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Abstract

Hydrothermal Synthesis of Barium Titanate Nanoparticles: The Effect of the Heating System †

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As the technological world evolves, so does the micro- and nano-electronic market. Nano-based electronic devices are becoming more prominent, with it being imperative to develop efficient ways to downsize their components [1]. Furthermore, there is an urge to improve such devices, mainly regarding their battery lives, by making them energetically self-sufficient through energy harvesting techniques, such as piezoelectricity-based techniques [2]. Barium titanate (BT) is a lead candidate for such applications, being well known for its remarkable dielectric and ferroelectric structures, as well as for presenting no risks for human health or the environment [3]. Early synthesis routes of BT nanoparticles were based on a solid-state reaction with the calcination steps of precursors at very high temperatures, leading to high energy expenditure and impurities. Hydrothermal synthesis (HT) is an alternative route that allows the production of well-defined BT nanoparticles at low temperature while controlling the evolution of the particle size and the crystallization degree [4]. This procedure often utilizes conventional oven-assisted heating; however, different heating routes have been coupled to hydrothermal synthesis such as ultrasound and microwave irradiation [5].

In this work, BT nanoparticles were produced via an HT route using two distinct heating systems: conventional oven-assisted heating, and microwave-assisted heating. Syntheses' initial mixtures, temperature and reaction time were kept the same for the two routes in order to compare both systems. The obtained nanoparticles were characterized by X-ray diffraction, Raman and scanning electron microscopy. Furthermore, powders were compressed into pellets for evaluation and comparison of their electrical and piezoelectric properties, using an LCR meter and piezoelectric response force microscopy (PFM). Using microwave-assisted heating, a faster formation of the BT phase was achieved, mainly at low synthesis durations (1 h), presenting a high degree of crystallinity and already identifiable cubic-shaped nanoparticles. The electrical performances, on the other hand, proved to be very similar between the two heating systems.

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References

1. Ashiri, R.; Nemati, A.; Ghamsari, M.S.; Sanjabi, S.; Aalipour, M. A modified method for barium titanate nanoparticles synthesis. *Mater. Res. Bull.* **2011**, *46*, 2291–2295. [CrossRef]
2. Zahid Kausar, A.; Reza, A.; Saleh, M.; Ramiah, H. Energizing wireless sensor networks by energy harvesting systems: Scopes, challenges and approaches. *Renew. Sustain. Energy Rev.* **2014**, *38*, 973–989. [CrossRef]
3. Vijatović, M.; Bobić, J.; Stojanović, B. History and challenges of barium titanate: Part I. *Sci. Sinter.* **2008**, *40*, 155–165. [CrossRef]
4. Liu, S.; Abothu, I.; Komarneni, S. Barium titanate ceramics prepared from conventional and microwave hydrothermal powders, *Mater. Lett.* **1999**, *38*, 344–350. [CrossRef]
5. Komarneni, S.; Roy, R.; Li, Q. Microwave-Hydrothermal synthesis of ceramic powders. *J. Chem. Inf. Model.* **2013**, *53*, 1689–1699. [CrossRef]