Control of phase composition in the hydrothermal synthesis of $Na_{0.5}Bi_{0.5}TiO_3$

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Sodium bismuth titanate, Na0.5Bi0.5TiO3 (NBT), is a complex perovskite extensively studied over past years due to its interesting piezoelectric and ferroelectric properties. The relaxor ferroelectric behavior of the NBT material opens up the possibility for application as a voltage-tunable capacitor. The aim of work was preparation of nano-sized crystalline NBT particles which would be subsequently employed in the form of a thin film. In contrast to other more conventional techniques, the hydrothermal synthesis attracted considerable attention because it enables production of nanosized highly crystalline powders from a variety of inexpensive precursors under moderate temperature conditions.

Several papers reported the hydrothermal preparation of NBT. In addition, Lencka et al. [1] performed thermodynamic modelling, predicting the region of stability for pure NBT phase. Syntheses were based on proposed model and supporting experimental findings.

The hydrothermal synthesis of the NBT powder was performed in a strong alkaline medium. TiO2 (anatase) and Bi(NO3)3·5H2O were used as the titanium and bismuth precursors and NaOH served as a source of sodium cations and to provide a highly basic environment. The influences of various alkaline conditions, the concentration of precursors, the reaction temperature and time on the formation of NBT were studied. The obtained powders were characterized by X-ray diffraction analysis and transmission electron microscopy.

Experimental results revealed that several parallel and consecutive reactions are proceeding in the reaction system, resulting in the formation of NBT along with secondary sodium titanate phases at the beginning of the reaction. Secondary phases arised also at lower alkali concentrations and mild temperature conditions. Both parameters significantly influence the solubility of precursors and the stability of NBT phase and therefore define the final phase composition obtained under chosen hydrothermal conditions. Secondary phase free composition was attained by employment of higher temperatures and stronger alkaline conditions. In addition, an excess of bismuth cations promoted the formation of phase pure product. Our experimental results led us to the conclusion that alkaline conditions ultimately define the crystallization process of NBT phase under hydrothermal treatment, mainly due to the significant contribution to the dissolution of precursors that enabled further recrystallization.

References:

[1] M. Lencka, M. Oledzka, and R.E. Riman, Hydrothermal Synthesis of Sodium and Potassium Bismuth Titanates, Chem. Mater., 2000, 12 (5), 1323–1330