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FUNCTIONAL FLUORINE-DOPED TIN OXIDE COATING FOR OPTO- ELECTROCHEMICAL LABEL-FREE BIOSENSORS

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Abstract

Biosensing is made possible by the characteristics that multi-domain sensors, such as optical and electrochemical ones, offer over single-domain sensors. Materials with a specific combination of properties are needed to combine such domains in a single sensing device. In this study, fluorine-doped tin oxide (FTO) thin film is considered as functional electrochemically, i.e. as a conductive material for a working electrode, and optically for directing loss modes. The optical and electrochemical performance of the FTO-based optical fiber loss-mode resonance (LMR) sensor is examined. The applied potential has a considerable impact on the LMR wavelength shift in the FTO-LMR counterparts throughout a wide potential range. It is demonstrated that label-free Biosensing applications of the FTO-LMR technique are feasible employing streptavidin as a target biomaterial. When cross-domain interactions are used, the dual-domain feature enables cross-verification of readouts from both domains and increases optical sensitivity.

Keywords

Fluorine-doped tin oxide (FTO), thin conductive oxides (TCO), Optical fiber sensor

1. Introduction

The sensors with these qualities can only be mass produced in small quantities and have limited scope for widespread use because they typically require expensive, complicated, and/or advanced technology [1], [2]. Those working in many domains can be taken into consideration as an alternative to sophisticated bio sensing devices where high accuracy and dependability are specifically anticipated[3]. Multi-domain sensors provide the ability to apply many detection methods simultaneously to the same sensor. The method provides for the cross-verification of results acquired in the domains [5], the enlargement of a measurement range [3], or the measurement of several parameters [4].Electrical, optical, chemical, mechanical, or thermal interactions may be the basis for biosensor operation [6]. In particular, optical domain sensors enable multiplexing and provide capacity for precise, quick, and dependable.

Fluorine-doped tin oxide (FTO) is an optically transparent material which has already been successfully applied as a working electrode in EC setups [6]. According to our best knowledge, in contrast to ITO, the material has been used in few optical sensing applications. The FTO-based dual-domain sensing concept has been also verified for label-free sensing of streptavidin and in the future can be further extended to other biological or chemical targets.

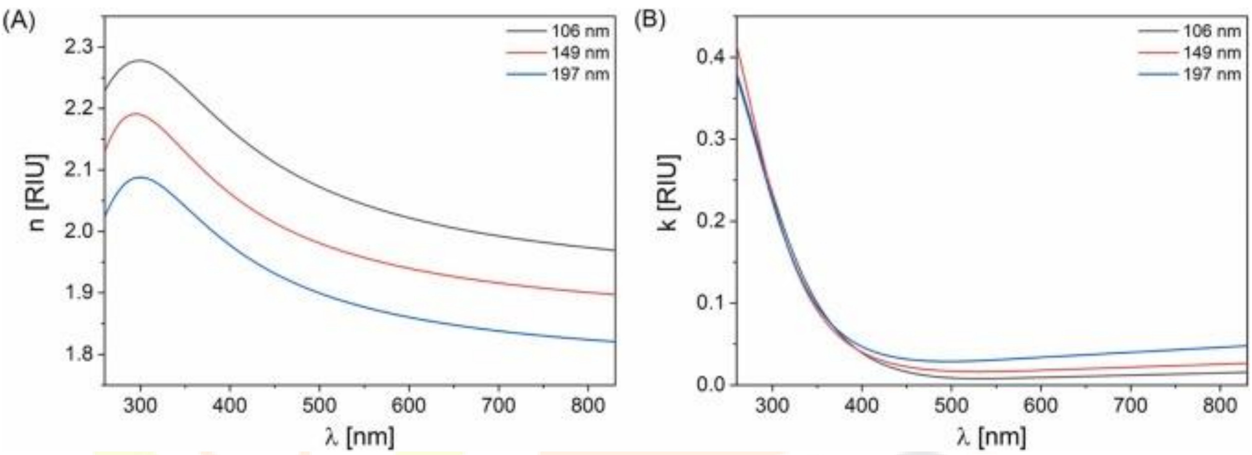
Thin film deposition and characterization

The FTO deposition was performed by magnetron sputtering in the UHV chamber with base pressure in order of 10^{-5} Pa. A 3-inch FTO target was applied with a SnO_2:SnF_2 composition of (97:3 wt%.). During the deposition, the samples were rotated to ensure the maximum possible homogeneity of the coating around the exposed fiber core. To increase the temperature during the deposition an electrical heater was additionally installed in the chamber. The pressure of the atmosphere. e in the chamber was set to 5 Pa to ensure sufficient heat transfer and enhanced homogeneity of the films due to increased diffusion of the sputtered species. Two alternative deposition configurations were tested, where the main difference between them was the distance between the sputtering source and fiber samples reaching 16 and 21 cm. Deposition configuration in the chamber has been described elsewhere [7].

3. Results and discussion

3.1. Optical properties of the deposited FTO

Optical properties and thickness of the LMR-supporting thin film material are crucial for the performance of the sensors [8]. The dispersion curves of *n* and *k* for selected FTO films in the operational spectral range of the sensors are shown in Fig. 1.



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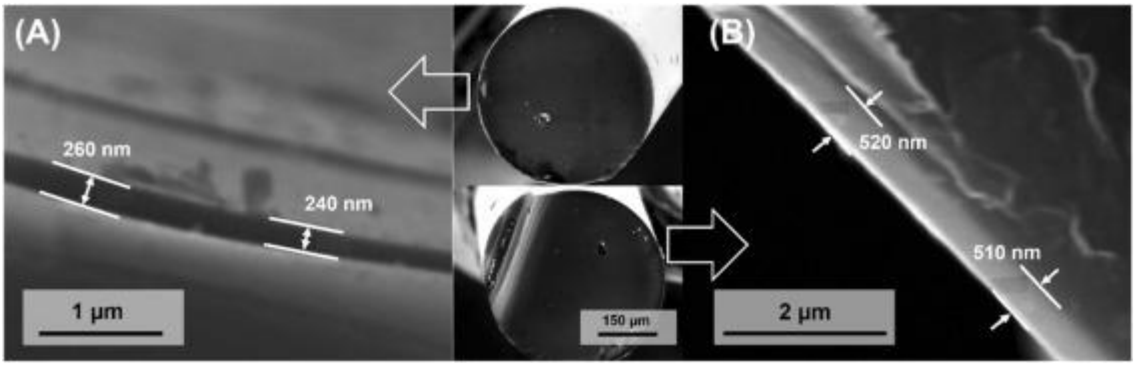
3.1. Optical properties of the deposited FTO

Optical properties and thickness of the LMR-supporting thin film material are crucial for the performance of the sensors [8]. The dispersion curves of *n* and *k* for selected FTO films in the operational spectral range of the sensors are shown in Fig. 1. For all the cases at $\lambda < 400$ nm the material shows high *k*, that corresponds to elevated absorption in the UV spectral range. Moreover, in this range also high changes of *n* are observed. Above that range, *n* and *k* change only slightly. In the IR range increase of *k* can be noticed and it corresponds to semi-metallic character of these films. Thus, it may be expected that the FTO thin films, similarly to some ITO films. However, in the Vis range FTO is suitable for guiding loss modes .



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At higher pressure, a large amount of gas particles in the deposition chamber occurs. An increased number of particles is followed by elastic collisions with the sputtered particles on their path from the FTO target to the substrate. Hence, the enhanced pressure results in the thermalization of sputtered target atoms and also encourages the diffusion processes [9]. The particle diffusion enables the deposition on surfaces that are not facing directly the target, i.e. on the back side of the substrate. This effect is more pronounced in the case of thin substrates, such as optical fibers. Moreover, it can contribute not only to different deposition rates but also to differences in other properties received on flat substrates and fibers. The particles deposited from behind arrive at the surface with a different energy than those deposited directly from the front.

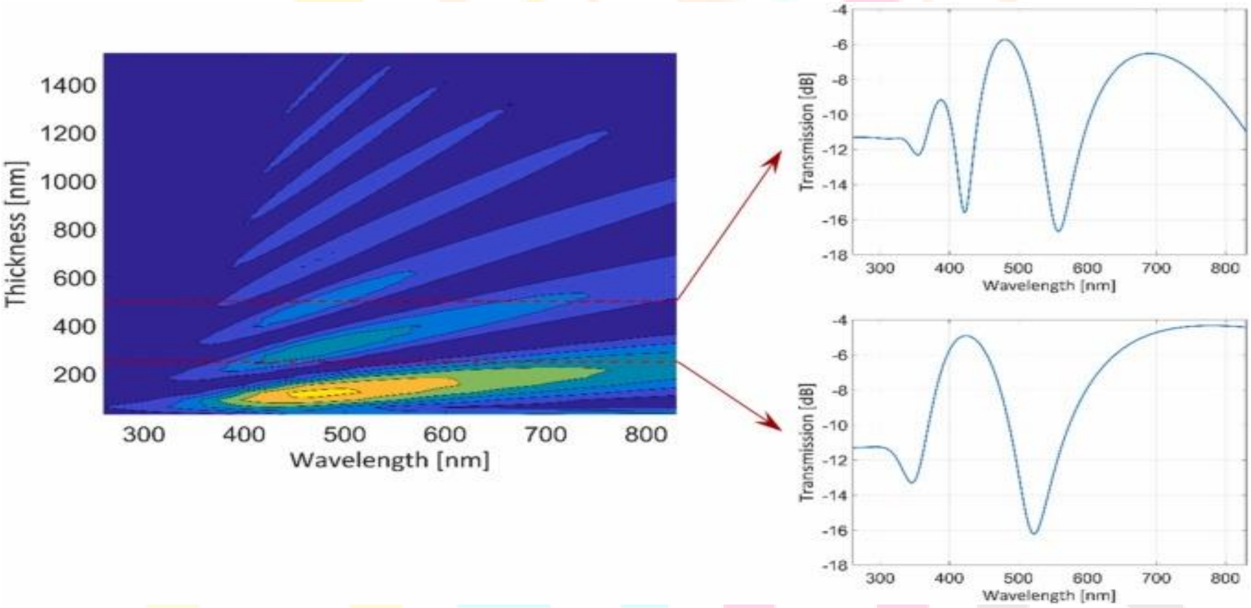

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Fig. 3.and 4 evolution for the FTO-coated optical fiber when surrounded by RI of deionizer water. The darker areas between the paler once signify higher attenuation bands and the LMR appearance. The dashed lines indicate map section at the thickness reaching 500 nm (right-top) and 250 nm (right bottom). A similar effect of target-substrate distance was also observed in the case of ITO films. The effect is attributed to different energy flux to the substrate which influences the growth of the film with a different fraction of crystalline phase in an amorphous film matrix . The same mechanism is expected also for FTO. The results for the sensor in the reflective configuration presented

previously in Fig. 2(B) are shown in Supplementary Information where the RI sensitivity is also reported. Importantly, both the presented configurations can be applied to the same extent after adjusting deposition parameters.

Conclusion

The sensors with these qualities can only be mass produced in small quantities and have limited scope for widespread use because they typically require expensive, complicated, and/or advanced technology [1], [2]. Those working in many domains can be taken into consideration as an alternative to sophisticated bio sensing devices where high accuracy and dependability are specifically anticipated. Multi-domain sensors provide the ability to apply many detection methods simultaneously to the same sensor. The method provides for the cross-verification of results acquired in the domains [5], the enlargement of a measurement range [3], or the measurement of several parameters [4].Electrical, optical, chemical, mechanical, or thermal interactions may be the basis for biosensor operation [6]. In particular, optical domain sensors enable multiplexing and provide capacity for precise, quick, and dependable.

References

1. S. Gupta, C.N. Murthy, C.R. Prabha Recent advances in carbon nanotube based electrochemical biosensors Int. J. Biol. Macromol., 108 (2018), pp. 687-703, 10.1016/j.ijbiomac.2017.12.038View articleView in ScopusGoogle Scholar.
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3. K. Kosiel, M. Koba, M. Masiewicz, M. Śmietana Tailoring properties of lossy-mode resonance optical fiber sensors with atomic layer deposition technique Opt. Laser Technol., 102 (2018), pp. 213-221, 10.1016/j.optlastec.2018.01.002 View articleView in ScopusGoogle Scholar.
4. S. Shanthi, C. Subramanian, P. Ramasamy Investigations on the optical properties of undoped, fluorine doped and antimony doped tin oxide films Cryst. Res. Technol., 34 (1999), pp. 1037-1046, 10.1002/(SICI)1521-4079(199909)34:8<1037::AID-CRAT1037>3.0.CO;2-JView article View in ScopusGoogle Scholar
5. [6] Boutahar A, Lassri H, Hlil E.K, 2015 J. Con. Matter Science. 221 9 – 13.
6. [7] Clavaguera N, Clavaguera – Mora and M.Fontana 1998 J. of Maetrials Research 13 744.
7. [8] Douglas A. Skoog et al 2012 “INSTRUMENTAL ANALYSIS” (Cengage Learning India Private Limited,India), 11th Edition.
8. [9] Flynn J.H. and Wall L. A. 1966 J. of Research of the National Bureau of Standards. 70A 487-523.
9. [10] Friedman H L 1964 J. of Polymer Science Part C 6 183 - 195.
10. [11] Ganesan K, Narayanasamy A, Kocnzos G and Nagarajan T 1992 J. Magn. Magn. Mat.
11. [12]Gao Y.Q. and Wang W. (1986) J. of Non - Crystalline Solids 6 129 - 134.
12. Graham. C. D, Egami. T Ann. Rev. Maler. Sci. 1978. 8 423 – 457.