Optimization of the Process of Obtaining P-Type Semiconductors (CuO) in the Laboratory using Lean Six Sigma

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Abstract: ***The following work shows comparisons of the results of experiments related to the obtaining of metal oxides, specifically copper nanoparticles (Cu), making a comparison between two obtaining techniques, one by Cu sheet with a purity of 99.99% and the optimization of the obtaining process using the Lean Six Sigma methodology to obtain a Cu film deposited by the sputtering method. This technique that was used to obtain this material presents notable adhesion to the substrate, compositional control and purity. Furthermore, it is an environmentally friendly and, above all, reproducible technique, allowing a wide range of metals to be synthesized and characterized with this sputtering technique. Likewise, samples of Copper (Cu) metal deposits were thermally treated with the intention of obtaining copper oxide. copper (CuO) and be used as a proposed p-type semiconductor material based on metal oxides, which was formed through the thermal oxidation technique in a high temperature tubular furnace at 900°C, with air flow at 600sccm to form an oxidizing environment and consequently form continuous layers of Copper Oxide (CuO) material and are structurally analyzed with X-ray diffraction.***

Keywords: Spraying, Oxides, Metals, Copper, Semiconductor

1. Introduction

Currently, we live with a wide variety of technological devices based on different semiconductor materials, which have provided us with great advances in the continuous development of electronics [1-7]. The materials used to design these devices are silicon and germanium [7]. A semiconductor material can act as a conductor or insulator depending on the input excitation, which can be luminescence, temperature, atomic structure [8], or electric field, allowing different operating states, such as the conduction state when an electric current is allowed to pass, or as an insulator preventing current flow for embedded device applications (Juntura). Nanostructured metal oxides have been widely studied for applications in electronics, optics, materials science, and biomedicine [9]. Among them, copper oxide (CuO) has become a key material in the industry due to its versatility, high chemical stability, high chemical capacity, high electron transport capacity and optical, electronic, magnetic and mechanical properties derived from nanometric confinement [10].

2. Development

Lean Six Sigma

Lean Six Sigma is a methodology whose objective is to improve processes, with the purpose of increasing their profitability and productivity. The Six Sigma project seeks to reduce the variability of processes. To do this, it uses a series of statistical tools. Thus, it gives priority to customer requirements. According to its philosophy, every process must adjust to these requirements. If you don't, they are bugs to be polished. In this way, the Lean Six Sigma methodology consists of eliminating aspects that prevent or hinder the adjustment of the product to the customer's requirements. Thus, it reduces its defects in the final delivery.

The DMAIC method

The acronym DMAIC (define, measure, analyze, improve and control) marks the direction of how the method works. With this succession of steps an improvement is achieved:

a) Define:

The problem, the value for the client, the team and the project. Thus, it is about finding the specific problem or defect and validating it while defining the program participants.

b) Measure:

It refers to performance and answers the question of what is needed to improve. It consists of mapping the process and determining the reliability of the data. You want to find an improvement solution.

c) Analyze:

Identify sources of variation and root causes. It focuses on processes and influencing factors. The objective is to be able to change the causes.

d) Improve:

It's about making changes to increase performance.

e) Control:

Makes sure to establish controls to maintain the improvements made. Essential measures must be taken to guarantee the continuity of improvement. In this way, both customer satisfaction and the economic term are valued.

Six Sigma Maturation Model

The maturation model shown in the following diagram was applied to optimize the process of obtaining Cupric Oxide with samples that started from commercial sheets and that were optimized following the steps of the method and to obtain a single phase of the material, since They presented mixtures of phases.

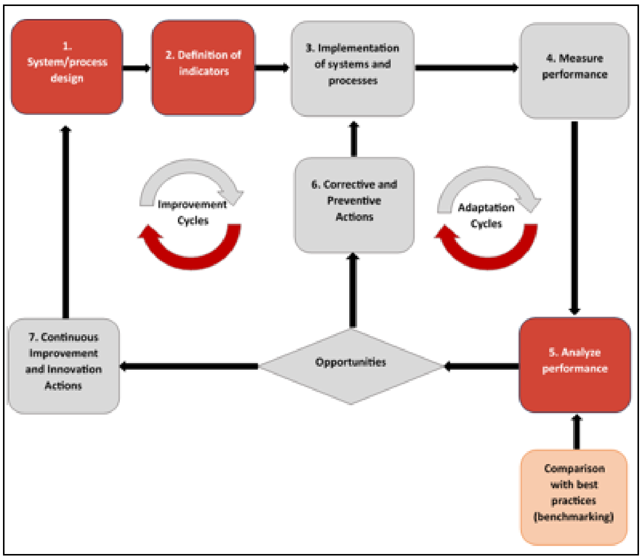

Figure 1: Diagram Six Sigma Maturation Model.

3. Materials and methods

Copper oxide

CuO is a semiconductor material that has a band gap of 1.12 eV, this makes it suitable for short wavelength optoelectronic applications. The difference in electronegativities between copper (Cu) and oxygen (O) produces a high degree of ionicity in its bond, making it one of the most ionic compounds of the metal oxides [1]

The current knowledge of the physical and chemical properties of CuO has not allowed the discovery of new ferromagnetic properties due to the doping of CuO with rare earth elements [2].

Cathodic Sputtering

Sputtering is a physical vapor deposition process to form thin films. The thickness of the layers varies from a few nanometers to several micrometers [3].

Thin films, due to their extreme thinness and fragility, are not usually isolated, but are supported on other thicker solids with different physical or chemical properties, which are called "substrates". In general terms, thin films are used for two purposes: the first is to optimize one or more of the properties of the substrates they cover or even provide them with new properties, in which case, thin films are usually referred to with the term "coating"; The second is the manufacture of devices with specific physicochemical properties, which have very little or no relationship with the initial properties of the substrate, which behaves as a simple physical support

Obtaining Copper (Cu) sheets

The state of the art of copper oxide materials for use as a semiconductor was studied, as well as the different oxidation methods and the temperature and time variables to be able to have CuO.

Mainly, a commercial sheet of copper (Cu) with a purity of 99.99% was obtained, which had a thickness of 500 microns. This sheet was cut into small plates measuring 2 cm x 2 cm to later be oxidized.

Degreasing and stripping of Copper (Cu) sheets

For this process, a commercial sonicator equipment was used to facilitate the washing of the supports used, with the aim of eliminating organic and inorganic residues that the substrates to be deposited and the copper (Cu) sheets may have and thus have surfaces free of elements. parasites.

The copper (Cu) sheets and the quartz substrates that will be used for the sputtering process are deposited inside a 50ml glass beaker, to which 20 ml of Xylene C6H4(CH3)2 are added to be The substrates were sonicated for 15 minutes at a power of 50 watts, this to eliminate organic residues from the substrates, the supports were removed and the sonication process was repeated for two other solvents, Acetone (CH3)2CO and Methanol CH3OH, each solvent was Use separately in the order mentioned above and then sonicate the substrates in the solutions for 15 minutes at the same power of 50 watts as shown in figure 2. At the end of the time, each of the residues of the different solvents were neutralized and discarded in the corresponding containers.

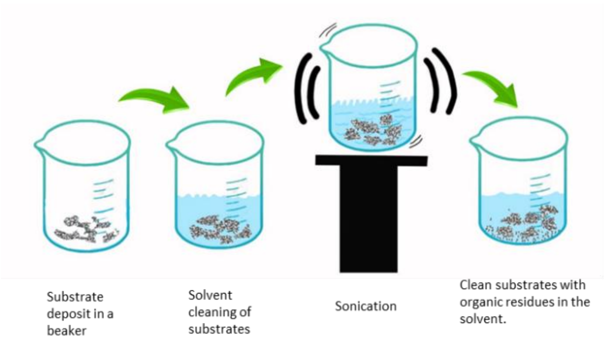

Fig. 2. Preparation of the substrates.

Obtaining Copper (Cu) films by sputtering

In order to carry out this sputtering process, it was necessary to manufacture a Copper (Cu) target starting from a commercial Copper (Cu) sheet with a purity of 99.99% where it was necessary to thin the sheet from 500 microns to a thickness of 300 microns. . Once the target was obtained, it was placed in the Agar Auto Sputter Coater (mod.108A) equipment, which works with the help of a pump that generates a vacuum in the deposit chamber where the working parameters are pressure (40 Mb) and the amperage (0.1 mA), these values are already established automatically by the equipment, the only parameter that we can control in automatic mode is the deposit time in seconds, this equipment only allows deposits to be made in a range of 5 to 500 seconds for each cycle. It was necessary to replicate samples of 75 minutes of deposit, that is, 15 cycles of 5 minutes. Clarifying that every 3 cycles it was necessary to let the equipment rest for 2 hours to avoid overheating of the vacuum pump of the sputtering equipment.

Oxidation of Copper (Cu) sheets

For this oxidation process, the copper sheet is placed on an alumina channel that will later be placed inside the horizontal tube resistive furnace (mod. CMOD-HAT-1100D25), in this process the parameters to control are the following; temperature 900°C, oxidation time 64 hours, air flow of 600 sccm, as shown in figure 3 this last parameter was implemented to create an oxidizing environment inside the oven chamber and facilitate the oxidation process, for this an air compressor was necessary in automatic mode, so that when the air pressure level dropped in automatic mode it would turn on and be able to have air flow throughout the entire process. Once the thermal oxidation time is over, the air flow is closed and cooling is natural, that is, the quartz tube is not removed from the horizontal tube resistive furnace until the furnace is at room temperature again, once the The quartz tube is dismantled from the substrate, resulting in the copper oxide (CuO) sample.

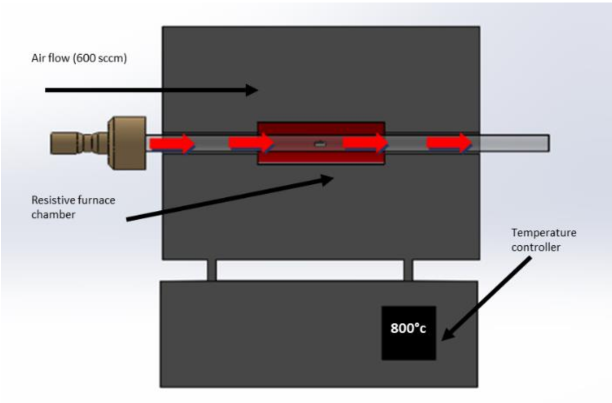

Figure 3: Oxidation of Cu sheets.

Oxidation of Copper (Cu) films obtained by cathodic sputtering

In this phase, the quartz tube is placed inside the horizontal tube resistive oven previously heated to 900°C. The sample obtained in the copper (Cu) sputtering process must already be placed inside the quartz tube. Before The quartz tube is placed inside the furnace and the air supply should be flowing. Once the quartz tube is placed, the thermal oxidation process of copper (Cu) lasts 24 hours with air flow at 600 sccm, as shown in the block diagram 4. For this, an air compressor in automatic mode was necessary, so that when the level of The air pressure will automatically turn on and be able to have air flow throughout the entire process. Once the thermal oxidation time is over, the air flow is closed and cooling is natural, that is, the quartz tube is not removed from the horizontal tube resistive furnace until the furnace is at room temperature again, once the The quartz tube is dismantled from the substrate, resulting in the copper oxide (CuO) sample.

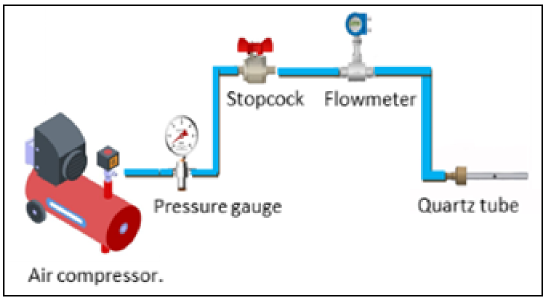

Fig. 4 Block diagram for obtaining copper oxide after sputtering.

4. Results

This section explains the results of the samples obtained with the methodologies described above: oxidation of copper sheets (Cu), sputtering of copper (Cu) and thermal oxidation to finally obtain copper oxide (CuO), to validate the results. . technicians. X-ray diffraction (XRD) characterization was used; This technique is used to characterize metal oxides such as semiconductors. The characteristic diffraction angle and intensity of a crystalline structure is unique for each material, so X-ray diffraction in polycrystalline samples allows identifying qualitative and quantitative aspects to determine physical and chemical properties.

The diffraction graph of the copper oxide sheet observed in Figure 5 shows a mixture of phases because only the outside of the sheet is oxidized, but the X-ray beam incident on the sample penetrates the surface of the sample. and the results indicate that internally the sheet is still copper.

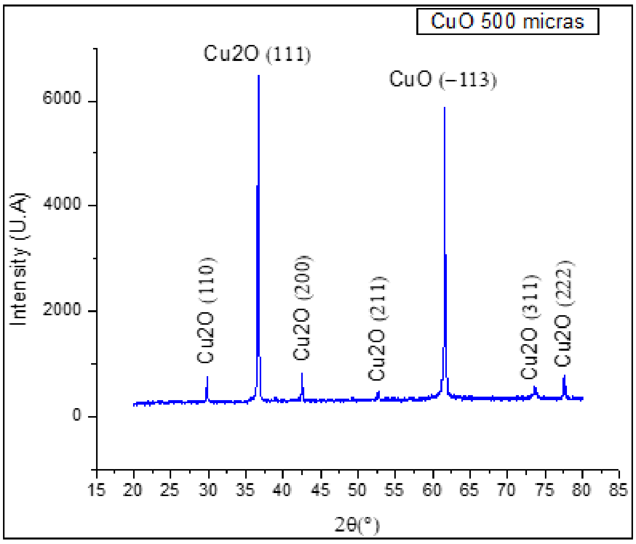

Figure 5: Diffractogram of Cu2O sheet.

While in the result of the sample obtained by sputtering, the graph in Figure 6 shows a single phase of the copper oxide material because the deposit film is thinner and the thermal oxidation process is easier to oxidize a thin film. compared to copper foil.

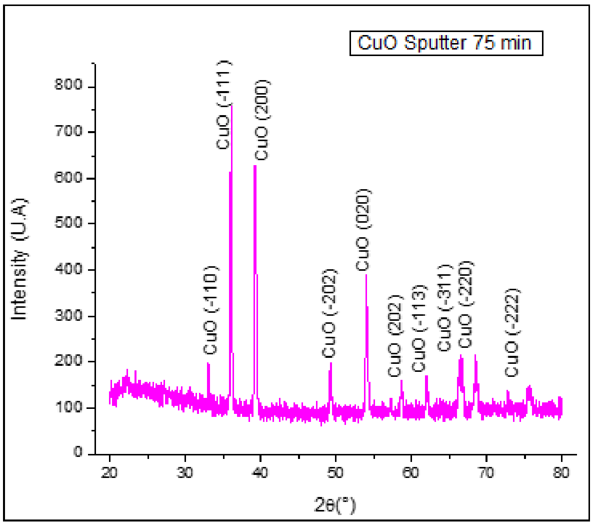

Figure 1.6: Diffractogram of CuO by sputtering

5. Conclusions

The results obtained in this work are the starting point for obtaining metal oxide materials through the sputtering process, a process in which the deposition stage can be controlled knowing that it forms a continuous layer of metal oxides obtaining the single phase of the CuO Copper Oxide material by the thermal oxidation method, the process was optimized in the controlled variable of the deposition rate, sample volume, temperature and excitation time of the sample based on the six sigma technique, in comparison of the samples sheet that after the oxidation process, a mixture of phases between Cu, CuO and Cu2O was obtained. The samples obtained by sputtering and thermal oxidation reach the single phase of the semiconductor material of the CuO case study by checking the volume of the sample through X-ray diffraction characterization, reflecting its structural characteristics.

6. References

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