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# Quality enhancement of copper oxide thin film synthesized under elevated gravity acceleration by two-axis spin coating

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ABSTRACT

Two-Axis spin coating as a new modified technique is employed to enhance the quality and surface leveling of thin films. The modified technology utilizes a synthetic centrifugal force perpendicular to the surface which generates an elevated gravity acceleration while spreading the coating on the entire wafer surface. In this paper, copper acetate sol-gel is coated by conventional and Two-Axis spin coating techniques. The coated layers are sintered in an air furnace at 275 °C. The fabricated layers are characterized by GIXRD, EDX, AFM and SEM devices. Wettability and Surface Free Energy (SFE) of sintered films using the contact angle technique are measured, and evaluated by the Owens-Wendt method. XRD and EDX spectra show a higher intensity of copper oxide phase using Two-Axis spin coating technology. AFM micrographs showed an improvement in the surface leveling within the Two-Axis spin coated layer. A comparison between the SFE of conventional and Two-Axis spin coated layers shows an increase in SFE of the layer synthesized under 200*g* artificial gravity acceleration.

## 1. Introduction

Cuprite ($CuO_2$) and Tenorite (CuO), as inorganic metallic materials, have a wide range of usage in technological industries. Cuprite is a member of the cubic p-type semiconductors family with a band gap around 2.0 eV; tenorite is a member of monoclinic p-type with a narrow band gap of 1.2–-1.5 eV [1–4]. The oxygen absorption of cuprite, tenorite, and their nano phasic chemical reactions classified them to be used as the catalyst devices for environmental reactions [5–13]. A change in the surface conductivity of copper oxide layers exposed by various types of gases and liquids, causes the layers to be used in the gas sensing instruments [14–19]. The contact angle of liquids is a method to measure the SFE and wettability of layers. A higher SFE of the copper oxide film leads to a higher wettability and lower interfacial contact angles [20,21]. $CuO_2$ thin films are one of the interest layers of photovoltaic and solar cell industries. Recently, optical industries have paid great attention to transparent conductive oxide thin films due to their low cost and high optical absorption efficiencies. The surface leveling of layers leads to an increase in the transparency and efficiency of photovoltaic cells [22,23].

Sintering temperature, curing time, rate of annealing, and applied protecting gas can be affected on the size of copper oxide particles and transform the nano phasic crystallites from cuprite to tenorite and vice versa [24].

Conventional spin coating is a low-cost method has been employed to fabricate conductive and semiconductive films in a wide range of thicknesses such as copper oxide layers. However, the thickness of films could not be well-controlled and leads to a probable porosity and cracks as well as secondary phases [25,26].

In this study, two different methods of spin coating, conventional and Two-Axis spin coating techniques, are employed to create copper oxide layers experimentally. The Two-Axis spin coating method benefits an elevated gravity acceleration while spreading the coating on substrate simultaneously. The elevation of gravity acceleration proposes penetration of copper microcrystals inside the coated layer before complete evaporation of solvents, and prevent the deposited sol to be thrown out by the horizontal centrifuge acceleration of conventional spinning. The elevation of gravity stimulates copper microcrystals to

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