$NaNbO_3$ particles in hydrogen production from water electrolysis: Influence of the particle morphology

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ABSTRACT

This work explores an alternative method for producing green hydrogen through water electrolysis. We employed $NaNbO_3$ fiber-like particles as electrodes in an alkaline medium. The fibers were obtained through conventional thermal treatment at 550 °C for 240 minutes from the $Na_2Nb_2O_6 \cdot H_2O$ metastable phase, previously synthesized by a microwave-assisted hydrothermal method. The synthesis of $Na_2Nb_2O_6 \cdot H_2O$ was conducted at 160 ºC for 40 minutes. Electrodes were prepared by dropping a suspension containing $NaNbO_3$ fibers onto a glassy carbon electrode. We compared the use of pure $NaNbO_3$ with $NaNbO_3$ combined with Vulcan carbon. Both conditions demonstrated activity for hydrogen production; however, $NaNbO_3$ combined with Vulcan carbon yielded a higher current density.

Keywords: $NaNbO_3$; microwave assisted hydrothermal synthesis; Vulcan carbon; conductivity, electrolysis.

INTRODUCTION

The global energy crisis is a pressing concern. The processing of multifunctional materials with perovskite structures offers a potential solution to this problem. Among these materials, sodium niobate ($NaNbO_3$) shows promise in producing green energy due to its piezoelectric and catalytic properties. In energy production, the piezoelectric effect allows for the conversion of mechanical energy into electrical energy [1], while its catalytic behavior enables the use of niobates in fuel cells [2] and electrochemical production of green hydrogen [3].

The crystalline structure and particle morphology are critical factors in achieving optimal performance. These characteristics can be controlled through synthesis methods. Both conventional hydrothermal and microwave-assisted hydrothermal synthesis provide excellent control over the crystalline structure and morphology of $NaNbO_3$ [4].

Flexible composites offer significant potential for harnessing piezoelectricity. When $NaNbO_3$ with varying morphologies is immersed in the α-phase of polyvinylidene fluoride (PVDF), the piezoelectric efficiency depends on the shape of the particles [5].

Surface modification and composite formation enhance the catalytic activity of $NaNbO_3$, improving its efficiency for degrading organic contaminants and producing hydrogen through water splitting [6, 7]. However, little is known about how morphology affects hydrogen production through electrochemical methods like electrolysis.

During electrolysis, a direct current causes water to decompose into hydrogen and oxygen gas, making it an economically efficient method for producing hydrogen without CO_2 emissions [8].

Based on these concepts, this work aims to explore the influence of particle morphology on the efficiency of hydrogen production by electrolysis using $NaNbO_3$-based electrodes.

MATERIALS AND METHODS

$NaNbO_3$ was produced by conventional heating at 550 °C for 240 minutes from the $Na_2Nb_2O_6 \cdot H_2O$ metastable phase, synthesized by a microwave-assisted hydrothermal method [1]. The morphology of the prepared $NaNbO_3$ was observed using high-resolution field-emission scanning electron microscopy (FE-SEM, JEOL, JSM-7500F).

Two routes were used to prepare the electrodes:i) $NaNbO_3$ was dispersed in isopropyl alcohol, and ii) $NaNbO_3$ was combined with Vulcan carbon (20% $NaNbO_3$/80% C) and then dispersed in a mixture of Nafion® and ethanol.

Both suspensions had a concentration of 2.0 mg/mL, and 30 µL of each suspension were dropped onto a glassy carbon electrode. Electrolysis was performed in a three-electrode electrochemical cell with a platinum gauze counter electrode and a saturated calomel electrode (SCE) as the reference, in a 1M NaOH medium. Linear sweep voltammetry (LSV) measurements were conducted using a potentiostat/galvanostat (microAutolab TYPE III) controlled by NOVA software (version 2.1.7).

RESULTS AND DISCUSSION

The great advantage of multifunctional materials is the possibility of exploring them for different applications. The $NaNbO_3$ fibers used in the processing of the electrodes were crystallized in a mixture of orthorhombic $NaNbO_3$ phases with the $P2_1ma$ and *Pbcm* space groups. These fibers are the same ones explored in the paper referenced in Reference 1, where readers can find a detailed discussion of the crystalline and morphological structure of the $NaNbO_3$ fibers, based on a combination of experimental and theoretical techniques. FEG-SEM micrographs revealed that the $NaNbO_3$ product consisted of fibers with a wide size distribution (**Fig. 1**).

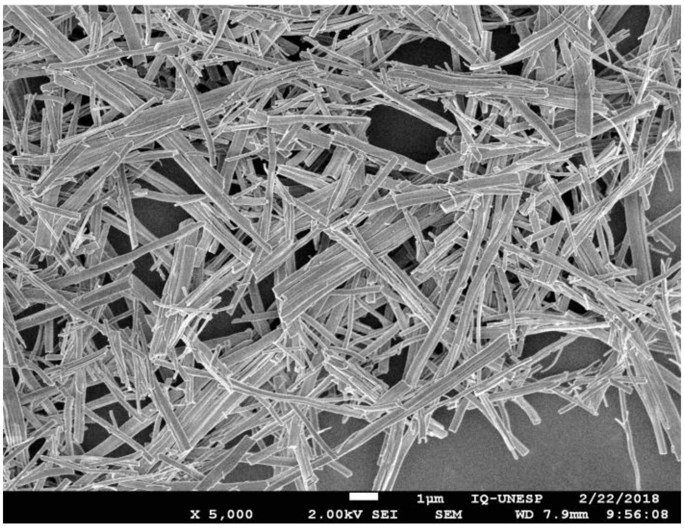

Figure 1. FE-SEM image of $NaNbO_3$-fiber like particles.

As seen in **Fig. 2**, linear sweep voltammetry measurements of $NaNbO_3$-based electrodes show that this material presents electrochemical activity toward hydrogen evolution reaction. In addition, **Fig. 2** shows that the current density for pure $NaNbO_3$ is significantly lower than when $NaNbO_3$ is combined with Vulcan carbon. This difference arises because the morphology of $NaNbO_3$ hinders the compaction of particles on the surface of the glassy carbon electrode. In contrast, Vulcan carbon, being a conductive material, fills the spaces between $NaNbO_3$ particles, improving electronic conduction and consequently increasing the current density for hydrogen production. Besides that, both electrodes showed an overpotential toward hydrogen evolution reaction close to 50 mV.

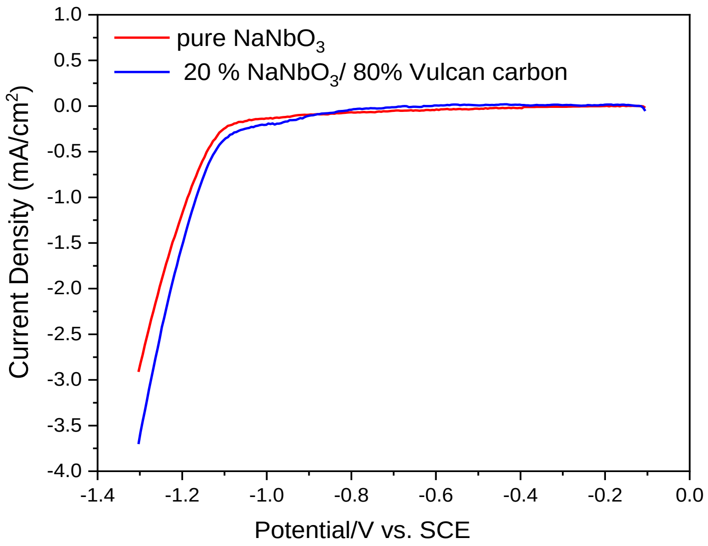

Figure 2: Linear sweep voltammetry recorded at room for $NaNbO_3$-based electrodes.

CONCLUSION

For hydrogen production through electrolysis, the combination of $NaNbO_3$ with Vulcan carbon proved more efficient. To further improve the efficiency of pure $NaNbO_3$, it is necessary to explore material processing methods aimed at modifying the morphological characteristics of the particles.

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