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Characterizations of thermal stability and electrical performance of Au-Ni coating on CuCrZr substrate for high vacuum radio-frequency contact application

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Abstract

Radio-frequency (RF) contacts—which are an example of electrical contacts—are commonly employed on accelerators and nuclear fusion experimental devices. RF contacts with a current load of 2 kA for steady-state operation were designed for application to the International Thermonuclear Experimental Reactor (ITER) device. In contrast to the typical working conditions of general commercial electrical contacts, those of RF contacts employed on fusion devices include high vacuum, high temperature, and neutron radiation. CuCrZr is currently of interest as a base material for the manufacture of louvers of RF contacts, which has excellent thermal and electrical properties and has low creep rate at 250 °C. In this study, a hard Au coating (Au-Ni) was electroplated on CuCrZr samples and the samples were then subjected to thermal aging treatment at 250 °C for 500 h in order to simulate the vacuum-commissioning process of the ITER. The effects of thermal aging on the hardness, elastic modulus, crystallite size, and compositions of the coating were investigated via microstructural and mechanical characterizations of the coating material. Metal atom migration in different coating layers during thermal aging was characterized and evaluated via scanning electron microscopy/energy dispersive X-ray spectroscopy observations of the cross-sectional surfaces, and the obtained results could be used to directly select the coating thickness for the final RF contact component. The contact resistance—an important parameter of the RF contact—was measured in a dedicated testbed built to simulate fusion reactor conditions between CuCrZr pins and stainless steel plates coated with Au-Ni and Rh, respectively.

Keyword: Au-Ni coating, thermal aging, diffusion, contact resistance

1. Introduction

Electrical contacts that operate under alternating current (AC), e.g., radio-frequency (RF) contacts, are commonly employed on large-scale scientific research devices in several fields such as high-energy physics and nuclear fusion [1, 2]. Electrical contacts employed on accelerators or nuclear-fusion-related research devices differ from general commercial electrical contacts mainly in terms of the specific working conditions: electrical contacts operate under conditions of long periods of high-temperature (250 °C) baking to attain ultrahigh vacuum and are subjected to high heat loads owing to ohmic losses during operation.