Synthesis of SnO2 Thin Layer with a Doping Fluorine by Sol-Gel Spin Coating Method

by Aris Doyan

Original Research Paper

Synthesis of SnO$_2$ Thin Layer with a Doping Fluorine by Sol-Gel Spin Coating Method

Lalu Muliyadi[1*], Aris Doyan[1], Susilawati[1], Syamsul Hakim[1]

[1]Master of Science Education Program, University of Mataram, Lombok, West Nusa Tenggara, Indonesia

Abstract: A thin layer of tin oxide with doping Fluorine was synthesized using the sol-gel spin coating method. The synthesis aims to determine the quality of thin layers formed based on temperature variations and the number of layers. The basic material used is SnCl$_2$.2H$_2$O, while the doping material used is NH$_4$F with variations in concentrations of dopants 0, 5, 10, 15, 20 and 25%. The substrate used is glass with a size of 10 x 10 x 3 mm. The synthesis of the thin layer includes substrate preparation, sol-gel making, thin film making, and heating process. At this stage SnO$_2$:F is deposited on a glass substrate with sol-gel spin coating technique at the concentration of sol 1 M with doping levels of Fluorine 0, 5, 10, 15, 20 and 25%, and treated with maturation for 24 hours. Making a thin layer using a spin coater at a speed of 2000 rpm for 3 minutes. The layer made consists of one layer, two layers, three layers and four layers. The resulting layer shows that the higher the doping percentage, the higher the transparency of the layer. In addition, the more the number of layers, the lower the transparency level.

Keywords: Thin Film, Tin Oxide, Fluorine, Sol-gel, Spin Coating

Introduction

The tin oxide (SnO$_2$) is one of nano-sized materials including semiconductor materials. The tin oxide is widely applied to solar cells, optoelectronic devices, transparent conductive oxide (TCO) and sensor gases. In addition, tin oxide has several advantages, which have high chemical stability, high transparency, and low resistivity, band gap width of around 3.6 eV (Schel et al, 2017). The tin oxide is also very sensitive to the presence of gas around it which makes it applied as a sensor gas (Carvalho et al, 2012).

In its application, tin oxide are known to have an energy band gap that is quite wide (~3.6 eV) so that waves are small absorbent. Because of these factors, tin oxide needs to be added to other impurities called dopants (Ikraman et al, 2017). The tin oxide is usually doped with antimony (Sb) or what is called ATO (Antimony Tin Oxide) (Hammad et al, 2011), FTO (Fluorine Tin Oxide) (Gurakar et al, 2014), AFTO (Antimony and Fluorine doped Tin Oxide) (Lin et al, 2017), and AITO (Aluminum Tin Oxide) (Doyan et al, 2018). Of the several existing doping elements, fluorine is one of the good doping elements in the thin layer tin oxide. This is because fluorine is more

chemically resistant, cheaper and the availability of raw materials is easier (Adnane et al, 2005). In addition, compared to other doping elements, fluorine is more resistant to heat treatment (Sima et al, 2010).

The addition of fluorine doping has been done by several previous researchers. These researchers include: Lin et al (2017), Bakr et al (2016), Kar et al (2015), and stated that the growth of thin layers of tin oxide by doping fluorine or SnO$_2$:F can reduce energy band gap, increase optical transmittance and conductivity electricity, changing structure, increasing response, selectivity and stability in sensor gases.

Besides addition of doping, the factors that affect the quality of the thin layer tin oxide and SnO$_2$:F produced are the preparation method and the growth conditions of the layers. Methods of preparation and growth of tin oxide layers, both pure and doping additives have been carried out by several previous researchers such as sol-gel spin coating to synthesize thin layer tin oxide with Aluminum doping (Doyan et al, 2017), pyrolysis spray to synthesize thin layer tin oxide with doping Fluorine (Bakr et al, 2016), and sol-gel dip coating to synthesize tin oxide thin layers (Carvalho et al, 2012). The dip coating method is the simplest

technique, can grow layers on various forms of substrate, but the thickness of the layer is less controlled (Doyan et al, 2017). The spray pyrolysis method has several advantages including the particle production process which is continuous, homogeneous, and uniform size distribution, but the morphology of the particles can be hollow, and the distribution of particles is uneven (Setiawan et al, 2016). Compared to the three techniques, sol-gel spin coating has more advantages, which are effective and very easy, simply by adjusting the rotational speed, time and viscosity of the solution through heating temperature measurements (Imawanti et al, 2017).

Method

This study uses the basic ingredients Tin (II) chloride dehydrate ($SnCl_2.2H_2O$) 23.702 grams with a molar mass of 225.63 grams/mol and purity of 98%. The solvent uses 20 ml ethanol (C_2H_5OH) with a molar mass of 46.07 gram/mol and purity of 98%. The material for doping is 0.555 grams of Ammonium Fluoride (NH_4F) with a molar mass of 37 grams/mol. The substrate used is glass with a size of 10 x 10 x 3 mm. Other supporting materials are aquades, detergent soap and alcohol used to clean the substrate. The thin layer synthesis includes substrate preparation, sol-gel making, thin film making, and heating process.

Preparation is done by inserting a glass substrate into a measuring cup containing a mixture of water and detergent and then vibrating with a shaker for 30 minutes. After that, rinse the glass substrate with aquades until clean, then soak it in alcohol for 30 minutes. Then drying the glass substrate using a furnace with 100^0C temperature for 1 hour.

Sol-gel preparation using variations of fluorine doping mass was 0%, 5%, 10%, 15%, 20%, and 25% respectively. The making is done by dissolving $SnCl_2.2H_2O$ and NH_4F into 20 ml ethanol with a fixed concentration of 1M, then stirrer using stirring magnetic until the solution is homogeneous. After that, the solution is left to stand for 24 hours.

Making a thin layer is done by dripping sol-gel on the glass substrate and then rotating using a spin coater at a speed of 2000 rpm for 3 minutes. After that, drying the substrate at room temperature. Next heat a thin layer using a furnace with a temperature of 150^0C for 1 hour.

Result and Discussion

Synthesis of SnO_2:F thin layer includes substrate preparation, sol-gel making, thin film making, and heating process. Substrate preparation aims to remove oil and dirt found on glass substrates.

Preparation of sol-gel made with fluorine doping variation of 0, 5, 10, 15, 20 and 25%, then in-stirrer using magnetic stirring, aiming to speed up the solution became homogeneous, then cured for 24 hours. The mass of $SnCl_2.2H_2O$ and NH_4F of each ingredient is determined by equations 1 and 2.

$$(100-n)\% = \frac{(m_t SnCl_2 \cdot 2H_2O) \, x \, \frac{1}{Mr \, SnCl_2 \cdot 2H_2O}}{(m_t \, NH_4F) \, x \, \frac{1}{Mr \, NH_4F}} \quad (1)$$

$$(n)\% = \frac{(m_t \, NH_4F) \, x \, \frac{1}{Mr \, NH_4F}}{(m_t SnCl_2 \cdot 2H_2O) \, x \, \frac{1}{Mr \, SnCl_2 \cdot 2H_2O}} \quad (2)$$

Based on the conditions 1 and 2, the mass of $SnCl_2.2H_2O$ and NH_4F was obtained as in table 1.

Table 1: Percentage of doping and number of masses

Doping Persentage (%)	$SnCl_2.2H_2O$ (gram)	NH_4F (gram)
100:0	4.515	0
95:5	4.289	0.037
90:10	4.063	0.074
85:15	3.837	0.111
80:20	3.612	0.148
75:25	3.386	0.185

Figure 1 shows that the higher the concentration of the dopant, the higher the transparency of the soles produced. This is caused by the addition of fluorine dopants can reduce the reaction of $SnCl_2$ with ethanol so that the transparency of the sol increases with increasing doping value (Ikraman et al, 2017).
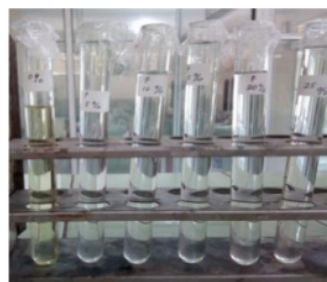

Figure 1. Sol SnO_2 for doping variation Fluorine

The next step is the process of making thin layers with doping variations and layer thickness using spin coating. Figure 2 shows a sample of

SnO_2:F which was synthesized using the spin coating method with 150 ^{0}C annealing temperature. The higher the concentration of doping, the higher the level of transparency of the formed layer.
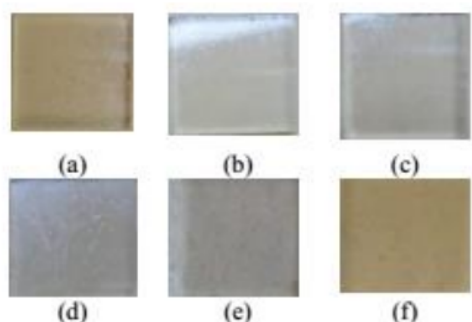

Figure 2. Thin layer with a temperature of 150 ^{o}C. Variations in SnO_2: F (a) 100: 0%, (b) 95: 5%, (c) 90: 10%, (d) 85: 15%, (e) 80: 20%, (f) 75: 25 %.
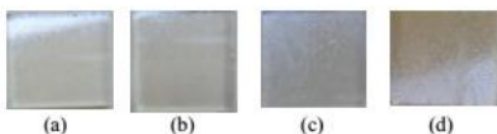

Figure 3. Thin layer SnO_2: F variations of layer (a) one layer, (b) two layers, (3) three layers, (d) four layers.

Figure 3 shows a sample of SnO_2:F synthesized using the spin coating method with various layers. The more the number of layers, the lower the transparency of the layer, so that the layer becomes more opaque. This is because the size of the grains increases as the number of layers increases (Ray et al, 2010).

Conclusion

The synthesis of a thin layer of fluorine tin oxide using spin coating sol gel technique has been successfully carried out. The level of transparency of the resulting tin oxide layer increases with increasing fluorine doping. In addition, the more the number of layers, the lower the transparency of the layer.

References

Adnane, M., H. Cachet, Folcher, G. and Hamzaoui, S. 2005. Beneficial Effects of Hydrogen Peroxide on Growth, Structural and Electrical Properties of Sprayed Fluorine-Doped SnO_2 Films. *Thin Solid Film*, 492 (2): 240-247.

Bakr, N.A., Salman, S.A. and Ali, M.N. 2016. Effect of Fluorine Doping on Structural and Optical Properties of SnO_2 Thin Films Prepared by Chemical Spray Pyrolysis Method. *Advances in Materials*, 5(4): 23-30.

Carvalho, D. H. Q., Schiavona, M. A., Raposoa, M. T., Paivaa, R., Alvesa, J. L. A., Paniagob, and Roberto, M. 2012. Synthesis and characterization of SnO_2 thin films prepared by dip-coating method. *Physics Procedia*, 28: 22 – 27.

Doyan, A., Susilawati and Imawanti, Y.D. 2017. Synthesis and Characterization of SnO_2 thin layer with a doping Aluminum is deposited on Quartz Substrates. *American Institute of Physics*, 1801: 1-7.

Doyan, A., Susilawati, Imawanti, Y.D. Gunawan, E.R. and Taufik, M. 2017. Characterization Thin Film Nano Particle Of Aluminum Tin Oxide (AITO) as Touch Screen. *Journal of Physics*, 1097: 1-9.

Doyan, A., Susilawati, Fitri, S.A. and Ahzan, S. 2017. Cristal Structure Charaterization of Thin Layer Zinc Oxide. *Materials Science and Engineering*, 196: 1-6.

Gurakar. 2014. Electrical and microstructural properties of (Cu, Al, In)-doped SnO_2 films deposited by spray pyrolysis. *Advanced Materials Letters*, 5(6): 309-314.

Hammad, T.M. and Hejazy, N.K. 2011. Structural, Electrical and Optical Properties of ATO Thin Films Fabricated by Dip Coating Method. Int. Nano Lett, 1(2): 123– 128.

Ikraman, N., Doyan, A. and Susilawati. 2017. Penumbuhan Film SnO_2 dengan Doping Al-Zn Menggunakan Teknik Solgel Dip Coating. *Jurnal Pendidikan Fisika dan Teknologi*, 3(2): 228-231. DOI: http://dx.doi.org/10.29303/jpft.v3i2.415

Imawanti, Y.D., Doyan, A. and Gunawan, E.R. 2017. Sintesis Lapisan Tipis (Thin Film) SnO_2 dan SnO_2:Al Menggunakan Teknik Sol-Gel Spin Coating pada Substrat Kaca dan Quartz. *Jurnal Penelitian Pendidikan IPA*, 3(1): 1-9. DOI: 10.29303/jppipa.v3i1.49

Lin O.S., Thu, Z., Zaw O. and Kaung, P. 2017. Optical and Electrical Properties of Antimony and Fluorine Doped Tin Oxide

Thin Films. *Universal Journal of Physics and Application*, 11(3): 91-96.

Mishra, R. L., Mishra, S. K. and Prakash S. G. 2009. Optical and Gas Sensing Characteristics of Tin Oxide Nano-Crystalline Thin Film. *Journal of Ovonic Research*, 5: 77-85.

Ray, S., Gupta, P. S. and Singh, G. 2010. Electrical and Optical Properties of Sol-Gel Prepared Pd Doped SnO_2 Thin Films: Effect of Multiple Layers and Its Use as Room Temperature Methane Gas Sensor. *Journal of Ovonic Research*, 6: 23-34.

Schell, J., Lupascu, D.C., Carbonari, A.W., Mansano, R.D., Dang, T.T. and Vianden, R. 2017. Implantation of cobalt in SnO_2 thin films studied by TDPAC. *American Institute of Physics Advances,* 7: 1-7.

Setiawan, A., Widiyastuti, Winardi, S. and Nugroho, A. 2016. Sintesis Biomaterial Hydroxyapatite dengan Proses *Flame Spray Pyrolysis* Disertai Penambahan Aditif Organik. Reaktor, 16(4): 189-198.

Synthesis of SnO2 Thin Layer with a Doping Fluorine by Sol-Gel Spin Coating Method

19% SIMILARITY INDEX

10% INTERNET SOURCES

11% PUBLICATIONS

14% STUDENT PAPERS

1	**Submitted to Universitas Mataram** Student Paper	**6**%
2	**jppipa.unram.ac.id** Internet Source	**4**%
3	Susilawati, A. Doyan, L. Muliyadi, S. Hakim, M. Taufik, Nazarudin. " Characteristics and Optical Properties of Fluorine Doped SnO Thin Film Prepared by a Sol–Gel Spin Coating ", Journal of Physics: Conference Series, 2019 Publication	**2**%
4	A. Doyan, Susilawati, S. Hakim, L. Muliyadi, M. Taufik, Nazarudin. " The Effect of Indium Doped SnO Thin Films on Optical Properties Prepared by Sol-Gel Spin Coating Technique ", Journal of Physics: Conference Series, 2019 Publication	**2**%
5	aip.scitation.org Internet Source	**1**%

worldwidescience.org

| 6 | Internet Source | 1% |

7 Aris Doyan, Susilawati, Siti Azizatul Fitri, Sukainil Ahzan. "Crystal Structure Characterization of Thin Layer Zinc Oxide", IOP Conference Series: Materials Science and Engineering, 2017
Publication

1%

8 A Doyan, Susilawati, N Ikraman, M Taufik. " Characterization of SnO Film with Al-Zn Doping Using Sol-Gel Dip Coating Techniques ", Journal of Physics: Conference Series, 2018
Publication

1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		