Investigation of shape control criteria for wire fabrication of alloys by the dewetting micro-pulling-down method

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Background:

The micro-pulling-down (μ-PD) method has been widely used as a rapid crystal growth method to study materials such as scintillator crystals. It can also be applied to metallic crystals using ceramic crucibles and is often referred to as the alloy μ-PD method (A-μ-PD method) [1]. The authors have shown that alloy wires with high melting points above 2000°C can be produced [2,3]. On the other hand, it is known that there are problems with the controllability of the crystal shape when using the μ-PD method as an alternative to conventional plastic forming methods. For example, it was empirically known that it was difficult to maintain a diameter error of 1 mm ± 20 μm over several meters, which is required for applications such as spark plugs and resistance heating wires, and that the shape controllability and achievable growth rate varied depending on the material system.

In the conventional μ-PD method, the melt is spontaneously exposed to the visible region through the capillary of the die by the capillary effect, so that the heating power and pull-down speed can be controlled to keep the crystal shape constant by visual observation[4]. In the μ-PD method for low-wetting systems, the melt does not spontaneously pass through the die and the meniscus cannot be directly observed. Therefore, it is difficult to optimize crystal growth conditions. In this study, the conditions for constant crystal shape have been investigated for the μ-PD method in low wettability systems, specifically defined as the dewetting μ-PD method, by focusing on the boundary conditions satisfied by the meniscus formed near the die.

Results & Discussion:

In this analysis, we modeled the wire geometry assuming an axisymmetric field and analyzed the meniscus shape that can be realized under certain crystal growth conditions (crystal diameter, melt properties, meniscus pressure, etc.) using the non-dimensionalized Young-Laplace equation. Fixed and free end conditions were assumed as the boundary conditions that the meniscus satisfies at the die wall, and it was shown that a dynamically stable meniscus can be obtained under either condition. In addition to obtaining the critical pressure for melt leakage, the necessary condition for the contact angle to obtain the target diameter of the wire was also derived. On the other hand, the predicted diameter was less than 70% of the diameter experimentally obtained by crystal growth, suggesting the existence of a shape stabilization process due to the effect of the dynamic contact angle.

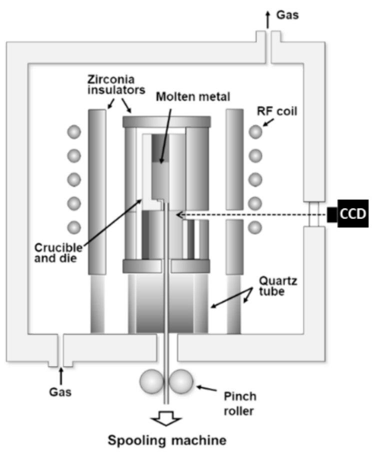

Fig1. Schematic of the dewetting μ-PD method

References

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