Single crystal gowth of Ru-Mo-W-Re alloy wire by the dewetting micro-pulling-down method

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Backgrounds: Recently we have developed a novel Ru-Mo-W alloy (Ruscaloy) wire for resistance heating element that improves energy efficiency in the vacuum deposition method such as for the organic electroluminescent thin film deposition [1]. Ru-based alloys are known its brittleness due to the intergranular fracture, however, the dewetting micro-pulling-down (μ-PD) method enables to make single-crystal wire from the melt [2]. Although Ruscaloy has a melting point of 2345 K, higher melting point and more reasonable value expand the usage (e.g., deposition of columnar scintillators), thus we tried to substitute Ru with Re whose melting point is 3459 K and its cost is 10 times lower. Additionally, reactivity with halides were compared with the conventional polycrystalline Ta wire.

Experiments and results: Raw materials with the purity of >99.9 % were firstly melted into button ingots using arc-melting furnace, and Ru-Mo-W-Re alloy wires were grown by the dewetting μ-PD method using yttria doped zirconia crucible. The diameters of the grown crystals were 0.8 mm and the length were 14.2 m as maximum. The grown crystals were cut and annealed at 2273 K for 3h in high purity argon atmosphere. Compositional analysis and crystal orientation analysis were performed by wavelength-dispersive X-ray fluorescence spectroscopy (WDX) and electron beam backscatter diffraction (EBSD). Electrical resistivity was measured at room temperature by the four-terminal method, and room-temperature tensile tests were performed.

A grown Ru-Mo-W-Re wire was single crystal oriented in the [2-1-10] direction and showed a maximum tensile strength of 658 MPa and fracture elongation of 89% , showing a suitable level of mechanical properties for heating elements. For compositions with high Re concentration, optimal temperature control was more difficult because the melting points were closer to the zirconia crucible. However, it was demonstrated for the first time that producing wires of a high Re content alloy is possible. The thermodynamic calculations on the solidus temperature and the reactivity with halides will also be reported in the presentation.

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[1] R. Murakami, A. Yoshikawa et al., Int. J. Refract. Met. Hard Mater. 114 (2023) 106235.

[2] R. Murakami, A. Yoshikawa et al., ACS Omega 6 (2021) 8131–8141.