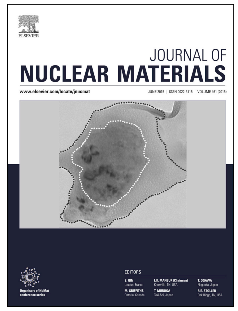
Accepted Manuscript



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Hai-yan Jiang, Wei-hua Wang, De-lin Chu, Wei Lu, De-sheng Cheng, Yi-na Huang, Yu-cheng Wu

PII: S0022-3115(16)30381-6

DOI: 10.1016/j.jnucmat.2017.07.034

Reference: NUMA 50406

To appear in: *Journal of Nuclear Materials*

Received Date: 7 July 2016

Revised Date: 24 June 2017

Accepted Date: 2 July 2017

Please cite this article as: H.-y. Jiang, W.-h. Wang, D.-l. Chu, W. Lu, D.-s. Cheng, Y.-n. Huang, Y.-c. Wu, Corrosion-erosion tests of fusion reactor materials in flowing nanofluids, *Journal of Nuclear Materials* (2017), doi: 10.1016/j.jnucmat.2017.07.034.

Corrosion-erosion tests of fusion reactor materials in flowing nanofluids

Hai-yan Jiang [a,b], Wei-hua Wang [a,c,]*, De-lin Chu [c], Wei Lu [c], De-sheng Cheng [c],

Yi-na Huang [b], Yu-cheng Wu [a,d,]*

[a]*School of Materials Science and Engineering, Hefei University of Technology, Hefei 230009, China*

[b]*School of Electronic Science & Applied physics, Hefei University of Technology, Hefei 230009, China*

[c]*Institute of Applied physics, Army Officer Academy of PLA, Hefei 230031,China*

[d]*National–Loca Joint Engineering Research Centre of Nonferrous Metals and Processing Technology, Hefei 230009, China*

Abstract: The rotating experimental devices are designed to investigate the compatibility of fusion reactor materials with Al_2O_3-water nanofluids. The specimens are exposed to different mass fraction nanofluids with relative flow velocity of 1.00-3.25 m/s at 70 ºC for 1224 h and 2136 h. Surface morphology and component analysis of the test specimens are characterized by SEM, EDS and XPS analysis. The preliminary results indicate that the compatibility of RAFM and 316L(N) steel with nanofluids is better than that of CuCrZr alloy. Metallic oxide film with pitting holes and cracks is detected on the surface of CuCrZr alloy, and its morphology is strongly influenced by the test duration, flow velocity and mass fraction of nanofluid. The dominating factor of the corrosion behavior is probably the couple effect of chemical corrosion and mechanical erosion.

Key Words: Corrosion-erosion; Fusion reactor materials; Nanofluid; Couple effect

1. Introduction

The concept of nanofluid was first proposed by Choi and his colleagues in 1995, which was expected to demonstrate high thermal conductivity by adding nanoparticles into heat transfer fluid [1]. Many of experiments and theoretical research focus on heat transfer of nanofluid in recent years. These studies indicate nanofluid has important engineering values for the improvement of 30% on the thermal conductivity and increment of the critical heat flux (CHF) by a factor of 2 or 3 [2-4]. Due to its great merits, nanofluid proves to be a powerful coolant used widely in heat transfer.

The cooling water system (CWS) is one of key issues to promote the safe operation of ITER [5,6]. The CWS is designed to transfer heat duty about 1.1 GW generated in Tokamak cooling water system (TCWS) and component cooling water system (CCWS) to environment. Demineralised water has been recommended as coolant for the primary circuit system. The testing water parameters are low conductivity (<0.1 μΩm/cm at 25℃), low chloride and fluoride (<1 wppb) and hydrogen addition (up to ~ 2 ppm). And the system is designed free from oxygen, however during plasma burns hydrogen peroxide (5-10 ppm) will be generated as a strong oxidant [7]. The flow velocity of water in the closed TCWS loops is limited ~ 6m/s and less than 4m/s in the CCWS pipes. The 316L(N) steel is used as the main structural material of water cooling pipe lines and shielding blanket [8]. Reduced activation ferritic/martensitic (RAFM) steel is chosen as the main structural material for ITER test blanket modules (TBMs), and CuCrZr alloy is proposed for heat sink material in the first wall (FW) and divertor [9,10]. For the circumstances mentioned above, some researchers suggest that the use of nanofluids as candidate coolant, instead of water, promises to enhance the heat transfer performance and the CHF of the high heat flux components [4,11-13].

The ITER is designed to operate steadily more than 20 years of duration. When materials are