Composition Dependence of Resistivity of Ru-Mo-W ternary system and single crystal wire growth by the dewetting micro-pulling-down method

Kotaro Yonemura[1,2], Rikito Murakami[2], Shiika Itoi[3], Kei Kamada[3,4], Takahiko Horiai[4], Takashi Hanada[2], Akihiro Yamaji[4], Masao Yoshino[4], Hiroki Sato[4], Yuji Ohashi[4], Shunsuke Kurosawa[4], Yuui Yokota[2], and Akira Yoshikawa[2,3,4]

[1]*Graduate School of Engineering, Tohoku University, Sendai, Japan*
[2]*Institute for Materials Research, Tohoku University, Sendai, Japan*
[3]*C&A Corporation, Sendai, Japan*
[4]*New Industry Creation Hatchery Center, Tohoku University, Sendai, Japan*

Recently, we have developed Ru-Mo-W single crystal alloy wires (Ruscaloy) by the dewetting micro-pulling-down (μ-PD) method[1] for the heaters of the vacuum evaporation method. Ruscaloy have higher electrical resistivity and approximately three times longer lifetime than that of Ta at 1873 K. μ-PD method causes macro segregation during crystal growth, therefore the Mo and W composition of wire may be different from the target composition. However, the relationship between composition change and crystallization yield of the alloy wire has been incompletely understood. Moreover, composition change may change resistivity. In Ru-Mo and Ru-W binary system, resistivities change in accordance with the Nordheim law[2]. However, the relationship between composition change and resistivities change of Ru-Mo-W ternary system has not been studied. In this study, we investigated the composition with macro segregation of Ruscaloy and the composition with resistivities of Ru-Mo-W ternary alloys along with their compositional change to suggest acceptance criteria for maintaining Ruscaloy quality.

$Ru_{1-x-y}Mo_xW_y$ (x = 0 to 0.42, y = 0 to 0.42) polycrystalline alloys were synthesized using an arc melting furnace with the raw materials of >99.9% purity. $Ru_{60}Mo_{15}W_{25}$ single crystal wire was growthed by dewetting μ-PD method. After the heat treating at 2273 K for 3 hours in high purity Ar atmosphere, wire specimens were cut from different crystallization yield and measured their composition. The resistivities of polycrystalline alloy specimens were measured by the 4-terminal method to investigate the relationship between composition and resistivity despite the effect of crystal anisotropy. A quadratic surface of the composition-resistivity relationship was fitted on the ternary diagram.

$Ru_{60}Mo_{15}W_{25}$ alloy wire with diameters of 0.78-0.80 mm was grown by controlling the maximum pulling-down rate at 100 mm/min. The wire had smooth sides and a stable circular cross-section. The length of the grown wire was 8.04 m and maximum crystallization yield was 45.6 %. The resistivities of polycrystalline specimens increased with both Mo and W composition. Resistivity change with W composition increase was higher than Mo. The details of the wire composition with crystallization yield will be presented.

JSPS KAKENHI [grant number 22K20473]

[1] R. Murakami, A. Yoshikawa et al., ACS Omega. 6 (2021), 8131-8141.
[2] R. Murakami, A. Yoshikawa et al., Int. J. Refract. Met. Hard Mater. 114 (2023) 106235.