Full Paper _____ *Thematic Section:* Research into New Technologies.
Reference Object Identifier – ROI: jbc-02/18-54-4-110 *Subsection:* Inorganic Chemistry.
Publication is available for discussion in the framework of the on-line Internet conference "*Butlerov readings*".
http://butlerov.com/readings/
Submitted on March 05, 2018.

Thematic section: Hydrochemical synthesis of the metal chalcogenides thin. Part 36.

Chemical bath deposition of sulfide tin(II) films with sodium thiosulfate

© **Larisa N. Maskaeva**,[1,2+] **Irina A. Berg**,[1]
Vyacheslav F. Markov,[1,2]* and **Nikolay V. Berg**[1]
[1] *Physical and Colloidal Chemistry Department. Ural Federal University Named After the First President of Russia B.N. Yeltsin. Mira St., 19. Yekaterinburg, 620002. Sverdlovsk Region. Russia. Phone: +7 (343) 375-93-18. E-mail: mln@ural.ru*
[2] *Chemistry and Combustion Process Department, Ural State Fire Service Institute of Emergency Ministry of Russia. Mira St., 22. Yekaterinburg, 620022. Sverdlovsk Region. Russia. Phone: +7 (343) 360-81-68.*

*Supervising author; +Corresponding author

Keywords: tin sulfide, ionic balance, boundary conditions for deposition, chemical bath deposition, thin films, elemental composition, morphology, conductivity typ.

Abstract

Thin films of a semiconductor compound of tin monosulphide SnS in view of high values of coefficient of optical absorption in visible and near infrared area of a range is of interest to optoelectronics. Due to the development of photovoltaic thin-film SnS technologies, having width of the forbidden zone for direct transitions 1.37 эВ, it is extremely promising as this value is near optimal for effective transformation of sunlight to electric energy on one-transitional solar elements. It suggests that when using SnS as the absorbing layer in photo-electric converters the efficiency to 24% theoretically can be reached. Thanks to a possibility of synthesis of films of sulfide of tin in low-temperature conditions in water environments and prevalence of tin in the nature, interest is caused to him. In this regard development of conditions of purposeful synthesis of SnS. In work the calculation method of forecasting of boundary conditions of formation of the solid phase of SnS developed by authors and approved on a number of chalcogenide of metals is used. The concentration areas of formation of sulfide of tin(II) are established for reactionary system «$SnCl_2$ – $Na_3C_6H_5O_7$ – $Na_2S_2O_3$» by the analysis of ionic balances at a temperature of 298 K taking into account the prevailing complex forms of tin. Calculation is show that the weakly acidic area (pH = 3÷4) is favorable for receiving sulfide of tin (II) and excludes formation of $Sn(OH)_2$. On the basis of the received results with use of the $Na_2S_2O_3$, $SnCl_2$, $Na_3C_6H_5O_7$ by hydrochemical deposition at T = 353 K were received mirror layers of SnS of gray color with good adhesion to a sitall substrate with thickness depending on conditions of carrying out process from 50 to 300 nm. By the energy dispersive analysis it is shown that the content of tin and sulfur in them is 50.43±1.0 and 49.57±1.0 ат. % respectively, i.e. the synthesized SnS films exhibit pronounced stoichiometry. Films are formed from plate with sizes ~50×100 nm.

References

[1] D. Avellaneda, G. Delgado, M.T.S. Nair, P.K. Nair. Structural and chemical transformations in SnS thin films used in chemically deposited photovoltaic cells. *Thin Solid Films*. **2007**. Vol.515. No.15. P.5771-5782.
[2] J.B. Johnson, H. Jones, B.S. Latham et.al. Optimization of photoconductivity in vacuum-evaporated tin sulfide thin films. *Semicond. Sci. Technol*. **1999**. Vol.14. No.6. P.501.
[3] S.A. Bashkirov, V.F. Gremenok, V.A. Ivanov. Physical properties of SnS thin films fabricated by hot wall deposition. *Semiconductors*. **2011**. Vol.45. No.6. P.749-752. (russian)
[4] M. Gunasekaran, M. Ichimura. Photovoltaic cells based on pulsed electrochemically deposited SnS and photochemically deposited CdS and $Cd_{1-x}Zn_xS$. *Solar Energy Mater and Solar.Cells*. **2007**. Vol.91. Iss.9. P.774-778.
[5] M. Sugiyama, K. Miyauchi, T. Minemura and et. Preparation of SnS Films by Sulfurization of Sn Sheet. *Jpn. J. Appl. Phys*. **2008**. Vol.47. No.6. P.4494-4495.

[6] N.P. Klochko, O.V. Momotenko, V.M. Lyubov and et. Tin Sulfide Films Obtained by Sulfurization of Electrodeposited Tin Precursors**.** *J. OF Nano- and electronic physics.* **2016**. Vol.7. No.1. P.01014. (russian)
[7] A. Ortiz, J.C. Alonso, M. Garcia, J. Toriz. Tin sulphide films deposited by plasma-enhanced chemical vapour deposition. *Semicond. Sci.Technol*. **1996**. Vol.11. No.2. P.243.
[8] S.A. Bashkirov, V.F. Gremenok, V.A. Ivanov. Microstructure and electrical properties of SnS thin films. *Physics of the Solid State*. **2012**. Vol.54. No.12. P.2497-2502. (russian)
[9] A. Tanuˇsevski, D. Poelman. Optical and photoconductive properties of SnS thin films prepared by electron beam evaporation. *Solar Energy Mater and Solar.Cells.* **2003**. Vol.80. Iss.3. P.297-303.
[10] N. Koteswara Reddy, K.T. Ramakrishna Reddy, G. Fisher and et.al. The structural behaviour of layers of SnS grown by spray pyrolysis. *Journal of Physics D: Applied Physics*. **1998**. Vol.32. P.988-990.
[11] S. Polivtseva, A. Katerski, E. Kärber. Post-deposition thermal treatment of sprayed SnS films. *Thin Solid Films*. **2017**. Vol.633. P.179-184.
[12] A. Basak, A. Hati, A. Mondaland et.al. Effect of substrate on the structural, optical and electrical properties of SnS thin films grown by thermal evaporation method. *Thin Solid Films*. **2018**. Vol. 645. P.97-101.
[13] M. Ganchev, P. Vitanov, M. Sendova-Vassileva, G. Popkirov, H. Dikov. Properties of SnS thin films grown by physical vapour deposition. *Journal of Physics: Conference Series*. **2016**. Vol.682. P.012019-012024
[14] Z. Zainal, M.Z. Hussein, A. Ghazali. Cathodic electrodeposition of SnS thin films from aqueous solution. *Solar Energy Materials and Solar Cells*. **1996**. Vol.40. P.347-357.
[15] T. Sajeesh, A. Warrier, C. Kartha, K. Vijayakumar. Optimization of parameters of chemical spray pyrolysis technique to get n and p-type layers of SnS. *Thin Solid Films*. **2010**. Vol.518. Iss.15. P.4370-4374.
[16] F. Kanga, M. Ichimura. Pulsed electrodeposition of oxygen-free tin monosulfide thin films using lactic acid/sodium lactate buffered electrolytes. *Thin Solid Films*. **2010**. Vol.519. Iss.2. P.725-728.
[17] B. Ghosh, M. Das, P. Banerjee, S. Das. Fabrication and optical properties of SnS thin films by SILAR method. *Applied Surface Science*. **2008**. Vol. 254. P.6436-6440.
[18] K. Urazov, A.E. Nurtazina, Dergacheva M.B., Matakova R. Electrochemical behavior of tin(II) at the electrodeposition tin sulfide on Mo-electrode. *Chemical Bulletin of Kazakh National University*. **2015**. No.1. P.77.
[19] Hankare P.P., Jadhav A.V., Chate P.A., Rathod K.C., Chavan P.A., Ingole S.A. Synthesis and characterization of tin sulphide thin films grown by chemical bath deposition technique. *Journal of Alloys and Compounds*. **2008**. Vol. 463. P.581-584.
[20] M. Ristov, G. Sinadinovski, M. Mitreski, M. Ristova. Photovoltaic cells based on chemically deposited p-type SnS. *Solar Energy Materials and Solar Cells*. **2001**. Vol.69. P.17-24.
[21] T.H. Patel. Influence of Deposition time on structural and optical properties of chemically deposited SnS thin films. *The Open Surface Science Journal.* **2012**. No.4. P.6-13.
[22] E. Guneri, F. Gode, C. Ulutas et. al. Properties of p-type SnS thin films prepared by chemical bath deposition. *Chalcogenide Letters*. **2010**. Vol.7. No.12. P.685-694.
[23] A.J. Ragina, K.C. Preetha, K.V. Murali, K. Deepa, T.L. Remadevi. Wet chemical synthesis and characterization of tin sulphide thin films from different host solutions. *Advances in Applied Science Research.* **2011**. Vol.2. No.3. P.438-444.
[24] A.R. Garcia-Angelmo, M.T.S. Nair, P.K. Nair. Evolution of crystalline structure in SnS thin films prepared by chemical deposition. *Solid State Sciences*. **2014**. Vol.30. P.26-35.
[25] M. Mnari, N. Kamoun, J. Bonnet, M. Dachraoui Chemical Bath Deposition of tin sulphide thin films in acid solution. *Comptes Rendus Chimie.* **2009**. Vol.12. Iss.6-7. P.824-827.
[26] Shahara Banu, Se Jin Ahn, Young Joo Eo and et.al.Tin monosulfide (SnS) thin films grown by liquid-phase deposition. *Solar Energy*. **2017**. Vol.145. P.33-41.
[27] U. Chalapathi, B. Poornaprakash, Si-Hyun Park. Effect of post-deposition annealing on the growth and properties of cubic SnS films. *Super lattices and Microstructures*. **2017**. Vol.103. P.221-229.
[28] U. Chalapathi, B. Poornaprakash, Si-Hyun Park. Chemically deposited cubic SnS thin films for solar cell applications. *Solar Energy*. **2016**. Vol.139. P.238-248.
[29] U. Chalapathi, B. Poornaprakash, Si-Hyun Park. Growth and properties of cubic SnS films prepared by chemical bath deposition using EDTA as the complexing agent. *Journal of Alloys and Compounds*. **2016**. Vol.689. P.938-944.
[30] R. Hayakawa, Y. Takano. Preparation of SnS films in chemical solution using microwave irradiation. *Thin Solid Films.* **2017**. Vol.636. P.171-176.

[31] V.F. Markov, N.A. Tretyakova, L.N. Maskayeva, D.S. Epaneshnikova. Structure and composition of hydrochemically deposited films of tin sulfide and selenide. *Fundamental problems of modern materials science*. **2005**. No.2. P.59-60.
[32] L.N. Maskaeva, E.A. Fedorova, A.I. Shemyakin. Kinetic and thermodynamic analysis of the conditions of colloidal-chemical deposition and AFM investigation of SnS films. *Butlerov Communications.* **2014**. Vol.37. No.2. P.1-9. ROI: jbc-02/14-37-2-1
[33] L.N. Maskaeva, A.A. Timina, A.I. Shemyakina, V.F. Markov. Estimation of formation conditions and synthesis of thin films of tin (II) sulfide from solutions using thiourea and thioacetamide. *Butlerov Communications.* **2016**. Vol.45. No.3. P.72-79. ROI: jbc-02/16-45-3-72
[34] Yu.Yu. Lurye. Handbook of Analytical Chemistry. *Moscow: Chemistry*. **1989**. 448p. (russian)
[35] V.B. Spivakovsky. Analytical chemistry of tin. *Moscow: Science.* **1975**. 252p. (russian)
[36] S.S. Tulenin, A.A. Timina, L.N. Maskaeva, V.F. Markov. Chemical bath deposition of thin nanocrystalline tin(II) sulfide films with thioacetamide. *Russian journal of applied chemistry.* **2017**. Vol.90. No.1. P.1507-1510. (russian)
[37] V.F. Markov, L.N. Maskaeva, P.N. Ivanov. Chemical bath deposition of metal sulfide films: modeling and experiment. *Ekaterinburg: UrO RAN*. **2006**. 218p. (russian)
[38] V.F. Markov, L.N. Maskaeva. Calculating the boundary conditions of the formation of solid-phase metal sulfides and selenides by deposition with thio- and selenourea. *Journal of Physical Chemistry*. **2010**. Vol.86. No.8. P.1421-1426. (russian)
[39] J.N. Butler. Ionic equilibria. *Moscow: Khimia*. **1973**. 448p. (russian)
[40] G.A. Kitaev, A.A. Uritskaya, N.S. Belova. Conditions of metal sulfide formation in aqueous sodium thiosulfate solutions. *Russian journal of applied chemistry.* **2000**. Vol.79. No.9. P.1507-1510. (russian)