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HYSYCVD Synthesis of 1D Nanostructures of TiO_2

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Abstract In this work, a synthesis route for 1D nanostructures (nanoribbons and nanofibers) of titanium oxide via hybrid precursor systems chemical vapor deposition (HYSYCVD) is proposed. The route is based on the thermal decomposition of K_2TiF_6 (solid precursor) in controlled air atmosphere. Synthesized TiO_2 corresponds to 1D crystalline nanostructures of Anatase, which can find potential applications in the development of thin-film transistor, dye-sensitized solar cells, and dosimeters. The versatility for synthesizing 1D TiO_2 nanostructures by HYSYCVD suggests the potential of the proposed route as economic and large-scale production technique.

Keywords Synthesis, Nanoribbons, TiO_2

1. Introduction

Titanium oxide (TiO_2) is a versatile metallic oxide semiconductor (n-type and 3.2 eV band gap) with a wide range of applications in different technological fields ranging from photocatalyst, chemical gas sensor, self-cleaning coating, antiseptic coatings, spintronic devices, dye-sensitized solar cells (DSSCs), thin-film transistor (TFTs) to dosimeters [1, 2]. Interest in ceramics based on nanostructured metallic oxides, such as, 1D nanostructures of TiO_2 has increased considerably in recent years, owing to their excellent properties and potential applications in TFTs, DSSCs and dosimeters. Nanostructured TiO_2 materials exhibit superior electrical and optical behaviour than the corresponding TiO_2 bulk materials. In addition, TiO_2 displays superior structural and functional properties in comparison with other oxides, and it is considered an efficient material for electronic devices [1, 3]. Crystalline TiO_2 presents polymorphisms, occurring in three polymorphic phases: Rutile, Anatase, and Brookite. The processing conditions and synthesis techniques influence the resulting crystalline structure, the physical and chemical properties. TiO_2 can be obtained by different techniques, such as: chemical solution decomposition, two-step wet chemical method, solgel, ultrasonic irradiation, solvothermal method, hydrothermal route, and chemical vapor deposition (gas precursor systems) [2]. An alternative synthesis method for TiO_2 is the thermal decomposition of solid precursors or hybrid precursor systems chemical vapor deposition (HYSYCVD). Originally, HYSYCVD was developed by Leal-Cruz and Pech-Canul in 2002 [4, 5], It is a modified CVD method based on thermal decomposition of solid precursors under controlled atmosphere for ceramics synthesis, such as Si_3N_4, Si_2N_2O, SiO_2, AlF_3, and Al_2O_3 [6]. In this work, a synthesis route via HYSYCVD in the K_2TiF_6 -air system is proposed with the aim of synthesizing 1D nanostructures of TiO_2 intended for TFTs, DSSCs and dosimeters.

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2. Experimental Procedure

TiO_2 was synthesized via thermal decomposition of solid precursor under controlled air atmosphere in a HYSYCVD reactor [4, 5]. K_2TiF_6 was used as titanium solid precursor and decomposed under the following processing conditions: temperature of 923.15 K, processing time of 2.5 h, heating rate of 10 °K/min, and atmospheric pressure. Prior to TiO_2 synthesis, K_2TiF_6 powders were compacted in a steel die (5 mm of diameter and 1mm of height) by biaxial compaction to obtain preforms. Processed preforms were removed and prepared for their characterization by X-ray diffraction (XRD), field emission scanning electron microscopy, and energy dispersive X-ray spectroscopy (FESEM/EDS). Additional, thermoluminescence (TL) characterizations were performed in the obtained materials.

3. Results and Discussion

3.1. Phase Identification by XRD

Figure 1 shows the XRD patterns corresponding to a representative sample processed by HYSYCVD showing phases associated with the formation of TiO_2.

Characterization by XRD of processed samples (Figure 1b) reveals the presence of Anatase polymorph of TiO_2 (JCPDS No. 00-041-1049; titanium oxide (TiO_2) or Anatase; tetragonal, a=b=4.14 Å, c=9.579 Å; and 25.209, 47.874, 37.327, 53.533). K_2TiF_6 (JCPDS No. 00-073-2110; potassium titanium fluoride (K_2TiF_6); hexagonal, a=b=5.715 Å, c=4.656 Å; and 41.282, 26.258, 31.728, 17.907) and $K_{2.67}TiO_{0.67}F_{5.33}$ (JCPDS No. 00-039-0781; potassium titanium oxide fluoride (K_2TiOF_5); cubic, a=b=c=8.624 Å; and 29.245, 41.845, 17.705, 20.512) are associated with titanium solid precursor and intermediate phases formed during the synthesis of TiO_2. TiO_2 and $K_{2.67}TiO_{0.67}F_{5.33}$ (intermediated product) allows confirming the mechanism of TiO_2 formation through direct and intermediate routes during decomposition of solid precursor (K_2TiF_6) predicted and proposed in a previous work [6].

3.2. Morphological Analysis of Phases by FESEM Technique

Figure 2 shows a representative FESEM image and TL glow curve induced by gamma radiation corresponding to samples processed by HYSYCVD.

FESEM results reveal that TiO_2 corresponds to nanoribbons and nanofibers. EDS analyses confirm the presence of titanium (T) and oxygen (O) corresponding to chemical elements belonging to TiO_2 phase in 1D nanostructures. According to the literature [2, 7], nanoribbons and nanofibers of TiO_2 semiconductor can find potential applications in the development of thin-film transistor and dye-sensitized solar cells. On the other hand, the versatility for synthesizing 1D nanostructure of TiO_2 by HYSYCVD at relatively low temperature, short times, and in situ process suggests the potential of the proposed route for the economic and large-scale production of 1D nanostructures of TiO_2. Additional characterizations by thermoluminescence (TL) shows that synthesized TiO_2 presents luminescent properties, which makes it promising for potential applications in dosimeters.

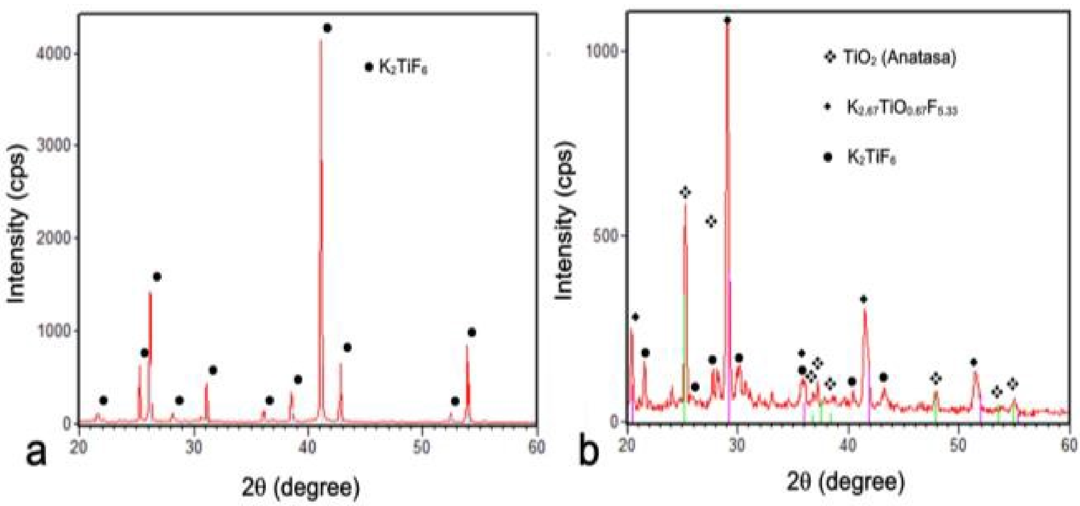

Figure 1. XRD patterns of K_2TiF_6 solid precursor before (a) and after (b) processing by HYSYCVD

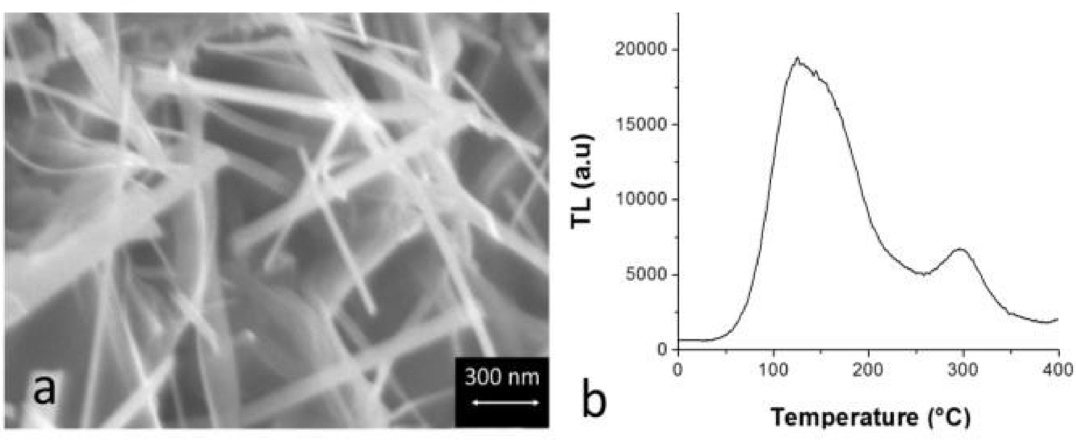

Figure 2. FESEM photomicrograph (a) and TL glow curve of samples processed via HYSYCVD

4. Conclusions

TiO_2-nanoribbons were successfully synthesized via the hybrid precursor systems chemical vapor deposition (HYSYCVD) by the thermal decomposition of K_2TiF_6 under controlled air atmosphere. 1D nanostructures of TiO_2 can find potential applications on TFTs, DSSCs and dosimetry. Lastly, HYSYCVD technique shows versatility for synthesizing TiO_2 and offers great potential to be considered as economic and large-scale production technique.

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REFERENCES

[1] J. C. Azorín-Vega, J. Azorín-Nieto, M. A. García-Hipólito, T. Rivera-Montalvo, "Thermoluminiscence properties of TiO_2 nanopowders", Radiation Measurement, vol. 47, pp. 613-616, 2007.

[2] S. S. Amin, A. W. Nicholls, T. T. Xu, "A facile approach to synthesize single-crystalline rutile TiO_2 one-dimensional nanostructures", Nanotechnology, vol. 18, pp. 445609 - 445609, 2007.

[3] M. Zamora, T. López, M. Azomoza, R. Meléndrez, R. Gómez, "Alkaline doped TiO_2 solgel catalyst activity and selectivity for acetone condensation", Catalysis Today, vol. 116, pp 234-238, 2006.

[4] A. L. Leal-Cruz, synthesis and characterization of silicon nitride reinforcements by thermal decomposition of Na_2SiF_6 in nitrogen containing atmosphere, Tesis, Cinvestav Saltillo. Saltillo Coah., México, 2004.

[5] A.L. Leal-Cruz, M.I. Pech-Canul, In situ synthesis of Si_3N_4 from Na_2SiF_6 as a silicon solid precursor, Materials Chemistry and Physics, vol. 98, pp. 27-33, 2006.

[6] A.L. Leal-Cruz, R. Meléndrez-Amavizca, C.I. Villavelázquez-Mendoza, A. Vera-Marquina, M. Barboza-Flores, "Estudio termodinámico de la descomposición de K_2TiF_6–formación de TiO_2 en el sistema K_2TiF_6-O_2-N_2", Memorias RUIM 2014, pp 233, 2014.

[7] J.H. Bang, P.V. Kamat, "Solar cells by design: photoelectrochemistry of TiO_2 nanorod arrays decorated with CdSe", Advanced Functional Materials, vol. 20, pp. 1970–1976, 2010.