Dielectric Behavior and Non-ohmic Behavior of CCTO/SiO_2 Composites

H. Talebinezhad*, Y. Tong, X. Lu and Z.Y. Cheng
Materials Research and Education Center, Auburn University, Auburn, AL 36849, USA
*Hossein Talebinezhad: h.talebinezhad@auburn.edu

The demand for miniaturization of electronic devices and increasing usage of these devices for many applications required materials with a high dielectric constant. $CaCu_3Ti_4O_{12}$ (CCTO) with a gigantic dielectric constant and strong nonlinear behavior make it a candidate to be used as a varistor.

Although its extraordinary dielectric constant of CCTO, low breaking down field limits its applications. Composites of CCTO with a good insulator have been used to improve the properties of CCTO such as decreasing dielectric loss and increasing breakdown field of composites [1]. SiO_2 is widely used as an insulator [2]. To investigate the effect of SiO_2 on the microstructure of composites, CCTO/ SiO_2 composites with different concentrations of SiO_2 are prepared at different conditions.

CCTO particles were first coated with a layer of SiO_2 by the sol-gel process. The SiO_2 coated CCTO particles were used as raw material to make glass-ceramic composites through the traditional ceramic process. Electrical properties were determined by using an Impedance analyzer in the range frequency of 100 to 1 MHz and I-V curve was characterized with P-E loop tester.

The results illustrate that electrical behavior of CCTO/ SiO_2 composites is sensitive to sintering conditions. This behavior is due to change in the microstructure, especially in grainboundary. The internal barrier layer capacitors (IBLC) model is used to explain the observed properties of CCTO [3]. In this model, grainboundary plays an important role in dielectric properties of the composite. SiO_2 layer makes the grainboundary become more insulator due to resistive properties. Insulative grain boundaries make the improvement in dielectric properties of CCTO as IBLC model.

The I-V results indicate that the breakdown field of the composites is more than 30 KV/cm which is ten times higher than pure CCTO. The I-V curve result can be fitted by Richardson empirical equation [4]:

$$J = A \times T^2 \exp\left(\frac{-\left(\emptyset_B - \beta\sqrt{E}\right)}{kT}\right)$$

where J is the current density, E is the applying electrical field, T is the temperature, k is the Boltzmann constant, A is the Richardson constant for materials, and $\emptyset_B$ and also β are materials properties which are corresponding to the potential barrier height and width, respectively, of interface regain. The results obtained from this method confirm the improvement of barrier in grain boundaries which lead to decrease in dielectric loss by increasing amount of SiO_2 in CCTO grain boundaries.

Reference

1. Chun-Hong Mu, Peng Liu, Ying He, Jian-Ping Zhou, Huai-Wu Zhang. An effective method to decrease the dielectric loss of $CaCu_3Ti_4O_{12}$ ceramics. Journal of Alloys and Compounds 471 (20 09) 137–141.
2. Kang-Min Kim, Sun-Jung Kim, Jong-Heun Lee, Doh-Yeon Kim. Microstructural evolution and dielectric properties of SiO_2-doped $CaCu_3Ti_4O_{12}$ ceramics. Journal of the European Ceramic Society 27 (2007) 3991–3995.
3. Tsang-Tse Fang, Hsu-Kai Shiau. Mechanism for Developing the Boundary Barrier Layers of $CaCu_3Ti_4O_{12}$, J. Am. Ceram. Soc., 87 [11] 2072–2079 (2004)
4. A.A. Felix, M.O. Orlandi, J.A. Varela. Schottky-type grain boundaries in CCTO ceramics. Solid State Communications 151 (2011) 1377–1381.