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Corrosion of Steel by Lead Bismuth Eutectic

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Task 3

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BACKGROUND

Materials for transmuter systems need to be able to tolerate high neutron fluxes, great temperatures, and chemical corrosion. For lead bismuth eutectic (LBE) systems, there is an additional challenge in that the corrosive behaviors of materials in LBE are not well understood. Additionally, the database for materials performance in LBE is poor. Most of the available information has come from the Russian programs. These programs focused on the engineering requirements of the LBE systems and not on the corrosion chemistry and mechanisms. As such, these studies do not provide adequate insight with regards to the interactions between LBE, steels, and the corrosion process.

This research program will analyze various steel samples that have been exposed to LBE as part of the national program to develop LBE and transmutation technologies. This information will be paramount in developing engineering efforts to control, avoid, and/or minimize the effect of corrosion of steels by LBE in transmuter and LBE systems. Additionally, this program provides UNLV researchers with hands-on experience that will be crucial in developing the UNLV LBE program, supporting the University's mission with the ISTC target complex, and the future development of additional facilities to examine LBE systems.

OBJECTIVES

The research group plans to test the hypothesis that oxygen in lead and bismuth corroborates the corrosion processes between lead bismuth eutectic, steels, and other system components by examining the evidence left in the corroded layers of the exposed steel samples. Data will provide the elemental composition of the samples and the spatial distribution of elements, both before and after corrosion. This should allow researchers to determine the chemical species present and their spatial heterogeneity, the chemical reactions occurring in the LBE/steel system, and the dependence of the chemical reactions upon composition, temperature, and time. During this work, the program also plans:

- To elucidate the mechanism(s) and kinetics of corrosion in LBE/steels, which have not been studied in detail;
- To determine the signature of chemical species in samples of steels previously in intimate contact with LBE;
- To determine the forms of solid oxides from corrosion products and lead and bismuth; and,
- To measure the different responses of different kinds of steels to LBE.

ACCOMPLISHMENTS

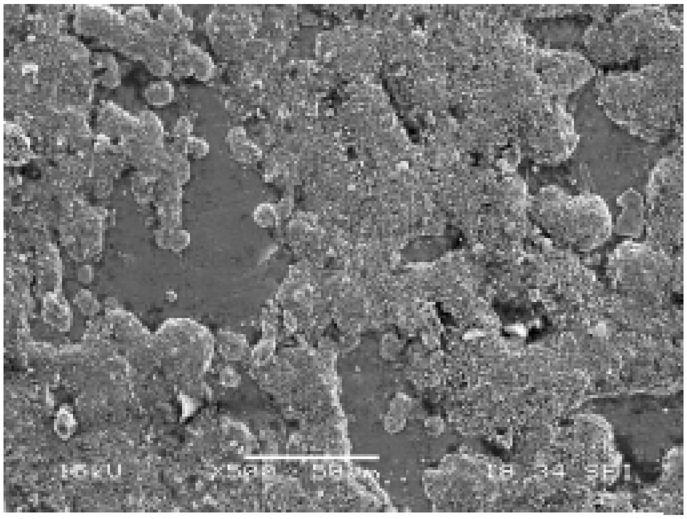
Numerous techniques have been employed for the analysis and characterization of samples. Four techniques, Electron Probe Microanalysis, Micro-Raman, X-ray photoelectron/Auger spectroscopy (XPS/Auger), and powder X-ray diffraction, employ laboratory instruments available at UNLV. One technique, which makes use of the X-ray fluorescence microprobe, requires use of the Advanced Light Source (ALS) at Lawrence Berkley National Laboratory (LBNL).

Several of these techniques examined those samples of stainless steel exposed to LBE in experiments conducted by the Russians. Los Alamos National Laboratory provided the samples to UNLV (through a contract with IPPE, Russia). Samples not exposed to LBE were also analyzed. Verification of the Russian sample analysis was completed in addition to the other analyses.

Graduate student Dan Koury found important differences with regards to oxygen and chromium in LBE corroded samples and fresh samples. An oxide layer, 1 micron thick, covered some areas while other areas were not covered. Additionally, it was observed that, while oxygen was present in LBE exposed samples, oxygen was absent from samples that were not exposed to LBE.

Sputter depth profiling was performed on the steel samples exposed to LBE at a Russian laboratory. Removing the outer layer of contamination via sputtering permits analysis of material further down in the sample. Preliminary analyses done at UNLV on the XPS resulted in a plot of elemental abundance as a function of depth at one location on the steel-LBE sample.

Professors Johnson and Farley with the XPS.



SEM of 316 steel sample exposed to LBE for 2000 hours at 450 C. EDAX analysis was performed on different, highly localized areas. A quick glance shows that some areas are covered with corrosion.

CONTINUED PROGRESS AND FUTURE GOALS

Evaluations of the fate of metal components following LBE exposure will be investigated. This should determine if metal components were dissolved into the LBE or left behind at the base of the corrosion layer as the corrosion layer grew. Advantages and disadvantages of sputtering at grazing incidence and at normal incidence have been identified, and will be used to direct future XPS investigations.

Additionally, a plethora of data (primarily XPS data) is currently being analyzed and provides enough material for at least one or two more scientific papers. Data acquisition from Laser Raman Spectroscopy, which will allow researchers to determine chemical species, is scheduled to begin after June 2002.

The results of this work are being presented to the scientific community. Currently, Allen Johnson plans to present at the 2002 AVS meeting in Denver (November 2002), and Dale Perry presents findings at the FACCS meeting in Boston, November 2002.

HIGHLIGHTS

- Completion of a M.S. graduate thesis by Dan Koury in August 2002.
- Student visits to national laboratories: Graduate students Dan Koury and Brian Hosterman to LANL, and undergraduate student Denise Parsons to ALS/LBNL.
- A new XPS facility was installed.
- The presentation of findings from EDAX and XPS at the 2001 Winter meeting of the American Nuclear Society in Reno, NV by graduate student, Dan Koury.
- A peer reviewed and revised conference paper was submitted to the Journal of Nuclear Materials and accepted for publication in 2002.
- Dan Koury presented findings with regards to oxygen and chromium content in samples to a delegation from DOE headquarters.
- A graduate project initiated by Brian Hosterman, who joined the research group in Fall 2001, examines LBE samples using the laser Raman system at UNLV. Data collection began in June 2002.
- Participation by undergraduate student, Denise Parsons, who brings experience from work carried out at the Nevada Test Site and the Yucca Mountain Project.

Brian Hosterman, Dan Koury, and Prof. Farley take a break from the ANS meeting in Reno, November 2001.

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