Directional Solidification of a Ternary Cu-Fe-Co Alloy under Magnetic Fields

Jun Wang [1*], Zichen Sun[1], Jinshan Li[1], Eric Baugnon[2]

[1] *State Key Laboratory of Solidification Processing, Northwestern Polytechnical University, Xi'an 710072, China*

[2]*Univ. Grenoble Alpes, INSA Toulouse, Univ. Toulouse Paul Sabatier, EMFL, CNRS, LNCMI, 38000 Grenoble, France*

**corresponding author:* nwpuwj@nwpu.edu.cn

Applying a magnetic field during metal solidification influences the microstructure and properties by inducing solute convection and affecting crystal orientation [1-3]. This study investigated the solidification behavior of directionally solidified immiscible Cu-Fe-Co alloys [4] under magnetic fields (0-1 T) at pulling speeds ranging from 5 to 100 μm/s. Increasing the pulling speed transformed the microstructure from cellular to fibrous, increasing the Fe–Co phase fraction by 13% and decreasing the phase size. Magnetic fields produced rate-dependent effects: at low pulling speeds (5 μm/s), dendrites coarsened with irregular interfaces and Cu-rich segregation due to magnetic damping, at high speeds (100 μm/s), enhanced thermo-electromagnetic convection refined the dendritic spacing. Magnetic fields suppressed solute transport, resulting in increased Cu entrapment within Fe–Co dendrites, as confirmed by EDS analysis. They also induced crystallographic reorientation, with a transition from <114> to <104> at 5 μm/s and from <104> to <100> at 100 μm/s. The dominance of the <001> texture was attributed to magnetocrystalline anisotropy. Performance improvements included increased strain gradients at phase interfaces, which enhanced ductility by modifying crack propagation at 100 μm/s. Additionally, room-temperature saturation magnetization increased by 40% due to accelerated <001> magnetization kinetics under a 1 T magnetic field at 100 μm/s. These findings demonstrate the synergistic role of magnetic fields in controlling phase alignment, solute distribution, and overall performance in directionally solidified Cu–Fe–Co alloys.

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