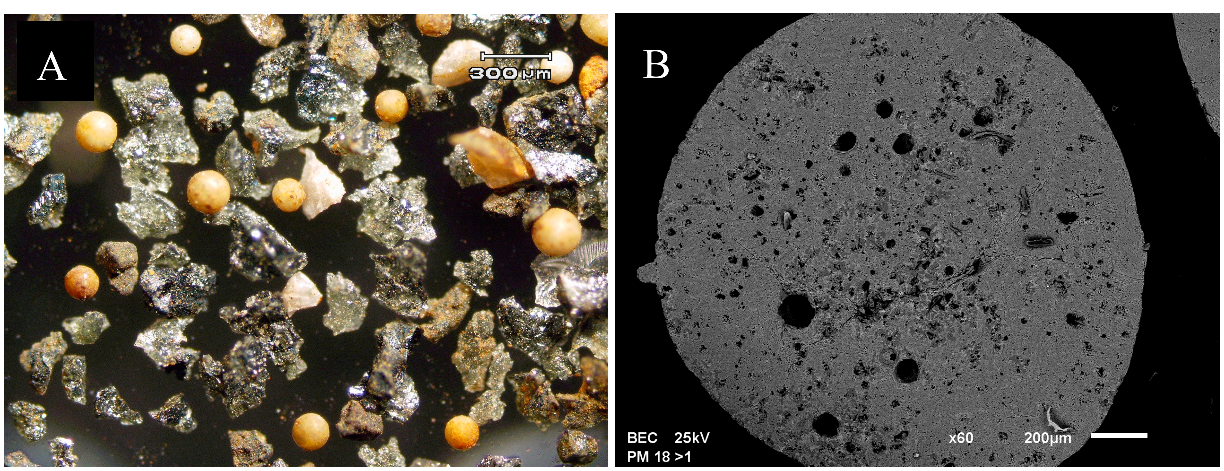

FIG 2. Optical (A) and SEM cross-section (B) micrographs of Al_2O_3-Fe debris coming from PREMIX facility.

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