$MgO/Mg_2Si/MgB_2$ナノ複合結晶の微細構造とその電気・磁気特性

Coherent interface structure and electronic and magnetic properties of $MgO/Mg_2Si/MgB_2$ nanocomposites

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The field of nanocomposites stimulates the study of multiphase material consisting of nanoscale materials with different mechanical, electric, magnetic and optical properties. As for ceramic-based nanocomposites, various sintering techniques, such as spark plasma sintering and hot isostatic pressing have been employed to obtain dense nanocomposite materials with improved interface quality. Although the above sintering techniques are promising, the atomistic mechanisms responsible for the grain boundary diffusion phenomena are often too complex to be controlled, sometimes leading to unwanted grain growth. In that sense, an approach alternative to conventional sintering techniques is desirable for further development and improvement of nanocrystalline ceramics. In this work, we propose a method to synthesize fully dense nanocomposites using solid phase reaction between metallic magnesium and bulk borosilicate glass.

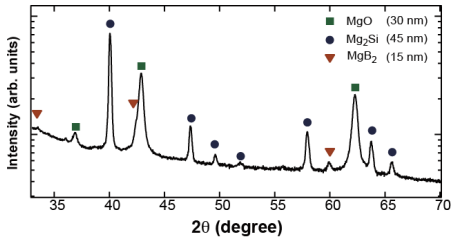

Figure 1. XRD pattern of the nano-composite.

We find that a nearly 100 % dense nanocomposite consisting of MgO (insulator), Mg_2Si (semiconductor), and MgB_2 (superconductor) is obtained without performing post-sintering heat treatments (Fig. 1). Also, the reactions lead to a self-grown periodic layered structure consisting of alternating MgO- and $MgSi_2$-rich layers (Fig. 2). We further reveal that atomically coherent interfaces are formed at the boundary of the MgO- and $MgSi_2$-rich layers (Fig. 3). The resulting composite shows a rather low resistivity of ~a few Ωcm at room temperature although it comprises more than 40 vol% of MgO. Moreover, the nanocomposite shows a semiconductor-superconducting transition at 36 K irrespective of a small volume fraction (~8 vol%) of MgB_2 in the composite. Resistive and magnetic measurements demonstrate that the superconducting transition proceeds in two stages, namely, the intragrain transition at 36 K due to the embedded MgB_2 nanograins and the intergrain transition at ~26 K induced by the Josephson coupled network over the whole of the nanostructures. Thus, the present approach can pave the way towards the creation of high-quality $MgO/Mg_2Si/MgB_2$ interfaces and the related strong Josephson junctions consisting of physically remote but electrically connected MgB_2 nanograins.

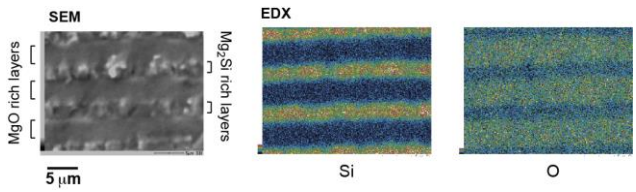

Figure 2. SEM and SEM/EDX images of the nanocomposite.

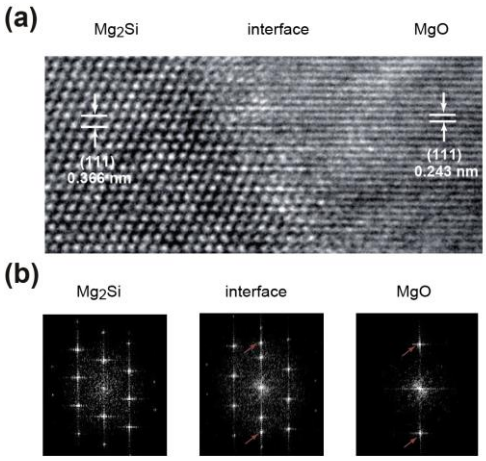

Figure 3. (a) TEM image of the nanocomposite and (b) the corre-sponding Fast Fourier Transform images.