Microstructure of ITO for Transparent Electrode on Glass Slide Prepare by RF Sputtering Technique

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Abstract. Indium tin oxide (ITO) is an absorber photovoltaic material and widely used for semiconductor work for long time. ITO has characteristics by high transparent and low resistivity that can use for electrode of photodetector. Area of photodetector has use for metal contact but if change metal contact to transparent contact will get more photocurrent. However, this paper will investigate microstructure of ITO by analyze physical properties of material by various deposit time. The results show that transparent properties show around 97% at growth 1h and annealing at 500 °C. XRD results show ITO peak (222), (400), (622) and (441) at sputtering time 60 mins.

Keywords: P-N photodetector, SEM, indium tin oxide (ITO), XRD, Transparent

1. Introduction
In generally, semiconductor device has defects from fabrication process and also in material mechanism. Then, the defects will impact to device performance that will effect to the efficiency and cannot response for every application. For example, switching time of power device drop by some of defects in silicon boundary and depletion level. However, many research and laboratory try to improve performance of device by compensate with many way such as doped gold-platinum that generate trapping center between conduction and valence band. [1]
In photodetector work, the performance of device drop by many reason. One of the reason reduced device performance by using some area for metal contact. Metal contact is important part of photodetector device for connect input-output for electrical circuit but this area will cover some of photovoltaic. Metal contact in photodetector may reduce photo current of device. [2]
In this paper will focus on transparent material for instead metal contact in photodetector. However, the optimization of physical and electrical properties is an important for transparent material due to principle of ITO has energy band around 3.59-4.07 eV [3]. Electrical and physical properties is an important for prepare ITO for photodetector contact. The goal of this study focus on physical properties of ITO material growth by RF sputtering by various sputter time.
2. Experimental procedure

2.1. Preparation process
In the process to prepare ITO for study physical properties. This material is kind of ceramic by hardness, high melting point but breakable. Sputtering will use for prepare ITO on glass slide. Thin film will growth by RF sputter by various time are 15, 30 and 60 mins then annealing in furnace by 500 °C for 15 mins. The experiment show table 1 below.

| Sputtering time (Min) | Annealing temp (°C) | Annealing time (Min) |
|-----------------------|---------------------|----------------------|
| 5                     | 800                 | 30                   |
| 15                    |                      |                      |
| 30                    |                      |                      |
| 60                    |                      |                      |

2.2. Study physical properties
The physical properties of ITO will study by scanning electron microscopy (SEM), x-ray diffraction (XRD), thickness, and transparent (%T). SEM will scan by using magnification around 100,000x and film thickness will using surface profiler tooling for measure compare with SEM.

3. Results and Discussions
This film thickness growth on glass slide show in Figure 1. From the results show thickness of 5 mins sputter time has thick around 75 nm and 229 nm at 15 mins. However, sputter time 30 and 60 mins has film thickness increase to 521 nm and 1,166 nm at 30, 60 mins, respectively.

Figure 1. Film thickness various sputter time (a) 5 mins, (b) 15 mins, (c) 30 mins and (d) 60 mins.

Figure 2 shows SEM image of thin film by various sputter time after annealing at 500 °C in furnace. From Figure 2(a) surface not smooth and thickness of thin film not symmetry, also small grain size with low density. Figure 2(b) sputter time at 15 mins show grain size same with sputter 5 mins but
surface roughness look symmetry and high density of grain. Figure 2(c) show grain size bigger than 5 and 15 mins and high density, also show good uniformity. From the results show that grain at sputter time 60 mins has biggest grain, polycrystalline, good adhesion and good uniformity in Figure 2(d). [4]

![Figure 2](image.png)

**Figure 2.** SEM image of ITO thin film by various sputter time (a) 5 mins, (b) 15 mins, (c) 30 mins and (d) 60 mins after annealing at 500 °C.

| Sputter time (min) | Thickness by SEM (nm) | Thickness by Surface profile (nm) |
|--------------------|------------------------|----------------------------------|
| 5                  | 75                     | *                                |
| 15                 | 229                    | *                                |
| 30                 | 521                    | 502                              |
| 60                 | 1,166                  | 1,120                            |

**Table 2.** Thickness compare between measure by SEM and surface profiler.

From table 2. shows film thickness compare between measure by SEM and surface profile. The thickness at from sputter 5 and 15 mins cannot measure by surface profile. While the thickness at 30 and 60 mins of sputter time show same trend results by thickness not significant different. Then, the results shows can use SEM technique measure thickness of thin film. [5]

Figure. 3 shows a results XRD of ITO prepare by RF sputtering with various sputter time. The composition of this film show cubic structure with predominate (222) for all of sputter time and (441) show when sputter at 15, 30 and 60 mins.
Figure 3. Composition of ITO thin film by various sputter time (a) 5 mins, (b) 15 mins, (c) 30 mins and (d) 60 mins.

The increase sputter time shows degree of preferential crystal orientation. However, peak (622) and (400) appear at sputter time 30 and 60, respectively. All peak (222), (400), (622) and (441) are the peak of indium doped in tin oxide [6]. As the results show in Figure 2(d), the oriental (400) has significant from thin film grain size bigger than lower sputter time and good polycrystalline structure at 60 mins. [7]

Figure 4 Transmission of thing film by various thickness from sputtering time.
Figure 4 shows transparent thin film by various thickness. The results measure by using laser with wavelength 670 nm. Although thickness 75 mins has thin but not the factor impact to transmission because amorphous grain then light will scatter for some of area. On the other hand, high transmission show at sputter time 60 mins because has good uniformity, low scattering grain and low grain boundary. [8-9]

4. Conclusions

From previous results shows that thin film after sputter time at 60 mins show good peak of ITO are (222), (441), (622) and (400). The peak can confirm ITO has good uniformity and good properties. SEM image confirm sputter at 30 and 60 mins has good uniformity of thin film, big grain size and low grain boundary that good for transparent of thin film. The transmission of this film at sputter 5 and 15 mins show a bit low than 30 and 60 mins because some of light scattering at grain boundary. By 60 mins of sputter film has high transparent then transmission of this time show around 97% by average of measure area. Finally, the results show pretty good because show good uniform and high transparent at sputtering 60 mins.

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