Magnetic Properties and Microstructural Analyses of Cu-Added Rare-Earth-Free MnAl Permanent Magnets

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The MnAl ferromagnetic phase has great potential for industrial applications as one of a family of non-rare-earth permanent magnets due to its large magnetocrystalline anisotropy, high magnetization, high Curie temperature, low cost, and relatively easy processing. This research exploited an induction casting furnace protected by an Ar atmosphere to prepare the τ-MnAl magnetic phase. Considering the appropriate compositions, pure ($Mn_{54}Al_{46}$, known as MnAl), 2 wt. % ($MnAl_{98}$–Cu_2), and 5 wt. % ($MnAl_{95}$–Cu_5) Cu-added MnAl samples were alloyed. The microhardness and bulk density of the melted ingots increased from pure to 2 wt. % Cu alloys accompanied by a slight decrease in 5 wt. % Cu-added sample. XRD and SEM confirmed the formation of the τ, γ, and β phases in all three sets of initially melted ingots. At the same time, it was revealed that the addition of Cu could facilitate the formation of the ferromagnetic τ-MnAl phase in both doped samples.

The research results showed that adding copper stabilizes the τ phase directly and affects the magnetic properties of the MnAl samples, resulting in an increase in the coercivity and remanence. The H_C of the $Mn_{54}Al_{46}$ and the five percent-copper-added samples changed from 250 to 500 Oe, respectively. While the saturation magnetization remained nearly unchanged, the remanence showed an uptrend and increased remarkably from 5.40 emu/g (pure) to 11.62 emu/g (for 5 wt. % Cu). The results of this study show that adding Cu could be beneficial in promoting the magnetic properties of pure MnAl. However, more systematic studies are needed to adjust the proper amount of Cu, especially for final heat-treated samples.

Keywords: MnAl, rare-earth-free magnets, magnetic characterization, copper