

Phase formation in undercooled Sm–Co alloy melts

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Abstract

Sm_xCo_{100-x} alloy melts ($x = 10.5, 12.5$ and 17 at.%) are processed containerlessly by electromagnetic levitation and drop-tube technique in order to get access to the metastable state of the undercooled melt. By dint of undercooling non-equilibrium phase formation is facilitated. The solidified specimen are subsequently analyzed by electron microscopy, X-ray diffraction and thermal magnetic analyses. The results show that different types of solidification behaviors are observed depending on alloy composition and undercooling level prior to solidification. Bulk samples processed by electromagnetic levitation technique are solidified by primary formation of either Sm₂Co₁₇ or SmCo₅, whereas primary phase formation of metastable SmCo₇ is detected in small particles attained by drop-tube processing where cooling rates lie in the order of 10^3 – 10^5 K/s.

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1. Introduction

Sm–Co alloys are important rare earth-transition metal magnetic materials for high temperature applications. In Co-rich composition, two equilibrium phases are formed which determine the properties of traditional permanent magnet materials: SmCo₅ of the hexagonal CaCu₅-type structure and Sm₂Co₁₇ of the rhombohedral Th₂Zn₁₇-type structure. The rhombohedral Sm₂Co₁₇ is related to hexagonal SmCo₅ through the ordered substitution of Sm by a pair of Co atoms (Co dumbbells) resulting in correlated unit cell parameters. Under non-equilibrium solidification a metastable phase, SmCo₇, is found [1,2] which has the same unit cell as the CaCu₅ structure, but a randomized (disordered) arrangement of Co dumbbells on the rare earth lattice sites, and hence different lattice parameters. This disordered arrangement belongs to the TbCu₇-type structure [3].

SmCo₇ is reported to exhibit a lower temperature coefficient of intrinsic coercivity than that of the stable phases [1,2,4,5], and is hence of high interest for application at elevated temperatures. In this work, it is studied how undercooling level and cooling rate enable the metastable phase formation of SmCo₇

and influence the microstructure of the solidified Sm–Co alloy specimen.

2. Experimental

Alloys with composition of Sm_{10.5}Co_{89.5}, Sm_{12.5}Co_{87.5} and Sm₁₇Co₈₃ (at.%) were prepared by arc-melting high purity elemental materials (Co 99.995% and Sm 99.9%) under the protection of an argon atmosphere (99.999% purity). Considering that levitated samples were usually subjected to a loss of elemental Sm during overheating, the effect of changing alloy composition on the formation of SmCo₇ should be considered. For this reason, an excess amount of 10% Sm was added to the three base compositions, Sm_{10.5}Co_{89.5}, Sm_{12.5}Co_{87.5} and Sm₁₇Co₈₃.

Before levitation, an alloy sample of about 1.2 g was placed onto a hollow quartz sample holder and positioned in the levitation coil of an electromagnetic levitation facility, of which the details can be found elsewhere [6]. After evacuation to a pressure in the order of 10^{-6} mbar, the chamber of the levitation facility was backfilled with highly purified helium gas (99.9999%) to a pressure of about 500 mbar. The alloy sample was then levitated and melted under this pressure. In order to attain a substantial undercooling, the sample was shortly overheated to a temperature of 100–200 K above liquidus temperature. Subsequently, the sample was cooled by blowing helium gas onto the

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