

# Effect of NH<sub>4</sub>F additive on the electrical properties of nanosized tin dioxide films obtained from lyophilic and lyophobic film-forming systems

Sayora Ibraimova<sup>1</sup>, Elena Dmitriyeva<sup>1</sup>, Igor Lebedev<sup>1</sup>, Anastasia Fedosimova<sup>1</sup>, Ekaterina Bondar<sup>1</sup>, Shongalova Aigul<sup>1</sup>, Issayeva Ulzhalgas<sup>2</sup>

<sup>1</sup> Institute of Physics and Technology, Satbayev University, Ibragimov 11, Almaty, 050013, Kazakhstan

<sup>2</sup> National Center for Research, Training and Education in the Field of Civil Protection, Baizakov 300, Almaty, 050040, Kazakhstan

Composite systems based on tin dioxide have many applications as a functional material [1, 2]. In this case, the properties of the resulting film can significantly depend on the method of obtaining a thin film. In this work, we studied the effect of NH<sub>4</sub>F addition on the electrical properties of nanosized tin dioxide films obtained from lyophilic and lyophobic film-forming systems. Thin films of tin dioxide were obtained from 5 film-forming systems, including those containing NH<sub>4</sub>F and NH<sub>4</sub>OH dopants: SnCl<sub>4</sub>/EtOH, SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>F, SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>OH, SnO<sub>2</sub>/EtOH, SnO<sub>2</sub>/EtOH/NH<sub>4</sub>F. For an assessment of the contribution of doping additives to the conductivity of the films, calculations of the surface resistance, resistivity, and conductivity of the films under study were made. The results are presented in Table 1.

Table 1 – Surface resistance, resistivity, specific conductivity of the studied films

The composition of the film-forming system	R <sub>sh</sub> , kOm/square	ρ, Om*cm	1/ρ, Om <sup>-1</sup> *cm <sup>-1</sup>
SnCl <sub>4</sub> /EtOH	15,6±1,4	0,390±0,035	2,6±0,2
SnCl <sub>4</sub> /EtOH/NH <sub>4</sub> F	6,7±0,6	0,097±0,008	10,3±0,8
SnCl <sub>4</sub> /EtOH/NH <sub>4</sub> OH	15,4±1,6	0,255±0,026	3,9±0,4
SnO <sub>2</sub> /EtOH	78,9±6,9	0,512±0,044	1,9±0,2
SnO <sub>2</sub> /EtOH/NH <sub>4</sub> F	69,4±8,3	0,590±0,070	1,7±0,2

Table 1 shows that the addition of NH<sub>4</sub>F to the lyophobic film-forming system SnO<sub>2</sub>/EtOH did not lead to an increase in the specific conductivity. At the same time, the addition of NH<sub>4</sub>F to the lyophilic film-forming system SnCl<sub>4</sub>/EtOH leads to an increase in the specific conductivity by several times. This confirms the presence of fluorine ions as additional sources of free charge carriers in the composition of the films [3]. The addition of an aqueous ammonia solution to the SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>OH film-forming system also led to an increase in the specific conductivity. Apparently, due to an unshared electron pair in the nitrogen atom.

X-ray diffraction analysis confirmed the presence of fluorine ions in the films obtained from the SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>F film-forming systems. The X-ray diffraction patterns are shown in Figure 1. It can be seen that all films consist of SnO<sub>2</sub> crystallites. On the X-ray diffraction pattern of the film obtained from the SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>F film-forming system, SnOF<sub>2</sub> peaks are observed. These peaks indicate the successful incorporation of tin ions into the film structure.

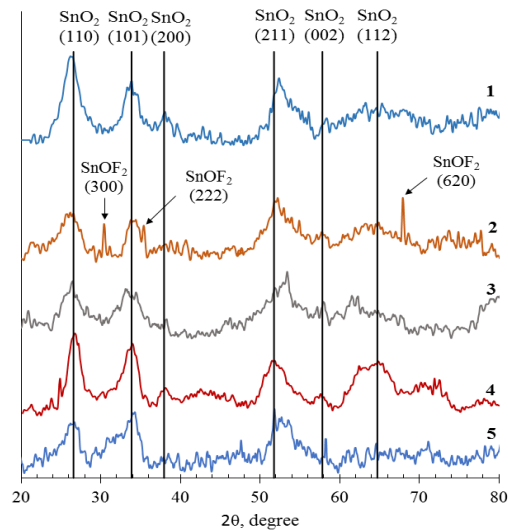


Figure 1 – X-ray patterns of thin films of tin dioxide obtained from different film-forming systems: 1 - SnCl<sub>4</sub>/EtOH, 2 - SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>F, 3 - SnCl<sub>4</sub>/EtOH/NH<sub>4</sub>OH, 4 - SnO<sub>2</sub>/EtOH, 5 - SnO<sub>2</sub>/EtOH/NH<sub>4</sub>F

This research was funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan grant number AP19574404.

## References

- Sehrish Gul, Anam Azam, Nazmina Imrose, Saira Riaz, Shahzad Naseem Tin oxide thin films prepared by sol-gel for PV applications // Materials Today: Proceedings. – 2015. – V.2. – P.5793 – 5798.
- Linghui Yang, Zhenlan Qin, Hongtao Pan, Hong Yun, Yulin Min, Qunjie Xu Corrosion protection of 304 stainless steel bipolar plates of PEMFC by coating SnO<sub>2</sub> film // Int. J. Electrochem. Sci. – 2017. – V.12. – P.10946–10957.
- Dmitriyeva E.A., Mukhamedshina D.M., Mit' K.A., Lebedev I.A, Girina I.I., Fedosimova A.I., Grushevskaya E.A. Doping of fluorine of tin dioxide films synthesized by sol-gel method // News of the National Academy of Sciences of the Republic of Kazakhstan (series of geology and technical sciences). – 2019. – V.433– P.73–79. doi:10.32014/2019.2518-170X.9.



Sayora Ibraimova - junior researcher, Institute of Physics and Technology, Satbayev University.  
 Scientific interests: study of the properties of nanosized tin dioxide films obtained from lyophilic and lyophobic film-forming systems.  
 Presentating author: Sayara Ibraimova, e-mail: s.ibraimova@sci.kz, tel: +7(747)5255676

