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OBTAINING NANO STRUCTURES OF COBALT TELLURIDE BY A SIMPLIFIED ION EXCHANGE REACTION AT AQUEOUS SOLUTION

O. ARELLANO-TÁNORI[a,*], E. CHÁVEZ-MENDIOLA[b,c,d],
R. GÁMEZ-CORRALES[e], X. M. GARCÍA-CRUZ[d], K. APODACA-IBARRA[a],
S. J. CASTILLO[b]
[a]Departamento de Ingeniería Industrial, Tecnológico Nacional de México/I. T. Hermosillo, Ave. Tecnológico y Periférico Poniente, S/N, C.P.83170, Col. Sahuaro, Hermosillo, Sonora, México
[b]Departamento de Investigación en Física, Universidad de Sonora, Apdo. Postal 5-088, CP. 83000, Hermosillo, Sonora, México
[c]Carrera de Ingeniería Mecatrónica, Universidad Tecnológica de Hermosillo, C.P. 83299, Parque Industrial, Hermosillo, Sonora, México
[d]Departamento de Metal-Mecánica, Tecnológico Nacional de México/I. T. Hermosillo, Av. Tecnológico y Periférico Poniente, S/N, C.P. 83170, Col. Sahuaro, Hermosillo Sonora, México
[e]Departamento de Física, Universidad de Sonora, Blvd. Luis Encinas y Rosales S/N, CP. 83000, Hermosillo, Sonora, México

How to obtain cobalt telluride through a versatile method, based on an ion exchange by aqueous chemical reaction, conformer by rongalite, sodium hydroxide and cobalt chloride. In the UV-vis characterization, a direct and indirect band gap interval of 2.32 eV and 2.04 eV was determined. In the optical absorption, two peaks are observed, one at 270 nm and 411 nm, wich correspond to this material. The FTIR study for cobalt telluride, absorption peaks are seen at 828 cm^{-1} corresponding to the O-Te group, while the peak of 621 cm -1 can be attributed to Te-O and finally the peak at 524 cm^{-1} corresponds to the vibration of Co-O links. The RAMAN spectro obtained, shows peaks of 460, 660 and 984 cm-1 corresponding to cobalt tellurium.

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1. Introduction

Metal Chalcogenide is a prospective counter electrode material in dye-sensitized solar cell owing to their high conductivity [1]. This material are currently candidates for thin films used in solar cells due to their low cost [2]. Tellurides are compounds that show a wide range of physical and chemical properties, for example some show metallic properties and others have strong covalent bonds [3, 4]. Tellurides are attractive materials for thermoelectric applications because their values are very high for thermopower, as well as the ability to produce type *p* and *n* materials for doping [3, 5]. These metal chalcogenides are in great demand due to their simplicity when they are synthesized [6], also showing a complex structure when characterized by several experimental techniques due to the diversity of compounds present in them [7]. For this reason, the properties of these depend on their composition and morphology. This is due to the type of procedure used to synthesize them [8], these methods usually demand high temperatures, high pressures, toxic precursors, and special matrices. In this work, we described a versatile method to obtain $CoTe_2$ based on an ionic exchange when tellurium powder is mixed with a rongalite solution and sodium hydroxide for posteriorly to react it with cobalt chloride, this method was reported by Castillo *et al.* [9].

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[*] Corresponding author: dr.oscar.arellano@gmail.com

2. Experimental details

The tellurium ions were obtained by a solution using four reagents, 2 ml of rongalite at 1M, 2 ml of deionized water, 2 ml of 2M sodium hydroxide and 30 mg of tellurium. The solution is heated in a heating plate so that the solution turns into a crystalline appearance, then 30 mg of cobalt chloride ($CoCl_2$) is added to the solution by shaking at 25 ° C, obtaining a dark precipitate corresponding to cobalt telluride; these samples were washed with pure water by centrifugation and dried in a desiccator for 24 hours.

The UV-vis spectrum was performed at a sample used on UV-vis lambda 2 spectrometer to obtain absorption, thus, the direct and indirect bandgap. Raman spectroscopy was obtained for Horiba Jobin Yvon spectrometer MicroRaman, it was using a source lase excitation (range of 532 nm, 638 nm and 785 nm) the power increments of the lasers were 100%, 50%, 25%, 10% and 1%. The detection of 1024 pixels at a high sensitivity CCD was realized. The Olympus microscope BX41TF (spatial resolution 1<µm), was used to set up the spectrometer MicroRaman. The XPS Perkin-Elmer, model phi 5000, was used to examine the chemical composition of a CoTe sample. Nicolete Protégé 460 was used to obtain FTIR spectrum. JEOL 5400LV, was used to investigate the morphology and energy dispersive spectroscopy (EDS), also the high-resolution transmission electron microscopy was obtained.

3. Results

UV-Visible was made to cobalt telluride in Fig. 1. The optical absorption shows an indirect and direct band gap of 2.32 eV and 2.04 eV respectively. Indirect and direct bang gap was determined using Tauc´s Model from the absorption spectrum by linear extrapolation of the curve $(\alpha h\nu)^{1/2} = 0$ to indirect bandgap and $(\alpha h\nu)^2 = 0$ to direct bandgap. M. S. Khan *et al.* [10], have reported a direct band gap of 2.05 eV for CoTe. In addition, the absorption spectrum exhibits two peaks at 270 nm and 411 nm, the first peak is due to the high absorption of UV radiation, which makes it a good candidate to UV dosimeter or UV filter, while the second peak that is broader, probably due to a band mixing and extreme anisotropy [10].

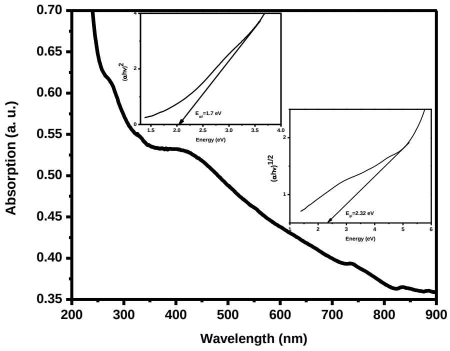

Fig. 1. Absorption spectrum of $CoTe_2$, the graph on the left shows the direct bandgap 2.32 eV and the right the indirect bandgap 2.04 eV.

An FTIR study was performed for the cobalt telluride sample, the spectrum is shown in Fig. 2; in the spectrum it can be seen that the absorption peaks in the 3446 and 1600 cm^{-1} for the cobalt telluride correspond to the vibration of the OH and the flexion vibration of H-O-H, respectively, this is due to the absorption of H_2O by the sample. Water absorption is very common in the cobalt telluride sample especially when they have been exposed to the atmosphere, on the other hand, also that this due to a strong hydrogen bond [11]. The peak in 828 cm^{-1} corresponds to the group O-Te-O or Te-O-, while the band in 621 cm^{-1}, can be attributed to TeO, in addition, the band that appears to the combination of these functional groups, these results are consistent whit those reported by O´Donnell *et al.* [12] and Ilieva *et al.* [13]. The band at 524 cm^{-1} corresponds to the vibration of the Co-O bonds, this indicates the formation of cobalt oxide and also the existence of this peak indicates the formation of nanoparticles of cobalt telluride [14].

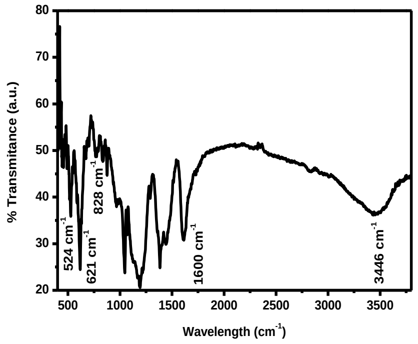

Fig. 2. FTIR spectrum of the $CoTe_2$ compound show characteristic peaks in 524 cm^{-1} (Co-O bonds), 828 cm^{-1} (groups O-Te-O or Te-O-) and 621 cm^{-1}(TeO).

Raman spectrum corresponding to the cobalt telluride compound is shown in figure 3, the characteristic peaks of this compound are 460, 660 and 984 cm^{-1}, Komatsu *et al.* [15], they have found peaks around 725 and 305 cm^{-1}, which are characteristic of the TeO_3 groups and the peaks around 650 - 670 cm^{-1} and 455 cm^{-1} are attributed to the TeO_4 group. On the other hand, Himei *et al.* [16], have also reported that peaks at 720 and 780 cm^{-1} correspond to TeO_3 and the peak at 655 cm^{-1} is assigned to TeO_4. In this way we can conclude that the peaks obtained for this compound through Raman spectroscopy coincide with what was reported.

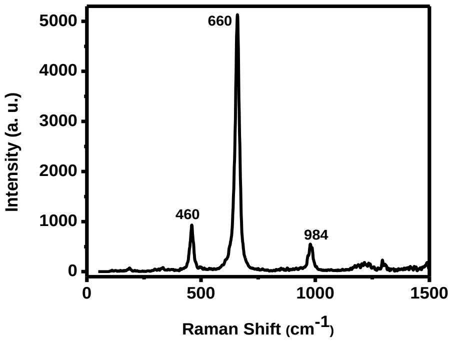

Fig. 3. Raman spectrum shows three peaks in 460, 660 and 984 cm^{-1} that correspond to $CoTe_2$.

The binding energies obtained in the analysis of XPS in Fig. 4, there are no evident peaks of cobalt oxide, nor tellurium oxide, which can be deducted that the compound is a high purity, the corresponding energies are Te 3d5/2 (574 eV) and Te 3d3/2 (583 eV), while for Co2p3/2 and Co 2p 1/2, they are approximately in the 783 eV and 790 eV, respectively. The energies are similar to those reported by Xie *et al.* [17], which indicate that the compound is obtained is $CoTe_2$.

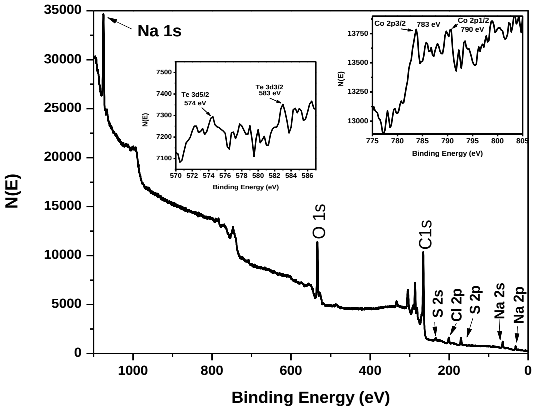

Fig. 4. XPS of $CoTe_2$ show energies in 574 eV, 583 eV, 783 eV and 790 eV, the first two energies correspond to Te and the last two to Co.

In Fig. 5 shows the TEM image made to the cobalt telluride sample, showing agglomeration, well-defined geometric structures are not visible. On the other hand, the diffraction of electrons provides information corresponding to the interplanar distances and thus elucidate the crystalline structure, in figure the corresponding distances of 3.28 Å and 1.97 Å are shown, which are characteristic distances to an orthorhombic structure corresponding to $CoTe_2$ whose crystallographic planes are [100] and [220] (JCPDS) 65-2572).

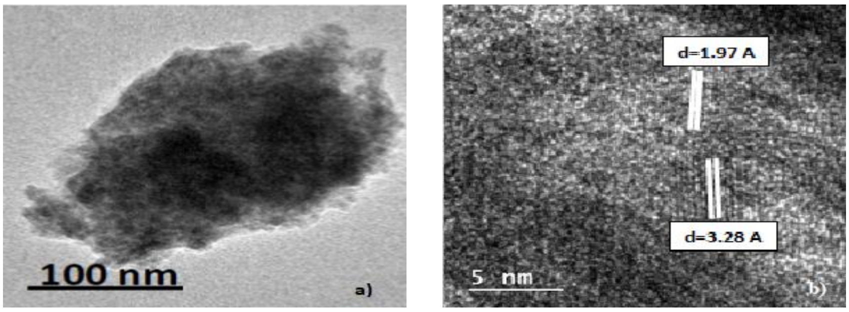

Fig. 5. a) TEM micrograph of the cobalt telluride sample, observe small agglomerations or aggregates of the compound, the scale indicated is 100 nm. b) Interplanar distances of the cobalt telluride compound, d = 3.28 Å and d = 1.97 Å.

4. Conclusions

The binary chalcogenide compound $CoTe_2$ was obtained by means of the ion exchange technique with a tellurium solution. The compound was characterized using Raman spectroscopy and FTIR, validating that said binary compound was obtained because the characteristic peaks of the functional groups are present. The chemical composition analyzed by XPS indicates the presence of the two main chemical elements, however it shows the presence of impurities which suggests that an additional purification process must be implemented on this chalcogenide. For the cobalt telluride, the characteristic bandgap are 1.7 eV and 2.32 eV. In addition, the compound is hygroscopic, this is demonstrated in FTIR studies, in turn, bands also appear below 500 cm^{-1}, which reveals the presence of cobalt nanoparticles, the peaks located at 828 cm^{-1} corresponds to tellurium oxide, which is confirmed with the Raman study, the XPS study, shows Co 2p3/2 and Co 2p1/2, and tellurium 3d5/2 and 3d3/2, these results indicate that the compound obtained is $CoTe_2$. The compound was characterized The TEM study shows an orthorhombic crystalline structure; it is further shown that they are agglomerated.

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