THE EFFECT OF CeO_2 NANOPARTICLE DOPING ON REFINEMENT OF Y-211 PARTICLES IN POIG PROCESSED YBCO COMPOSITES

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Doping of non-interacting nanoparticles in YBCO superconductors in order to get fine microstructure defects has been studied. Y-211 inclusion, itself has large potential to create structural defects without affecting Y-123 matrix phase. Nanoparticles of grain refining agent like $\text{CeO}_2/\text{Pt}/\text{PtO}_2$ are interesting dopants, especially CeO_2 for being cheaper than Pt. POIG process, as is one of the advance processing techniques to get uniform distribution of fine Y-211 particles of the order of 1-2 μm , throughout the YBCO composites. Finer Y-211 particles can drastically increase the pinning centers. Introduction of fine sized CeO_2 as grain refining agent to reduce the size of Y-211 particles would create additional pinning centers. In the present work, the effect of CeO_2 on Y-211 size and distribution in POIG processed YBCO composite was studied. It was observed that with increase in CeO_2 content Y-211 particle size decreases below 1 μm and even less than 0.5 μm for 10 weight percent CeO_2 doping. The mechanism for refinement appears to be the formation of BaCeO_3 on the surface of Y-211 during liquid phase infiltration that leads to splitting of Y-211 into smaller particles.

Keywords: CeO_2 nanoparticles; microstructure of YBCO-Ce composites; refinement of Y-211.

1. Introduction

High critical current density (J_c) is essential for most of the practical applications. High J_c in REBCO material even at high field is due to the effective flux pinning at 211/123. Interfacial defects and structural defects in the 123 matrix which are of the order of coherence lengths of the superconductors¹. Fine Y-211 particle with spherical morphology has more curved 211/123 interface which can improve the pinning of flux

lines. Increase in defect density per unit volume of continuous superconducting matrix can be achieved with fine spherical particles².

In this context, nanoparticle doping into REBCO to improve the flux pinning is of interest. Various groups across the world have studied the doping of nanoparticles such as BaZrO₃, MgO, Al₂O₃, BaCeO₃, PtO₂, CeO₂ etc. Among these dopants CeO₂ and PtO₂ are the most effective as they refine Y-211 particle and increase defect densities³. But CeO₂ is much cheaper than PtO₂ making it viable for most of the practical applications. Very few reports are available in literature for addition of CeO₂ in YBCO through IG process. Since Preform Optimized Infiltration Growth Process (POIGP), gives very fine Y-211 distribution in Y-123 matrix without any grain refiners; it is interesting to see whether CeO₂ could further refine Y-211 in POIG processed samples.

In this paper, study on the effect of nano-CeO₂ on Y-211 particles in a POIG processed YBCO composite is presented. Microstructural study of YBCO composites with 2, 5 and 10 weight percent of CeO₂ with respect to Y-211 content is discussed and compared with YBCO composite processed through POIG process without any dopant.

2. Experimental Details

Synthesis of precursor powders {YBa₂Cu₃O₇ (Y-123) and Y₂BaCuO₅ (Y-211)} and processing of composites are similar to that reported in⁴. Nanoparticles of CeO₂ were introduced into Y-211 preform in 2, 5 and 10 weight percent through a slurry based technique which we refer to as nano dispersed sol casting (NDSC) and then subjected to POIG process after infiltrating liquid Ba₃Cu₅O₈ phase⁴. Now on these samples are referred to as Ce-0 (CeO₂ free), Ce-2, Ce-5 and Ce-10 as per CeO₂ content. The YBCO composites were then sectioned mounted in Bakelite mount and polished down to 0.25 μm. FESEM was employed to investigate the microstructure and histograms were plotted using Axio vision software.

3. Results and Discussion

Microstructures of Ce-2, Ce-5 and Ce-10 at 1000 X magnification, as observed under FESEM, are shown in Figure 1. Histograms of Y-211 particle size distribution in YBCO composites are shown along with the micrographs. In Ce-0 as shown in Figure 1.(a), the size of the Y-211 particles were found to be around 1-2 μm with a distribution width of 2 μm. In Ce-2 composite as shown in Figure 1.(b), size of the Y-211 particles is around 1 μm with a narrow distribution width of 1 μm. A few larger Y-211 particles were found with size around 5 μm. There are some Y-211 free regions observed in the micrograph with non uniform distribution in size of Y-211 particles.

In Ce-5 composites as shown in Figure 1.(c), majority of the Y-211 particles are sized around 0.5 μm and all the particles are below 2 μm, which is finer than the average size of Y-211 obtained in Ce-0 sample. There are still some Y-211 free regions but the distribution of Y-211 particles is more uniform than Ce-2 with some agglomerated Y-211 cluster sized around 2 μm. In Ce-10 as shown in Figure 1.(d) further refinement is

Fig. 1. Microstructure of Ce-0, Ce-2, Ce-5 and Ce-10 at 1Kx as observed under FESEM and corresponding histograms of Y-211 distribution obtained using Axio vision software.

observed in Y-211 particle, large numbers of Y-211 particles are below 0.5mm. There are a few Y-211 particles of 1.5 mm. No Y-211 free regions were found in Ce-10 and fine Y-211 particles are distributed uniformly throughout the YBCO composites.

Substantial refinement and uniform distribution of fine Y-211 particles with CeO₂ addition is a remarkable improvement over Ce-0. Nanoparticles of CeO₂ react with Y-211 in presence of liquid phase to form fine BaCeO₃⁵ of the order of 100 nm. High reactivity on the surface of Y-211 particles due to the presence of nanoparticles of CeO₂ and liquid phase during infiltration process at high temperatures (≈ 1100 °C) leads to splitting of Y-211 into finer Y-211.

4. Conclusions

Nanoparticles of CeO₂ have substantially reduced the particle size of Y-211 than Y-211 in POIG processed YBCO composites. Refinement is proportional to the concentration of CeO₂. Refinement in Y-211 is by splitting during the interaction of CeO₂ and liquid phase on the surface of Y-211 to form BaCeO₃.

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References

1. D. F. Lee, V. Selvamanickam and K. Salama, *Physica C* **202**, 83 (1992).
2. T. Haugan¹, P. N. Barnes, R. Wheeler, F. Meisenkothen and M. Sumption, *Nature* **430**, 867 (2004).
3. M. P. Delamare et. al. *Supercond. Sci. Technol.* **9**, 534–542 (1996).
4. N. Devendra Kumar, T. Rajasekharan, K. Muraleedharan, A. Banerjee and V. Seshubai, *Supercond. Sci. Technol.* **23**, 105020 (2010).
5. N. Vilalta, F. Sandiumenge, S. Pinol, and X. Obradors, *J. Mater. Res.* **12**, 1 (1997).