Developed spray pyrolysis reactor for fabricating fluorine-doped tin oxide (FTO)

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Abstract. It was developed spray pyrolysis reactor for fabricating FTO glass. Nabulizer was used for spraying the solution to glass on hotplate. In optimizing sheet resistance of FTO, concentration and deposition time was investigated. The optimum sheet resistance of the FTO glass was about 56 Ω/cm² and the transmittance was obtained over 80%. Scanning Electron Microscopy was also used to examine the morphology characteristic of FTO.

1. Introduction
Spray pyrolysis is a simple and cheap method for producing FTO [1, 2]. Moreover, some researcher also reported that it can produce high performance FTO which can be applied in photovoltaic device [3-5]. Unfortunately, it hasn’t been ever FTO factory in Indonesia and so the researcher should buy from overseas with high price. Hence, photovoltaic research was less productive. In order to meet FTO need in Indonesia, developed of FTO reactor was should done.

To produce FTO, solution was spray to substrate by using nabulizer as shown by figure 1. Then, substrate was heated in 450°C for 30 minutes and FTO was resulted. Solution concentration, time deposition, temperature and distance between nebulizer to the substrate were several parameter in affecting FTO performance in fabrication process [6-8]. Performance of FTO can be optimized by used proper parameter.

Figure 1. Spray pyrolysis method design for fabricating FTO [6,8].
In this paper, we reported developed of spray pyrolysis reactor for producing high performance of FTO. We proposed reactor of spray pyrolysis and investigated the parameter such as solution concentration and deposition time.

2. Research Methods
In Fabricating of the FTO glass, the solution of Tin(II) Chloride (SnCl₂·2H₂O, Merck, Germany), Ammonium Fluoride (NH₄F, Merck, Germany), and Ethanol (96%, Merck, Germany) were used. About 1 gram the SnCl₂ and NH₄F materials were fed into the ethanol solvent then stirred until homogeneous. Then, the solvent was spray on a glass substrate (1 cm x 1 cm) by using nebulizer. The best FTO parameter was found by combination concentration of solution and time deposition parameter. Investigating of morphology was done by Scanning Electron Microscopy and the other hand four point probe were applied for knowing FTO resistance. Transparency of the film was also found by using UV-Vis Spectroscopy.

3. Results and Discussion
In developing FTO reactor, we investigated some parameter i.e concentration and deposition time. Then, the parameter applied in fabricating of FTO and characterization was done. The best parameter was choosen based on lowest resistance and highest transmitance.

3.1 Solution Concentration
Solution concentration was an important parameter in fabricating FTO. It was related to ratio between nanoparticle material and the solvent [9-12]. In this study, it was used 0.3 M, 0.5 M and 0.7 M of solution concentration. Scanning Electron Microscopy observation for three sample was shown in figure 2.

![Scanning Electron Microscopy of varying concentration](image)

Figure 2. Scanning Electron Microscopy of varying concentration: (a) 0.3 M; (b) 0.5 M and (c) 0.7 M.

Figure 2 shows that density and size grain of nanoparticle was increase with increasing of solution concentration. It was also related to performance of FTO as shown by table 1.

| No | Concentration (M) | Time Deposition (Minute) | Resistance (Ω/cm²) | Transmittance (%) |
|----|-------------------|--------------------------|--------------------|-------------------|
| 1  | 0.3               | 10                       | 630.5              | 83.202            |
| 2  | 0.5               | 10                       | 181.25             | 90.242            |
| 3  | 0.7               | 10                       | 137.25             | 89.063            |

In order to know effect of concentration, it was tested three concentration and deposition time was kept constant (10 minutes). Then, performance of FTO was evaluated by measuring resistance and transmittance. Table 1 shows that performance of FTO increase by increasing of solution concentration. The best parameter was obtain for 0.7 M and this parameter was used for investigating deposition time parameter.
3.2 Deposition Time
Deposition time is related to the length of time the particles were deposited above the substrate using the spray pyrolysis method [13-14]. In investigating deposition time, it was used 10 minute; 20 minute and 30 minute of deposition time for fabricating FTO. It was found SEM observation of the sample as depicted by figure 3.

![Figure 3. Scanning Electron Microscopy (SEM) of varying deposition time: (a) 10 minute; (b) 20 minute and (c) 30 minute.](image)

Figure 3 also shows that density and size grain of nanoparticle was increase with increasing of deposition time. A lot of pore (space between particle) was found in lowest deposition time (10 minute) and small pore can be observed in highest deposition time (30 minute).

Investigating for FTO performance was also done for three sample as listed in table 2. Data on table 2 showed that deposition time less than 20 minute produce high resistance with higher transmittance. On the other hand, deposition time more than 20 minute can produce low resistance but it was also low in transmittance.

### Table 2. Performance of FTO in varying deposition time.

| No | Concentration (M) | Deposition Time (Minute) | Resistance ($\Omega/cm^2$) | Transmittance (%) |
|----|-------------------|---------------------------|---------------------------|-------------------|
| 1  | 0.7               | 10                        | 578                       | 84.21             |
| 2  | 0.7               | 20                        | 56                        | 80.77             |
| 3  | 0.7               | 30                        | 29                        | 77.65             |

Based on investigating result, it can be concluded that the best parameter for fabricating FTO were 0.7 M and 20 minute.

4. Conclusion
The conductive thin layer of FTO with a good conductivity about 56 $\Omega/cm^2$ and transmittance over 80% has been successfully made using spray pyrolysis method. The best result was found by optimized concentration and deposition time. In observation by employing SEM was found that the density and grain size of particle was increase with increasing both parameter. In high concentration (0.7 M) was obtain high performance of FTO and the best deposition time was found in 20 minutes.

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