ISSN 1062-8738, Bulletin of the Russian Academy of Sciences: Physics, 2009, Vol. 73, No. 9, pp. 1199–1201. © Allerton Press, Inc., 2009.
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Grain Boundary Wetting in the Al–Mg System and Synthesis of Magnesium Diboride in Contact with Melt

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Abstract—The interaction between a Mg-containing melt and B under conditions of partial and complete wetting of Al/Al grain boundaries by Al–Mg melt has been investigated. The study was performed on Al polycrystals with Mg contents of 5, 10, 15, 18, and 25 wt %. Correspondingly, the Mg content in the melt was determined by the liquidus line and was in the range from 5 to 30 wt %. The obtained metal-matrix composites were investigated by light and scanning electron microscopy, electron-probe microanalysis, and X-ray diffraction. The possibility of synthesizing MgB_2 in the contact with a melt having a relatively low Mg content (from 15 to 30 wt %) has been demonstrated.

DOI: 10.3103/S1062873809090056

INTRODUCTION

In 2001 magnesium diboride (MgB_2) was found to have a superconducting transition temperature of 39 K [1]. Since that time, this superconductor has figured prominently in the superconductor technology. Currently, MgB_2-based superconducting wire up to few kilometers long has been commercially produced. Magnesium diboride is a brittle compound; therefore, it is important to develop the fundamental bases of various technologies making it possible to form a plastic metal matrix of sufficiently high conductivity with MgB_2-filled channels or interlayers inside.

Currently, either MgB_2 superconducting channels are formed from a previously synthesized powder or MgB_2 is synthesized in situ. In the latter case, a mixture of boron and magnesium is placed in a tube made of a metal with a sufficiently high melting temperature (copper, niobium, iron, etc.) to react upon heating with the formation of MgB_2. The mixture is heated above the Mg melting point and then B reacts with the Mg melt. However, this method has a number of significant drawbacks.

First, heating should be performed to a temperature above the Mg melting temperature, which is fairly high (650°C). Second, high-temperature synthesis of MgB_2 is generally performed after rolling or drawing a metal rod or bar with the Mg–B reaction mixture inside. Since Mg has a hexagonal lattice, its deformability is low. Recently, an original method has been proposed to increase the deformability of pieces with a metallic shell and a reaction mixture inside to synthesize MgB_2 [2, 3].

In this method, not magnesium but its alloy with about 12 wt % lithium is placed in the mechanical shell before rolling or drawing. This alloy has a bcc lattice and is more plastic than pure magnesium. In this case, boron reacts not with molten magnesium but with the melt containing both Mg and Li. Nevertheless, it was shown in [2, 3] that this technique makes it possible to successfully synthesize continuous superconducting MgB_2 layers.

We proposed to use not only pure magnesium melt but also melts containing other elements, along with Mg, to synthesize MgB_2 in situ. To obtain composites with a plastic metal matrix and superconducting MgB_2-based interlayers, one can also use the effect of the so-called grain-boundary wetting, which has been recently found and investigated in detail by us.

The essence of grain-boundary wetting is that the liquid phase in a number of systems in the two-phase region of the solid solution + melt phase diagrams can completely wet the solid-phase grain boundaries. In this state (Fig. 1), liquid interlayers in equilibrium separate solid-phase grains. Changing the temperature, one can pass from complete to partial wetting and thus change the morphology of liquid channels in the solid matrix (Figs. 1b, 1c). In particular, this effect was found by us in the Al–Mg system [4, 5]. Thus, in a certain temperature range an Al–Mg alloy may consist of solid grains poor in magnesium and interlayers or channels of Mg-rich melt. The concept of this study is that boron would react not with pure magnesium but with a composite where an Al–Mg melt is confined between solid metal grains having a fairly high plasticity.