Materials Compatibility and Salt Chemistry Control: Case For Molten Salt Actinide Recycler & Transmuter

Victor Ignatiev, Valery Afonichkin, Olga Feynberg and Aleksandr Surenkov
NRC-Kurchatov Institute, Russia

Abstract

Last decade R&D on Molten Salt Reactor (MSR) is focused of fast spectrum concepts which have been recognized as a long term alternatives to solid fuelled fast neutron reactors with attractive features (very negative feedback coefficients, smaller fissile inventory, easy in-service inspection, simplified fuel cycle). Single and two fluid Molten Salt Actinide Recycler & Transmuter (MOSART) designs without and with fertile materials support are now available for for long lived actinides burning and new fuel breeding. It was demonstrated that the MOSART system without graphite moderator can operate with different loadings and make up based on transuranium elements from used LWR fuel without Th support as special Li,Be/F actinide burner (for spent LWR fuel with Pu/(Np+MA) ratio down to 1.5 and with Th support as self-sustainable system (CR=1) or even as a breeder (CR>1). It seems that for transition to more poor fuel feedings on the base of MA only, molten fluoride solvents with higher solubility of MAF_3 are necessary (e.g. LiF-NaF-KF eutectic fuelled by 7.6 mole % of MAF_3). But this will need very high (much more than 30 t of MA) loading to get criticality.

Selection of the salt composition strongly depends on the specific design application. For MOSART design, materials selection in primary circuit is a very important issue. This paper summarizes results of an experimental investigation conducted recently to understand the mechanism and to develop a means of controlling uniform corrosion and tellurium embrittlement in the Ni – base alloys.

The addition of a chromium telluride to salt can be used to provide small partial pressures of tellurium simulating a reactor environment where tellurium appears as a fission product. Tellurium corrosion of Ni-based alloys in stressed and unloaded conditions studies was tested at temperatures up to 750°C with measurement of the salt redox potential in LiF-(NaF)-BeF_2 and LiF-(BeF_2)-ThF_4-UF_4 fuel salts in the range of U4+/U3+ ratios from 1 till to 500. Following Hastelloy N-type modified alloys: HN80M-VI with 1.5% Nb, HN80MTY with 1% Al and MONICR with about 2% Fe were used for the study in the 15LiF-58NaF-27BeF_2 corrosion facilities. Materials investigated in molten 75LiF-5BeF_2-20ThF_4-UF_4 mixture fuelled by 2 mole% UF_4 included, in addition to mentioned above, high temperature 77Ni-7Cr-10Mo-6W and 65Ni-28W-7Cr alloys.

The intergranular cracking (IGC) produced in Hastelloy N (or HN80M) -type alloys when exposed to this chromium telluride-salt mixture can be reduced by adding niobium or aluminum to the Ni base alloy or by controlling the oxidation potential of the salt in the reducing range. It was shown that both Re and Y additions only slightly increase the alloy's resistance to tellurium cracking. The alloy doped with Nb alone significantly increases IGC resistance. The alloy containing both Ti and Nb did not provided required resistance to tellurium corrosion. Addition of Mn gives a significant increase in alloy resistance to tellurium IGC. HN80MTY alloy is the most resistant to tellurium IGC of Ni-base alloys under study.

After materials exposure in the fuel salt with the [U(IV)]/[U(III)] ratio from 1 to 100 there was revealed no traces of tellurium intergranular cracking on specimens surface. Te IGC was found on tested alloys only after exposure in fuel salt with [U(IV)]/[U(III)] = 500. For each of the tested alloys the intensity of IGC was essentially lower in unstressed state than in stress condition.

Study on deuterium permeation through nickel-based HN80MTY and EM721 alloys is also carried out. Temperature dependences of deuterium solubility, coefficients of permeability and diffusion in alloys were built.

The practical realization of the system under consideration highly depends on the further experimental investigations of the chemical and physical properties for the chosen fuel / blanket salts and metallic materials. The status of technology and planned development activity is discussed in details.