# Abstract

The present study lays emphasis on the effect of varying degrees of undercooling, composition and cooling rate on the microstructure development of the binary Cu-Fe immiscible alloy system. A sufficiently high undercooling was achieved using the aerodynamic levitation (ADL) technique whereas a W-wire holding method in the same ADL setups was employed to attain relatively low undercooling during solidification at critical composition. In addition, solidification experiments were also performed by varying the composition using both ADL and W-wire methods. Thus, the effect of a wide range of undercooling, composition and cooling rates on the phase separation and microstructural development of the Cu-Fe system was systematically investigated.

At critical composition, a range of undercooling was obtained by using ADL and W-wire methods. In varied composition conditions undercooling achieved in the Cu-rich alloys is in the range of 230-250°C (pure Cu: 230 °C, Cu75Fe25: 245 °C.) whereas, the undercooling obtained in Fe-rich alloys is between 70 °C and 93 °C (pure Fe: 93 ° C, Cu25Fe75: 70 °C). In the case of Cu50Fe50 composition, the undercooling of 115 °C was achieved in the samples prepared by the W-wire method. A similar trend between the undercooling and Cu concentration (i.e. increase in Cu concentration increases the undercooling level) is observed in the samples prepared using ADL method. Whereas, the observed undercooling is 20-30 °C higher than the undercooling observed in the W-wire method. Higher undercooling accounts for planner growth front, resulting in a distinct planar surface morphology of pure Cu and Cu75Fe25 samples. The moderate undercooling in the Cu50Fe50 composition produces a cellular surface morphology. In the case of Cu25Fe75 alloy, the low undercooling allows enough time for nucleation and growth of γFe, resulting in a dendritic structure in pure Fe and Cu25Fe75 composition samples prepared by w-wire method. The higher level of undercooling in ADL resulted in the Cu rich composition to form a planner growth front and develops a planar surface morphology in pure Cu and Cu75Fe25 samples. In the case of Fe-rich compositions, relatively lower undercooling promotes cellular surface morphology in pure Fe and Cu25Fe75 samples as analyzed by scanning electron microscopy (SEM). In a substantially undercooled ADL sample, a complete phase-separated micrograph was obtained, but the sample prepared by W-wire or semi-molten condition, although there is a substantial undercooling still complete phase separation does not takes place rather a discontinuous network of Cu in interconnected Fe dendritic areas observed. For the sample prepared using the W-wire method: the tomography revels that the top portion of the sample consists of a Fe rich phase whereas the bottom of the sample is occupied by Cu rich phase. In the case of pure Cu and Fe, a single phase is observed with a void formed by volumetric contraction at the sample's top surface. A core shell structure is observed in all other compositions of the sample prepared by the ADL method, with Fe present in the shell and Cu at the core. The presence of centrifugal force in the ADL process aids in the separation of Fe in the absence of critical undercooling, which is not the case in the semi-molten or W-wire sample as determined by the energy dispersive spectroscopy (EDS). X-ray diffraction (XRD) of the sample cross-section confirms that the phases present at the end of the solidification process are α-Fe and Cu, regardless of the degree of undercooling or composition variation. In the instance of the ADL sample, the entrapment of Cu droplets in the inter-connected Fe dendritic area due to a combination of high undercooling and centrifugal force was detected using X-ray tomography, and the orientation distribution of the samples was determined using Electron Backscatter Diffraction (EBSD).

Keywords: *Immiscible alloy, Aerodynamic Levitation (ADL), W-wire method, Solidification, Undercooling, Cu-Fe Alloy, Phase separation.*