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Production and Characterization of Superconductor/Polymer Nonocomposites

S.Bhadrakumari [a], M.T.Mathew [b], and P.Predeep [c]

[a]*Department of Physics, M.S.M. College, Kayamkulam, Kerala, India.*

[b] *Dept. of Orthopedic Surgery, Rush University Medical Centre (RUMC), Chicago, USA.*

[c]*Laboratory for unconventional electronics and photonics, NIT, Calicut, Kerala, India.*

Introduction

Electromagnetic shielding using high temperature superconductor (HTSC) plays a vital role in medical industry, high energy physics and electronic industry. However, high T_c superconductors have some inherent problems like brittleness, difficulty in shaping and chemical instability which have impeded the development of their applications. In the recent times, efforts are being made to overcome these difficulties and to achieve the desired physical properties, by preparing high temperature superconductor/polymer composites in nano form.

In recent years, the preparation, characterization, and applications of nanosized materials have received increasing attention in various fields, e.g., chemistry, physics, material science, biology, and the corresponding engineering [1-3]. Since the nanoparticles usually exhibit unusual electronic, optical, magnetic and chemical properties significantly different from those of the bulk materials due to their extremely small sizes and large specific surface areas, they have various potential applications such as catalysts,

electronic, optical and mechanic devices, superconductors, high-performance engineering materials and drug delivery system.

In this study, nanoscale high T_c Yittrium based superconductor (YBCO) filler was synthesized using the microemulsion method. Microemulsion method consists of aqueous domains (termed reverse micelles) dispersed in a continuous oil phase [4-7]. The microemulsion systems were characterized using conductivity and surface tension methods. Linear Low Density Polyethylene (LLDPE), which is used as the polymer matrix in this study, is a semicrystalline material and have a range of properties depending [8] on the amount of crystallinity. The possible applications of superconductor/polymer composites are in the areas of magnetic shielding and levitation where contact from one superconducting grain to another is not essential to the function.

Experimental

Two microemulsions were used to prepare the nanoparticles. The compositions of the two microemulsion systems are summarized in Table 1. Microemulsion I was slowly added in to microemulsion II under stirring, and continuously mixed for 1 hr. The resulting precipitates were washed with a mixture of methanol and chloroform (volume ratio is 1:1), and with ethanol, then dried. After synthesizing the YBCO precipitate, the precipitate powders were calcined under different conditions: 700^{o}C, 750^{o}C, 800^{o}C, 850^{o}C and 900^{o}C separately for 6 hr. The particles obtained using the microemulsion method was characterized using X-ray diffraction. The YBCO/LLDPE nanocomposites were prepared in a Brabender mixer at 140°C for 20 minutes and hot pressed for 30 minutes at 500°C. AFM experiments are carried out with a D3 100 nanoscope from Digital Instruments Inc. (Santa Brabara, CA) in the contact mode.

TABLE 1: Composition of the microemulsion

	Surfactant phase	Oil phase	Aqueous phase
Microemulsion I	CTAB+1-butanol	n-octane	(Y, Ba, Cu) nitrate solution, Total metal conc.=0.26 N
Microemulsion II	CTAB+1-butanol	n-octane	Ammonium oxalate solution, conc.=0.54 N
Weight fraction (for both I and II)	30%	60%	10%

Results and Discussion

The variation of surface tension and conductivity with CTAB (cetylmethyl ammonium bromide) content is shown in Figures 1(A) and (B). Based on the surface tension results, the critical micelle concentration (CMC) of CTAB was 0.4 g/L and the surface tension was 38 dynes/cm.

The conductivity increased continuously up to the CMC and then approached a limited value and hence conductivity measurements can be used to determine the CMC. The powder obtained by the microemulsion method after heat treatment had different colours varying from gray to black. XRD patterns were also different. When the size of the particles was decreased, the heating temperature needed to obtain the YBCO-123 phase was also decreased. The XRD patterns of the composites show that the orthorhombic structure is preserved throughout the entire LLDPE range with no change in the lattice parameter. This indicates that the oxygen content is stable and not affected by LLDPE. Reliable and high quality AFM measurements have been carried out and carefully analyzed for all our YBCO/LLDPE composite samples. A shift in morphology from a flat, continuous form of Y-123 grains in to a more granular structure with higher degree of grain to grain contact is evidenced. Figures 2 represent the AFM image of a composite sample.

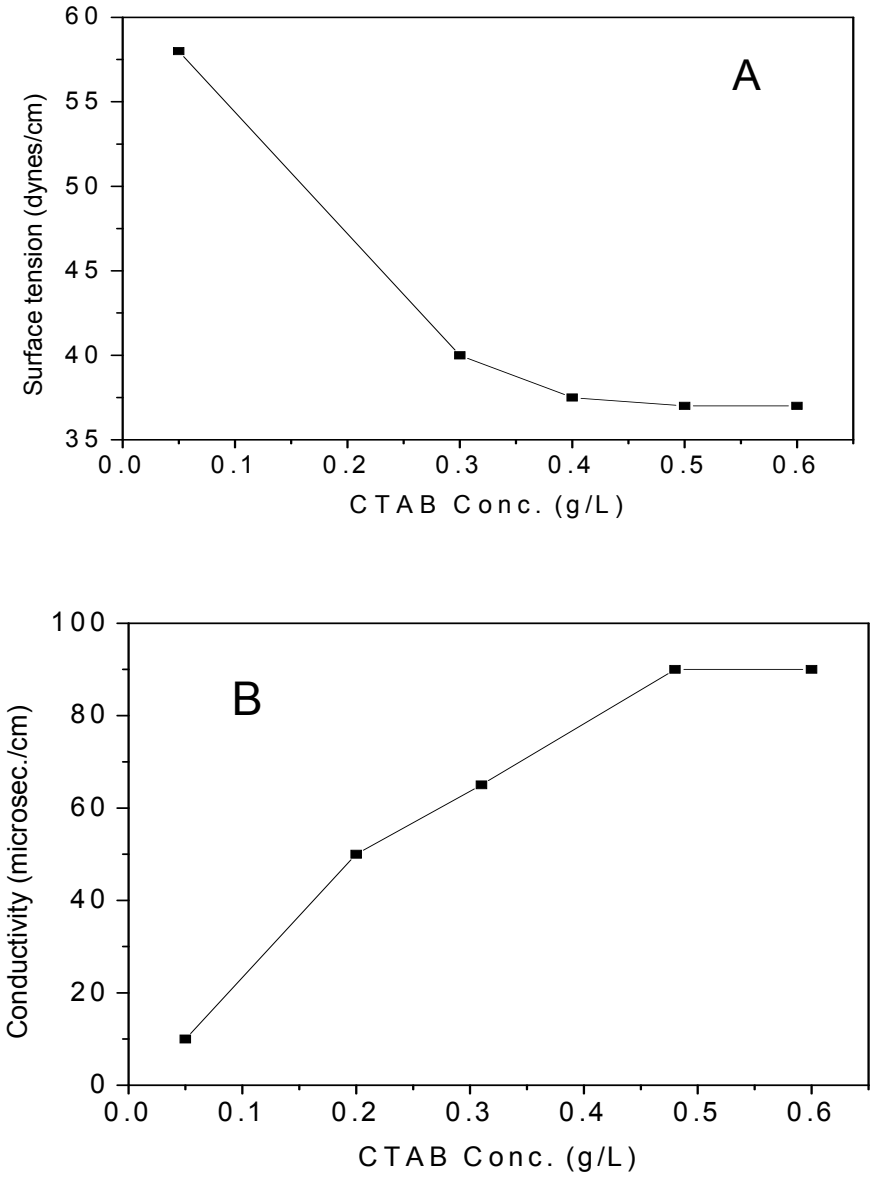

Figure 1: (A) Characterizing the CTAB solutions using surface tension, (B) using conductivity measurements.

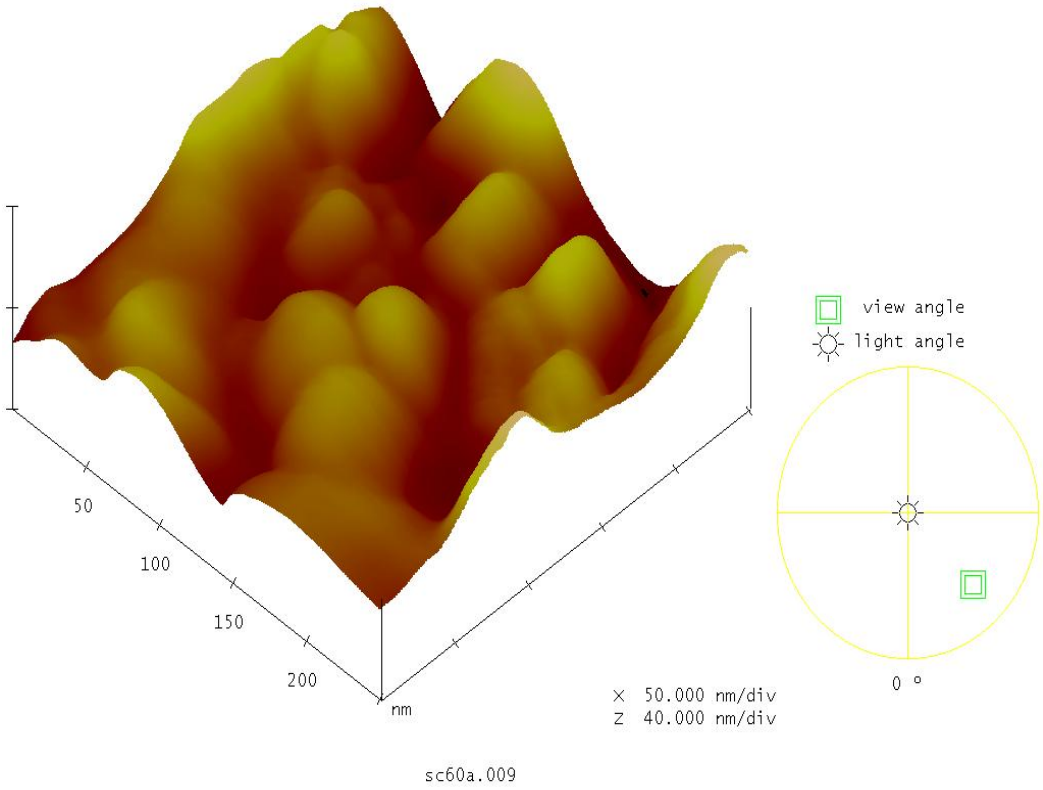

Figure 2 : AFM image of YBCO/LLDPE composite sample.

Conclusions

Nanoscale particles of YBCO-123, with an average diameter of 116 nm are produced using the microemulsion method. When the size of the particles was decreased, the heating temperature needed to obtain the YBCO-123 phase was also decreased, from above 900^{o}C to 800^{o}C. The results obtained from XRD measurements show that the superconductor and polymer remain as two separate phases in the composites. The transformation progression grain by grain at a nanometer scale is observed and the surface morphology of the samples which is an indicator of the internal crystal perfection is also studied by AFM. These results showed that the microemulsion method could be used to produce 123 nanoparticles for YBCO applications.

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