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Morphological Study of 1D Sodium Niobate Nanostructures

Beatriz Rodrigues Canabarro[1*], Paula Mendes Jardim[1]

[1.] Department of Metallurgical and Materials Engineering / Federal University of Rio de Janeiro (COPPE/UFRJ), Rio de Janeiro, Brazil.
*Corresponding author: canabarro@metalmat.ufrj.br

Nanostructured sodium niobate ($NaNbO_3$) has gained scientific attention due to its properties as semiconductivity, piezoelectricity, and photoactivity, that combined can be used as a piezo phototronic device [1]. Motivated by the potential efficiency improvement, this nanomaterial can be synthesized in the nanoscale by alkali hydrothermal route followed by heat treatment at 550°C in a vacuum furnace [2,3]. In this study, it was used metallic niobium platelets as a substrate and also as a precursor, that reacting with NaOH solution generates the oriented growth of sodium niobate nanocrystals onto niobium surface [4]. This material was synthesized varying three variables, temperature (40 - 120°C), alkali concentration (0.25 – 0.75 M), and reaction duration (12 – 36h), following an experimental design 2^3 with three center points (80°C, 24h, 0.50 M), where it was possible to observe the influence of these variables in the sodium niobate layer thickness and in the nanostructure morphology [4]. In order to use this system composed by a nanostructured layer of $NaNbO_3$ supported on metallic niobium as a possible piezo phototronic device, it is necessary to understand its nanostructure organization, such as morphology, crystallographic orientation, growth and polarization directions. Morphological properties of sodium niobate nanostructure were obtained with scanning transmission electron microscopy (STEM), with an acceleration voltage of 300kV and high angular dark field (HAADF) detector, and electron tomography, varying the tilt angle of the sample holder in steps of 2° from -70° to 70°. The results revealed the formation of 1D nanostructured orthorhombic perovskite $NaNbO_3$ ($P2_1ma$) with the formation of facets at the surface, exposing the crystallographic planes (010), (001) and (011) (Figure 1). Electron tomography analyses showed that the dimensions and morphology (nanowires or nanoribbons) of the 1D nanocrystals could change depending on the synthesis conditions. It was observed the presence of nanoribbons in the sample obtained with more severe synthesis conditions ([NaOH]=0.75M, 120°C, 12h) (Figure 2), while it was observed a combination of nanowires and nanoribbons with mild conditions ([NaOH]=0.75M, 40°C, 36h) (Figure 3). In conclusion, it was possible to identify the formation of a layer of an orthorhombic sodium niobate onto the metallic niobium surface, and also the presence of different sodium niobate nanostructure morphologies, synthesized with different alkali hydrothermal route conditions, applying the method of electron tomography with STEM mode. Although it was observed a difference in morphology depending on synthesis conditions, the growth direction observed [001] were the same in both of them. The next step of this study is to understand the polarization direction in the sodium niobate nanostructure.

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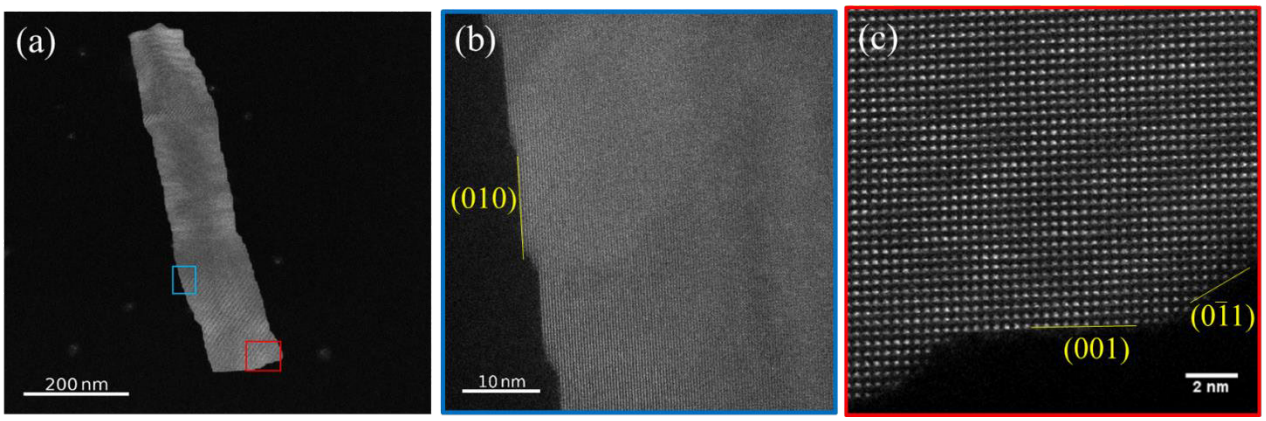

Figure 1. STEM HAADF images of the sample ([NaOH]=0.75M, 120°C, 12h) in low magnification (a) highlighting the regions of high resolution oriented in the zone axis <100> showing the facet planes (010) (b), and (001) and (0-11) (c).

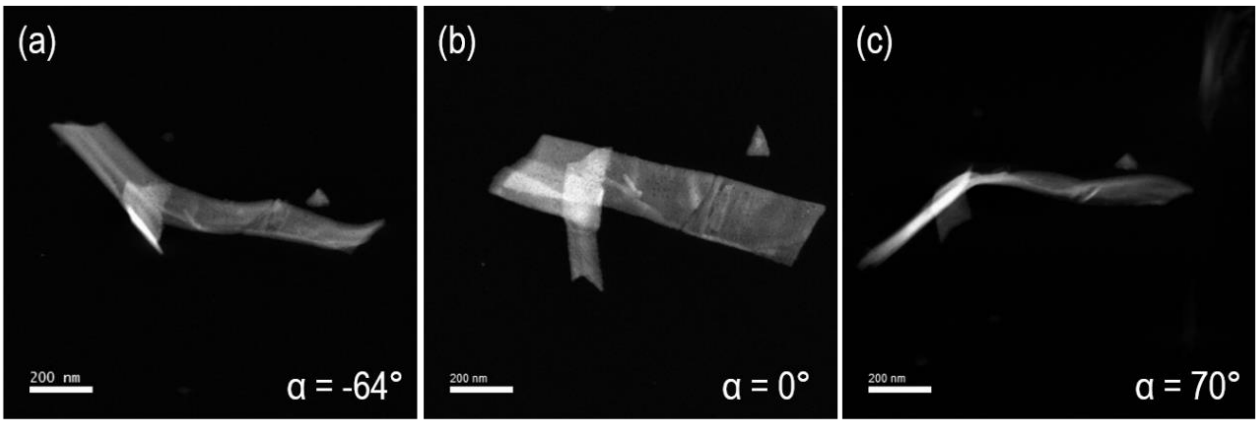

Figure 2. STEM images of the sample ([NaOH]=0.75M, 120°C, 12h) in three different holder tilt angle (α) -64° (a), 0° (b) e 70° (c).

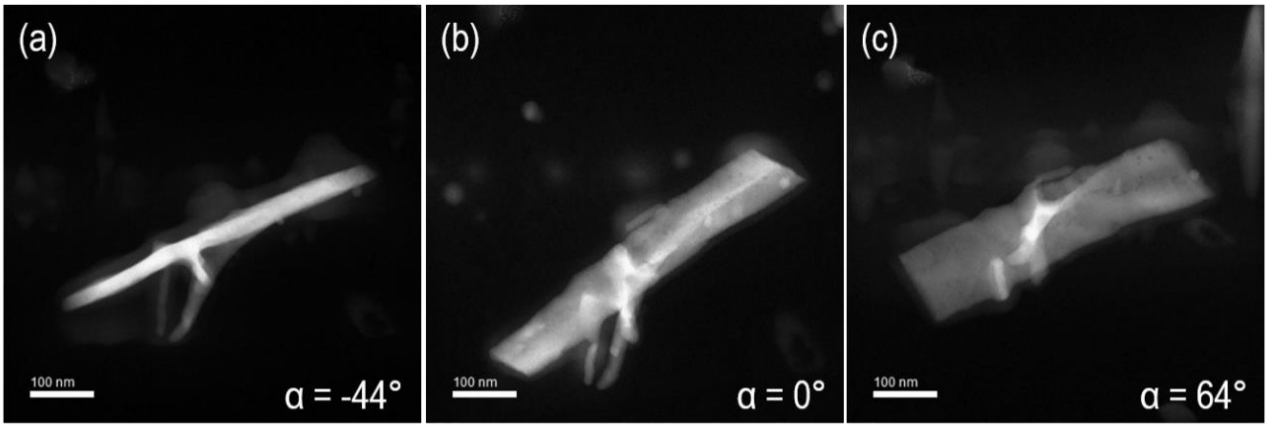

Figure 3. STEM images of the sample ([NaOH]=0.75M, 40°C, 36h) in three different holder tilt angle (α) -44° (a), 0° (b) e 64° (c).

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