Aerosol-assisted chemical vapour deposition synthesis of fluorine-doped tin oxide (FTO) for dye-sensitized solar cells (DSSCs): Effect of doping with fluorine.

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Abstract:

In this study, investigation of influence of fluorine doping on conductivity of transparent conducting tin oxide (SnO2) for dye-sensitized solar cells (DSSCs) was carried out. Tin Oxide (SnO2) doped with different percentage of fluorine was deposited by the Aerosol Assisted Chemical Vapour Deposition on the substrate layers of transparent glass slide. Effect of wavelength on the optical properties, and also characterization of the substrate layers was investigated. The results obtained from the UV-VIS spectra indicated that fluorine was successfully doped on the substrate. The doped SnO2 was found to have a lower absorbance when compared to the un-doped one. Transmittance obtained shows that as the wavelength increased, better transmittance was obtained; for instance above 80% for 12% doped F:SnO2, but at lower wavelength of 230 nm. The highest optimum transmittance of 50% was obtained for 4% doped F:SnO2. The thickness of SnO2 nanoparticles was 150 nm for the un-doped; 200 nm for the 4% doped SnO2; 50 nm for the 8% doped SnO2; and 40 nm for the 12% doped SnO2. The conductivity and mobility were 2.426 (Ωcm)⁻¹ and 1.347 cm²/vs for un-doped; 5.039 (Ωcm)⁻¹ and 11.40 cm²/vs for 4% doped SnO2; 20.85 (Ωcm)⁻¹ and 7.457 cm²/vs for 8% doped SnO2; and 1.596 (Ωcm)⁻¹ and 7.457 cm²/vs for 12% doped SnO2. Conclusively, it is evident that FTO is greatly affected by the wavelength as well as the percentage of doping. In case of thin films, conductivity will also depend upon the film thickness. If the thickness is too large beyond an optimum limit, conductivity decreases because grain size of nanoparticle will increase leading to an increase in bandgap (quantum confinement effect).

Keywords: DSSC; FTO; Doping; Absorbance; Transmittance
1 INTRODUCTION

There is a growing interest for researchers on solar energy which is as a result of high demand for a more sustainable form of energy resulting from the rapid collapse of oil price over the last decade. However photovoltaic has gained wide attention owing to the fact that our planet enjoys over 120,000 TW of solar energy compared to its consumption of 16TW and this has led to a dramatic expansion making it the world’s fastest growing technology [18]. The amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources [2][11]. Having this in view, new and existing technologies now spring up in order to capture sunlight and produce electricity and the efficiency and robustness of these photovoltaic systems is improving daily.

![World energy consumption](image)

Figure 1: The energy consumed plotted as a function of year for oil, coal, natural gas, hydro, nuclear, and other renewable energy resources [17]

The need for efficient and low cost solar cells fabrication using abundance of non-toxic materials with simple manufacturing processes has led to some modification of the original DSSC design of Michael Grätzel. This has resulted to progress in the DSSC technology thus giving the technology a commercial market advantage. For over twenty-five years since the breakthrough discovery of DSSCs, numerous and positive efforts have been made on the improvement of DSSCs performance. However, the effect of improving a single part on a
Dye sensitized solar cells (DSSCs) is the most recent of advanced solar cell technology which can be likened to artificial photosynthesis due to the way it absorbs light from the sun, separates it and generates charges. DSSC comprises of several parts that can be optimized hence improving its efficiency. In order for effective light harvesting, the Transparent Conducting Material (TCM) commonly made up of Fluorine Doped Tin Oxide (FTO) can be improved. Transparent conductive materials (TCMs) are generally a class of materials which possess simultaneously the properties of optical transmission and electrical conductivity. Currently the most important TCMs are transparent conductive oxides (TCOs). TCOs are usually n- and p-type semiconductors with band gap higher than 3 eV in order to be transparent in the visible portion of the spectrum (approximately 1.8-3.0 eV, see Figure 1.6a for reference). The oxides are often extrinsically doped to render high conductivity. To date, the most important binary n-type TCOs are In$_2$O$_3$, ZnO, and SnO$_2$ [5][6][17]. The fluorine-doped tin or tin-doped indium oxide (FTO or ITO) are most commonly used TCO because it can make the glass plates serve as electrodes helping them to collect electric charge produced within the cell. They are very transparent throughout the visible spectrum and they are more absorbent in ranges closer to UV radiation, making them well suited for the main part of the Sun’s output [9]. FTO can be mechanically, chemically and electrochemically stable utilizing numerous technologies other than solar cells. There are several methods used in fabricating the FTO nanocomposites which includes the hydrothermal method, chemical vapour deposition (CVD), RF sputtering and spray pyrolysis method. The preparation of FTO by CVD has different variations which includes low pressure CVD [4], plasma enhanced CVD, Aerosol Assisted CVD, and the atmospheric pressure CVD which is very productive and economic [15].

Ref.[12] used the atmospheric pressure CVD method to prepare FTO by depositing it onto a glass substrate at different substrate temperature and was later kept constant at 500°C using air as both the career gas and the oxidizing agent. Investigating the electrical properties of the prepared thin film showed that its properties tends to vary with the varying substrate temperatures ranging from an insulator thin film to a highly conductive thin film [12]. Under X-ray diffraction, the structural property was seen to be poly-crystalline at higher temperatures and amorphous at lower temperature.

In a quest to optimize the performance the FTO, [7] prepared thin films of un-doped SnO$_2$ and fluorine doped tin oxide (FTO) using the spray pyrolysis on glass substrates while a
systematic optimization of the solvent and precursor was investigated. [7] found out that when the spray time, the temperature of the substrate and solution concentrations was increased, it resulted in subsequent increase in film thickness and a decrease in sheet resistance. This invariably means that as thickness of film is achieved, growth rate of SnO$_2$ is optimized. The electrical and optical properties of FTO is essential both for effective light harvesting and sheet resistance. Ref. [7] observed that the electrical resistance of the film is thickness dependent and as such, the increased thickness as a result of the increase in spray time, substrate temperature and solution concentration led to a decrease in the sheet resistance thereby enhancing the conductivity.

SnO$_2$. Tin oxide doped with F (FTO) or Sb (ATO) was the first TCO used on an industrial scale, especially for low-emissivity coatings on glass [16]. The resistivity of SnO$_2$-based TCO is slightly higher than that of AZO with the best ones in the order of 3-4 ×10$^{-4.96}$ Compared to In$_2$O$_3$ and ZnO, which are both prepared by more expensive vacuum-based sputtering technique, SnO$_2$ can also be prepared using cheap chemical methods such as spray pyrolysis with cheap raw materials as tin chlorides [1][10][11][13]. Due to its easy deposition, FTO coating can be integrated into the glass production line, and high volume manufacturing
of commercial FTO coated glass is currently available, which in turn makes the FTO economically more advantageous than other TCOs for the thin film PV applications.

Improving the efficiency of the DSSC, this research work will go a long way to improve some individual components of the cell. This study was carried out by preparing fluorine doped tin oxide using AACVD method and coating it to the metal oxide ((SnO$_2$F, FTO)

2 Methodology

FTO was prepared using AACVD method as shown in the Fig.3 below, a simple and versatile method. Like spray pyrolysis, it uses a precursor solution which could be a solid or liquid dissolved in a solvent, for deposition. The rate of deposition onto the glass substrate could be determine by the level of the solution.

The experiment started with production of tin acetylacetonate which was used as tin (II) oxide (SnO$_2$) for spraying the film. The precursor solution, Tin acetyl acetone was prepared by dissolving 1.128 g of Tin (II) chloride (SnCl$_2$) and 2.003g acetyl acetone in acetone up to 50ml mark of a 100 ml beaker. The solution was covered with a watch glass to reduce evaporation and reaction with water molecule, and then heated for about 5 min to enhance solubility. Supply of the tin acetylacetone solution was done by measuring it with a 1ml syringe, which accurately measures the dispensed volume. The syringe was held on the AACVD machine over the glass slide. The speed of deposition (Flow rate) was influenced by the height of the solution (The higher the volume of the solution the higher the flowrate), so precautions were taken to prevent lowering the volume of the solution). This was done by refilling the mechanized syringe at every 0.1 ml reduction. Also, precautions were taken to ensure that the syringe was not blocked. The process was carried out for 0.2 ml, 0.4 ml, 0.6 ml and 0.8 ml. The different volumes were deposited onto different glass slide, properly labelled after each deposition and tested for conductivity. The glass substrate was kept at constant temperature before deposition. The slides were taken to the lab for characterization and to compare their properties.

FTO was prepared by using ammonium fluoride as the dopant (NH$_4$F). 0.074 g of ammonium fluoride was dissolved in methanol up to a 50ml mark. Doping was carried out for 4%, 6%, 8%, and 12%. For 4%, 8 ml of the dopant (NH$_4$F) was added to 192 ml of tin acetyl acetone and mixed thoroughly. 1 ml of the solution was measured and introduced on each slide by the mechanized syringe. Same procedure and precautions were taken as carried out with the SnO$_2$. The process was repeated for 6%, 8%, and 12%.
3 RESULTS AND DISCUSSION

The samples were improved in order to explore the effect of doping SnO$_2$ with fluorine at different percentage. As shown in Table 1, the deposition of the FTO on the glass substrate using AACVD method at various intervals. The optical properties of the un-doped SnO$_2$ and various percentage of doped SnO$_2$ were studied.

Table 1: Absorbance and transmittance of doped and un-doped SnO$_2$ at 230 nm and 1100 nm wavelength.

| S/N | Sample ID | Fluorine Doping (%) | Deposition Time (min) | Absorbance ($\lambda = 230 \text{ nm}$) | Transmittance ($\lambda = 230 \text{ nm}$) | Absorbance ($\lambda = 1100 \text{ nm}$) | Transmittance ($\lambda = 1100 \text{ nm}$) |
|-----|-----------|---------------------|-----------------------|--------------------------------------|----------------------------------------|----------------------------------|----------------------------------------|
| 1   | SnO$_2$   | 0                   | 13                    | 1.1937                               | 6.40                                   | 0.1363                           | 73.0634                                |
| 2   | F:SnO$_2$ | 4                   | 15                    | 0.2980                               | 50.35                                  | 0.08                             | 83.1764                                |
| 3   | F:SnO$_2$ | 8                   | 25                    | 0.5000                               | 31.62                                  | 0.0828                           | 82.6418                                |
| 4   | F:SnO$_2$ | 12                  | 38                    | 0.8770                               | 13.27                                  | 0.0432                           | 90.5316                                |
Figure 4: Absorbance Spectra of Un-doped SnO$_2$ Thin Films Deposited on Glass Substrate

Figure 5: Absorbance Spectra of 4% F:SnO$_2$ Thin Films Deposited on Glass Substrate
Figure 6: Absorbance spectra of 8% F:SnO$_2$ Thin Films Deposited on Glass Substrate

Figure 7: Absorbance spectra of 12% F:SnO$_2$ Thin Films Deposited on Glass Substrate and wavelength
Table 2: Absorbance and transmittance for doped and un-doped F:SnO₂

| Wavelength (nm) | SNO₂ | 4% F:SnO₂ | 8% F:SnO₂ | 12% F:SnO₂ |
|-----------------|------|-----------|-----------|-----------|
|                 | Absorbance | Transmittance | Absorbance | Transmittance | Absorbance | Transmittance |
| 230             | 1.1937 | 6.4018     | 0.298     | 50.3501    | 0.5       | 31.6228     | 0.877     | 12.2739   |
| 401.74          | 0.405  | 39.355     | 0.2629    | 54.5884    | 0.2889    | 51.4162    | 0.0944    | 80.4637   |
| 576.25          | 0.0593 | 25.527     | 0.0437    | 90.4274    | 0.0369    | 91.8544    | 0.0175    | 96.0506   |
| 750.76          | 0.04   | 91.2011    | 0.0313    | 93.0465    | 0.0146    | 96.6941    | 0.0146    | 96.6941   |
| 925.57          | 0.0298 | 93.3684    | 0.0138    | 96.8724    | 0.0164    | 96.2942    | 0.0091    | 97.9264   |
| 1100            | 0.1363 | 73.0634    | 0.08      | 83.1764    | 0.0828    | 82.6418    | 0.0432    | 90.5316   |

Table 8: Absorbance and transmittance for doped and un-doped F:SnO₂

| Wavelength (nm) | SNO₂ | 4% F:SnO₂ | 8% F:SnO₂ | 12% F:SnO₂ |
|-----------------|------|-----------|-----------|-----------|
|                 | Absorbance | Transmittance | Absorbance | Transmittance | Absorbance | Transmittance |
| 230             | 120  | 6.4018     | 29.8      | 50.3501    | 50       | 31.6228     | 87.7     | 12.2739   |
| 401.74          | 40.5 | 39.355     | 26.29     | 54.5884    | 28.89    | 51.4162    | 9.44     | 80.4637   |
| 576.25          | 59.3 | 25.527     | 4.37      | 90.4274    | 3.69     | 91.8544    | 1.75     | 96.0506   |
| 750.76          | 4    | 91.2011    | 3.13      | 93.0465    | 1.46     | 96.6941    | 1.46     | 96.6941   |
| 925.57          | 2.98 | 93.3684    | 1.38      | 96.8724    | 1.64     | 96.2942    | 0.91     | 97.9264   |
| 1100            | 13.63| 73.0634    | 8         | 83.1764    | 8.28     | 82.6418    | 4.32     | 90.5316   |
3.1 OPTICAL PROPERTIES AND CHARACTERISATION

The optical properties of the fluorine doped tin oxide and the undoped (SnO₂ deposited) tin oxide thin films, prepared and deposited by AACVD method on the glass substrate was studied. The transmittance and the absorbance spectra were measured in range of wavelength from 230 nm – 1100 nm for 4%, 8% and 12% F:SnO₂ and the undoped tin oxide. The results at wavelength 230 nm and 1100 nm are presented in table 1. The results showed that more time is required as Fluorine doping is carried out on the substrate (i.e. the more the percentage of doping the more time it required to deposit the FTO on the glass substrate). The undoped SnO₂ was deposited faster while the 12% F:SnO₂ had the slowest deposition time.

3.2 Effect of Wavelength on Absorbance

The Figures 2- 5, are the result of UV-VIS spectrophotometer measurement of the un-doped and doped tin oxide prepared by AACVD method. The figure indicates the absorbance spectra of undoped SnO₂ and the various percentage doped SnO₂. The Fluorine was doped on the different slides at vary percentage (4%, 8%, 12%). Figure 2 represents the absorbance in 230nm to 1100nm range of wavelength. Highest absorbance for undoped was at 271.55nm then experienced a decrease and an increase after which decreases monotonically until it reaches 1100nm. However, this behaviour exercised by the absorbance spectra was seen to be typical for fixed size scattering centers which usually diffuse more effectively at shorter...
wavelengths [17]. This was similarly experience at the various percentage dopant unlike the undoped SnO₂, the peak values of the absorbance of the doped SnO₂ were found be to lower. At the lowest wavelength of 230nm, the 4% F:SnO₂ has the lowest absorbance value while at the highest wavelength, the 12% F:SnO₂ has the lowest absorbance value.

3.3 Effect of Wavelength on Optical Transmittance

As it was shown in table 2 and table 3, the optical transmittance (T) properties of the thin films prepared at different dopant have been characterized by UV-VIS spectrophotometer (Perkin Elmer, Lambda 35) within the range of 230nm to 1100nm. The transmittance was observed to increase as the wavelength increases. At 230nm, the highest transmittance of light was found to 4% F:SnO₂ while the undoped has the lowest transmittance. The value of transmittance at 900 nm calculated was 90%. The values are comparable with literature [3][6]. For both the doped and the undoped, the transmittance increases with an increase in wavelength [3], in other words when the wavelength increases the optical transmittance is increased.
Fig. 11: X-RD profile pattern of SnO$_2$ thin film
Fig. 12: X-RD profile pattern of 4% F:SnO$_2$ thin film
Fig. 13: X-RD profile pattern of 8% F:SnO$_2$ thin film
Fig. 14: X-RD profile pattern of 12% F:SnO₂ thin film

| Element Number | Element Symbol | Element Name   | Atomic Conc. | Weight Conc. |
|----------------|----------------|---------------|--------------|--------------|
| 50             | Sn             | Tin           | 70.94        | 89.99        |
| 14             | Si             | Silicon       | 6.34         | 1.90         |
| 20             | Ca             | Calcium       | 3.84         | 1.65         |
| 17             | Cl              | Chlorine     | 4.03         | 1.53         |
| 13             | Al              | Aluminium     | 3.45         | 0.99         |
| 15             | P               | Phosphorus    | 2.40         | 0.79         |
| 22             | Ti              | Titanium      | 1.55         | 0.79         |
| 16             | S               | Sulfur        | 2.27         | 0.78         |
| 19             | K               | Potassium     | 1.64         | 0.69         |
| 11             | Na              | Sodium        | 1.85         | 0.45         |
| 12             | Mg              | Magnesium     | 1.70         | 0.44         |

Table 4: Composition of SnO₂

Fig. 15: 0.4 ml SnO₂ FOV: 537 µm, Mode: 10 kV - Image, Detector: BSD Full, Time: SEP 6 2019 08:24
Table 5: Composition of 4% F:SnO$_2$

| Element Number | Element Symbol | Element Name   | Atomic Conc. | Weight Conc. |
|----------------|----------------|----------------|--------------|--------------|
| 50             | Sn             | Tin            | 61.08        | 85.57        |
| 14             | Si             | Silicon        | 10.08        | 3.34         |
| 22             | Ti             | Titanium       | 3.48         | 1.96         |
| 20             | Ca             | Calcium        | 3.09         | 1.46         |
| 17             | Cl             | Chlorine       | 3.45         | 1.45         |
| 13             | Al             | Aluminium      | 3.49         | 1.11         |
| 15             | P              | Phosphorus     | 2.85         | 1.04         |
| 19             | K              | Potassium      | 2.22         | 1.03         |
| 16             | S              | Sulfur         | 2.64         | 1.00         |
| 11             | Na             | Sodium         | 3.41         | 0.92         |
| 12             | Mg             | Magnesium      | 2.75         | 0.79         |
| 9              | F              | Fluorine       | 1.47         | 0.33         |
| 26             | Fe             | Iron           | 0.00         | 0.00         |

Figure 16: EDX spectrum of SnO$_2$ thin film before doping.

Figure 17: 4% F:SnO$_2$ FOV: 537 µm, Mode: 10kV - Image, Detector: BSD Full, Time: SEP 6 2019 08:43
Figure 18: EDX spectrum of 4% F:SnO$_2$ thin film.

| Element Number | Element Symbol | Element Name  | Atomic Conc. | Weight Conc. |
|----------------|----------------|---------------|--------------|--------------|
| 50             | Sn             | Tin           | 71.30        | 90.60        |
| 13             | Al             | Aluminium     | 6.32         | 1.82         |
| 17             | Cl             | Chlorine      | 4.61         | 1.75         |
| 14             | Si             | Silicon       | 5.06         | 1.52         |
| 20             | Ca             | Calcium       | 3.31         | 1.42         |
| 15             | P              | Phosphorus    | 2.73         | 0.90         |
| 16             | S              | Sulfur        | 2.39         | 0.82         |
| 12             | Mg             | Magnesium     | 2.12         | 0.55         |
| 11             | Na             | Sodium        | 1.74         | 0.43         |
| 19             | K              | Potassium     | 0.42         | 0.18         |

Table 6: 8% F:SnO$_2$ Composition

Figure 19: 8% F:SnO$_2$ FOV: 537 µm, Mode: 10kV - Image, Detector: BSD Full, Time: SEP 5 2019 16:41
Figure 20: EDX spectrum of 8% F:SnO$_2$ thin film.

| Element Number | Element Symbol | Element Name | Atomic Conc. | Weight Conc. |
|----------------|----------------|--------------|--------------|--------------|
| 74             | W              | Tungsten     | 20.77        | 52.37        |
| 50             | Sn             | Tin          | 13.02        | 21.20        |
| 14             | Si             | Silicon      | 39.50        | 15.21        |
| 20             | Ca             | Calcium      | 5.60         | 3.08         |
| 11             | Na             | Sodium       | 8.17         | 2.58         |
| 12             | Mg             | Magnesium    | 3.85         | 1.28         |
| 22             | Ti             | Titanium     | 1.41         | 0.92         |
| 17             | Cl             | Chlorine     | 1.72         | 0.84         |
| 13             | Al             | Aluminium    | 2.26         | 0.84         |
| 19             | K              | Potassium    | 1.47         | 0.79         |
| 16             | S              | Sulfur       | 1.16         | 0.51         |
| 15             | P              | Phosphorus   | 0.59         | 0.25         |
| 9              | F              | Fluorine     | 0.48         | 0.13         |
| 26             | Fe             | Iron         | 0.00         | 0.00         |

Table 7: 12% F:SnO$_2$ Composition

Figure 21: 12% F:SnO$_2$ FOV: 488 µm, Mode: 10kV - Image, Detector: BSD Full, Time: SEP 6 2019 08:53

Figure 22: EDX spectrum of 12% SnO$_2$ thin film.
### Table 8: Results of Hall Effect Analysis

| S/N | OPTICAL PROPERTIES | 0.4 ml SnO₂ | 4% F:SnO₂ | 8% F:SnO₂ | 12% F:SnO₂ |
|-----|---------------------|-------------|------------|-----------|------------|
| 1   | Bulk Concentration /cm³ | 1.124 x 10¹⁹ | -2.760 x 10²¹ | -1.745 x 10¹⁷ | -4.192 x 10¹³ |
| 2   | Mobility cm²/Vs      | 1.347       | 1.140 x 10¹  | 7.457     | 2.377 x 10¹⁷ |
| 3   | Sheet-Resistance Ω/² | 4.12 x 10⁴  | 2.481 x 10⁴  | 1.199 x 10⁶  | 3.132 x 10⁵  |
| 4   | Resistivity Ωcm      | 4.122 x 10⁻¹ | 1.984 x 10⁻¹ | 4.796     | 6.264 x 10⁻¹  |
| 5   | A-C Cross Hall Coefficient cm³/C | -5.367 x 10¹⁰ | 1.293 x 10¹  | -1.101 x 10¹² | -2.360 x 10²  |
| 6   | Magneto-Resistance Ω | 4.268 x 10²  | 1.913 x 10²  | 7.335 x 10³  | 2.940 x 10⁴  |
| 7   | Sheet Concentration /cm² | 1.102 x 10¹⁴ | -2.208 x 10¹¹ | -6.981 x 10¹³ | -8.383 x 10¹³ |
| 8   | Conductivity 1/Ωcm   | 2.426       | 5.039       | 2.085 x 10⁻¹ | 1.596       |
| 9   | Average Hall Coefficient cm³/C | 5.552 x 10⁻¹ | -2.262     | -3.577 x 10⁻¹ | -1.489 x 10⁻¹ |
| 10  | B-D Cross Hall Coefficient cm³/C | 5.48 x 10⁻¹ | -1.75 x 10⁻¹ | 3.85 x 10⁻¹  | 2.06 x 10⁻²  |
| 11  | Ratio of Vertical/Horizontal | -1.35 x 10⁻⁴ | 4.29 x 10⁻³ | -6.43 x 10⁻⁴ | 8.35 x 10⁻⁵  |

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**Figure 23: 3D graph of optical properties of sampled ID**
3.4 Effect of Thickness on Conductivity

Results from figure 8 to 11 show the thickness of undoped and doped (from profile results) nanoparticles ranges from 150nm, 200nm, 50nm and 40nm for 0.4ml, 4%, 8% and 12% respectively. The more the thickness of the thin film, the conductivity, and the more the photon absorbed. While Figure 20 to 23 shows the conductivity and mobility, and thus, 2.426E+0 (Ωcm)^{-1}, 1.347E+0 cm^2/vs for 0.4ml, 5.039E+0 (Ωcm)^{-1}, 1.140E+1 cm^2/vs for 4%, (2.085E+1 (Ωcm)^{-1}, 7.457E+0 cm^2/vs for 8%) and (1.596E+0 (Ωcm)^{-1}, 7.457E+0 cm^2/vs for 12%) respectively. The obtained results revealed that FTO was greatly affected by the wavelength as well as the percentage of doping. At the lowest wavelength of 230nm, the 4% F:SnO2 has the lowest absorbance value of 0.2980 a.u, while at the highest wavelength, 12% F:SnO2 has the lowest absorbance value of 0.0432 a.u. In case of thin films, conductivity will also depend upon the film thickness. If the thickness is too large beyond an optimum limit, conductivity starts to decrease again because grain size of nanoparticle will increase leading to an increase bandgap (quantum confinement effect).

4. CONCLUSION

Tin oxide thin films doped with fluorine (F:SnO2) were successfully deposited by AACVD method at different doping percentage on the glass substrate. The optical property of the FTO and substrate layers were characterized by investigating the absorbance spectra. The study revealed that the fluorine has been successfully doped into the SnO2 thin films. The results obtained showed that a better lower absorbance resulting to a better transmittance was seen to be the 4% F:SnO2 indicating it has the best capacity to transmit optical energy. The results obtained from the absorbance spectra of UV-VIS also indicated that the absorbance tends to monotonically decreases at certain wavelength for both the doped and the undoped, however this leads to an increase in the transmittance.

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