

Investigation of effect by the late-phase release of boron-containing atmosphere on CsI deposit formed on reactor structural material SUS304L

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The gaseous species interaction with the early FP deposits (mostly Cs and I) on the surface of reactor coolant system (RCS) material is considered as one of the factors of gaseous iodine generation at the late phase and could affect the containment atmosphere. In this study, we investigated the reaction of CsI deposit formed on stainless steel type 304L with the steam-boron flow. The experiments for reproducing the RCS temperature gradient in the range of 1000–400 K showed a significant depletion of CsI at 850 K, resulted in the formation of low volatile cesium borates on the former surface, and simultaneously released gaseous iodine that could reach a range below 400 K.

Keywords: Cesium iodide, boron, thermal gradient tube, cesium borates, SUS304L

1. Introduction

The results of Phebus-FP experiments [1] had shown that the volatile radioactive fission products (FP) such as iodine and cesium after being released from degraded fuel in the event of nuclear severe accident (SA) could be transported to the reactor coolant system (RCS) and the contained building. During the transport, Cs and I can cause chemical reactions and significantly deposit on the surface of the RCS materials as CsI [1]. In the event of a late-phase release of boron, the stable deposit of CsI and the generation of gaseous iodine are likely to be affected by chemical interaction with steam-boron flow. This late phase release of gaseous iodine should be considered in SA analysis, but there is limited data on the reaction. Therefore, we performed an experimental study using a thermal gradient tube (TGT) to investigate the possible mechanism of gaseous iodine formation due to the interaction of CsI deposits with a high-temperature steam atmosphere containing boron.

2. Experimental method

The experimental setup called TeRRa [2] was used to simulate the chemical interaction of simulant FP during the transport to the lower temperature regions. The experiment was divided into two sequences: (1) vaporization of CsI from alumina crucible and deposition on the TGT with temperature 1000–400 K, and (2) introduction of boron-containing atmosphere. After that, the inner parts of TGT and the filters located downstream of TGT were taken and dissolved in NaOH solution for the measurement of deposition amount of Cs, I, and B by ICP-MS. The deposits on the sampling coupons at various temperatures were separately analyzed using SEM/EDS, XRD, and Raman spectrometer.

3. Results and discussion

The deposition profiles in the TGT for Cs, I, and B are presented in Figure 1 (a). At the initial deposition, CsI was largely deposited at 850–800 K. After introducing boron, the deposit at 850 K was confirmed to be unstable and tend to re-vaporize (primarily as CsI vapor/aerosol). This revaporization caused a significant decrease of such deposits (i.e. 41% of Cs and 76% of I). Following the revaporization, the CsI was then re-deposited at 800–750 K. At the downstream of TGT where the temperature was lower than 400 K, the gaseous iodine was accumulated in the gas trapping system. Greater boron retention at 850–800 K in TGT was likely to induce such gaseous iodine generation, which is initiated by the chemical interaction with predeposited CsI. The Raman spectra of samples at this location supported this inference where cesium borates (tetra- and pentaborate) were identified (Figure 1 (b)). In the scope of the present investigation, the role of steam-boron atmosphere for inducing gaseous iodine generation at late phase had been confirmed. Thus, this role should be considered for the evaluation of iodine in the SA analysis.

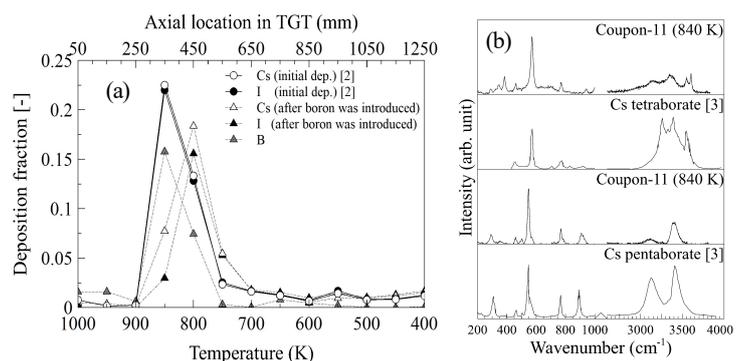


Figure 1. (a) Deposition profile of Cs, I, and B in TGT at initial deposition [2] and after boron was introduced; (b) raman spectra of sampling coupon

References

- [1] N. Girault et al., *Ann Nucl Energy*, 2013, 61, 143–156. [2] N. Miyahara et al., *J Nucl Sci Technol*, 2020, 57(12), 1287–1296. [3] Z. Lixia et al., *Russ J Inorg Chem*, 2007, 52, 1786–1792.