An Active Laboratory Scale Facility for Molten Salt Electrorefining Studies

EXECUTIVE SUMMARY

Molten salt electro-refining is pyrochemical method ideally suited for reprocessing metallic fuels-The development of which is very important for metal fuel cycle. A laboratory scale facility having high purity argon atmosphere with <20 vpm of moisture and oxygen has been used for the last twelve years for studies on uranium based alloys. The facility has been made suitable for handling radioactive samples and electro-refining studies on plutonium bearing material have been initiated

OUTLINE

Molten salt electro-refining offers several advantages such as less number of steps, reduction in cooling time etc. over the aqueous methods for reprocessing metallic fuels. It is a high temperature electrochemical process operated at 773 K and uses molten salts such as LiCl-KCl which are sensitive to moisture. The actinide metals handled by the process are highly pyrophoric. Hence a high purity argon atmosphere has to be maintained in the facility in which molten salt electro-refining has to be carried out.

The electro-refining process exploits the differences in the thermodynamic stabilities of the chlorides of actinide fuel materials, U and Pu and those of the fission products to achieve the separation. It uses LiCl-KCl eutectic as electrolyte, spent fuel as the anode and molten cadmium or a solid rod as the cathode. There is no experience with this process in our country and has to be developed for the first time.

A high purity argon atmosphere laboratory scale facility for carrying out studies on molten salt electro-refining process was set up and is being operated for the last twelve years (Fig. 1). It comprises five interconnected glove boxes. It is has integrated systems for argon gas feed, exhaust, purification and recirculation. The system is maintained at a negative pressure of 25-40 mm with respect to the ambient, as it has to handle radioactivity. The argon gas inside the facility is monitored periodically for the oxygen and moisture contents. which are maintained below 20 vpm each.

The facility incorporates equipment for salt preparation, electro-refining at 773 K , distillation of salt/cadmium and an induction heated facility for reaching temperatures upto 1400 K for melting the actinide metal residues obtained after distillation of cadmium and salt. The facility has been extensively used for the studies on uranium based alloys such as U-Zr, U-Ce-Pd etc. for determination of the separation factors for Zr, Ce and Pd. Injection casting of U and the U alloy rods have also been carried out in this facility

The necessary leak tight conditions for handling radioactitvity were ensured and electro-refining experiments have been initiated. Considering the fact that even worldwide very few studies on electro-refining have been carried out especially on plutonium bearing alloys, the development assumes significance. About 20 g Pu metal was taken and equilibrated at 773 K with LiCl-KCl eutectic salt containing stoichiometric quantities of $CdCl_2$. About 7 g of $PuCl_3$ was loaded in the electrolyte salt.

Electro-refining experiments were carried out using Pu metal immersed in cadmium metal as the anode, the above salt as the electrolyte and a solid rod as the cathode. Dendritic deposit of Pu metal (Fig.2) was obtained on the cathode which was covered with the electrolyte salt. The metal deposit was melted by dipping the cathode rod in a crucible containing excess of LiCl-KCl. Globules of metals obtained are being characterized. Characterisation of the salt, deposit and anode samples are in progress for working out the material balance.

Fig. 1 : Electro-refining cell inside glove box

Fig. 2 : Pu metal deposited on solid cathode

ADDITIONAL INFORMATION ABOUT PYROCHEMICAL REPROCESSING

Pyrochemical Reprocessing techniques use molten salts and molten metals at high temperatures to achieve the separation of fuel materials and other constituents of the spent fuel for enabling refabrication of fuel pins using the fuel materials thus recovered. Molten salt electro-refining is a pyrochemical method that is considered ideally suited for reprocessing metallic fuels.

GENERAL EXPLANATION RELATED TO THE DESCRIPTION

U-Pu-Zr alloys are, in general, used as the metallic fuels in sodium cooled fast reactors. In India, it is proposed to introduce metal fuels in FBRs in the next decade. Molten salt electro-refining offers several advantages over the currently developed and practised aqueous reprocessing methods for reprocessing the metallic fuels. Hence there is an urgent need to develop the molten salt electro-refining process. and other associated process steps.

In this process, as shown in the schematic diagram (Fig. 3), spent fuel cut into pieces and immersed in the electrolyte salt of LiCl-KCl is the used as the anode and a solid rod or molten cadmium cathode is used as the anode. It is possible to separate U from the spent fuel and deposit it on the solid cathode whereas co-deposition of U and Pu is possible on cadmium cathode. The salt covering the metal deposit on a solid cathode or the cadmium in case of cadmium cathode is distilled off and the residue of U/Pu metals are melted to recover them as buttons.

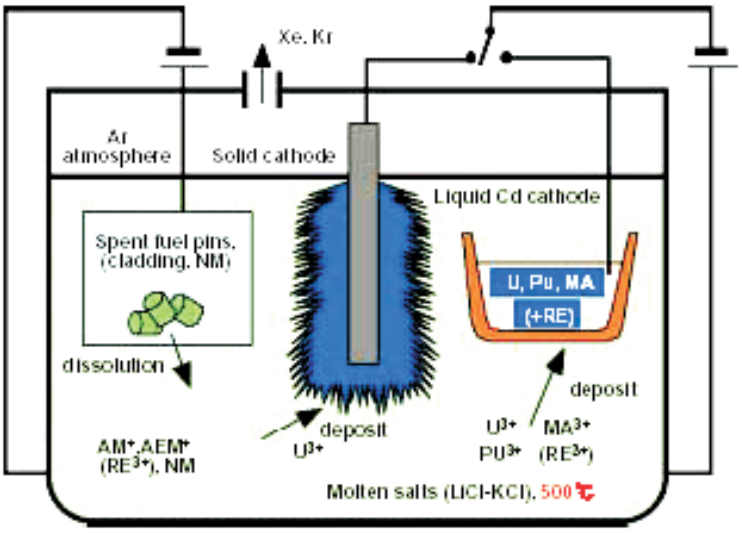

Fig. 3 : Schematic diagram of the molten salt electro-refining process

THERMODYNAMIC BASIS FOR SEPARATION

The chlorides of the alkali, alkaline earth and the rare earth fission products are more stable than those of U and Pu whereas those of noble metal fission products are less stable. Thus in the process, U and Pu are transported to cathode and deposited, the alkali, alkaline earth and rare earth fission products go to the salt and stay there. Noble metals remain in the anode itself.

ACHIEVEMENT

There is little experience in this technology in this country. The technology is complex in view of the high temperature and high purity requirements. Experience with the process operation especially on active samples will give inputs for designing a future reprocessing plant based on this process. Thus commissioning of an active facility for forms an important milestone for metal fuel cycle.

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