The effect of argon:oxygen gas ratio on the energy gap of nickel-chromium oxide thin film deposited using DC sputtering techniques

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Abstract. Nickel chromium oxide (NiCrO) deposition has been carried out on a glass substrate with a variation of the Argon / oxygen (Ar:O) gas ratio using DC sputtering. The purpose of this study is to determine the effect of the Ar:O gas ratio on the energy gap of the NiCrO layer. NiCrO thin film deposition was carried out using a variation ratio of Argon gas and oxygen 60:40, 70:30, 80:20, and 90:10. To determine the phase formed was analyzed using X-Ray Diffraction (XRD). UV-Vis spectrophotometer test was carried out to determine the transmittance value (% T), then from this data, it can be used to calculate the gap energy. Based on the results of the variation of the gas ratio obtained the largest energy gap of 3.44 eV on the gas ratio variation of 80:20.

1. Introduction
Spintronics is a new field in modern technology today. The term spintronics comes from the word spin-based electronics, namely electronics that utilizes the nature of electron spin and the nature of its charge. Spintronic devices work by utilizing electron spins to control the movement of charge carriers. Much research on semiconductors has focused on making spintronic devices, which are devices that can combine magnetic storage media with spin controllers so that they are more efficient for spin-RAM and spin-injection applications [1]. To achieve this, semiconductors are expected to exhibit stable ferromagnetic (FM) properties at room temperature. Spintronic devices have many advantages, including higher data processing rates, smaller and compact device sizes, and smaller energy consumption. The superiority of the spintronic device has prompted many researchers to conduct research in this field [2].

A very promising new material for realizing spintronic devices is Dilute Magnetic Semiconductor (DMS) or ferromagnetic semiconductors [3]. DMS is a semiconductor material that has ferromagnetic properties. Most semiconductors are non-magnetic materials [4]. Semiconductor compounds of groups III-V and groups II-VI have many desirable properties for optoelectronic, photovoltaics and spintronic applications. Among these semiconductor compounds, GaN and ZnO have received the attention of many researchers because they have almost the same energy gap of 3.5 eV. ZnO has recently attracted more attention than GaN and is a promising material for ultraviolet (UV), LED and laser diodes, because it has an energy gap of 3.37 eV. Because of the high energy gap, ZnO semiconductors are very efficient in absorbing ultraviolet light and emitting blue light [5]. Based on the structure and optical properties, NiCrO materials are similar to ZnO and are predicted to be suitable for the development of ferromagnetic
This study offers an alternative to spintronic materials namely NiCrO material because the optical properties are similar to ZnO having a wide energy gap of 3.41 to 3.60 eV [7]. Several methods have been used for fabricating NiCrO films such as thermal evaporation, sol-gel, thermal treatment and sputtering. The manufacture of NiCrO thin films using sol-gel can form semiconductor nanoparticles for photoelectric device applications [8]. NiCrO nanoparticles were successfully made with thermal treatment techniques at temperatures of 750 °C and 850 °C [9]. In NiCrO deposition with the sputtering technique the effect of the comparison of oxygen gas with argon shows that with increasing intensity of the X-ray diffraction peak the resistivity of the film decreases [10]. This research was conducted to obtain optical properties in the form of energy gap NiCrO thin films by the Tauc Plot method.

2. Research methods
In this study several steps were carried out including, sample preparation, thin layer deposition process and characterization of deposition results. The material used is rectangular glass (SiO₂) preparations with a length of 10mm, a width of 25mm and a thickness of 2mm. The sample preparation is was hed using an ultrasonic cleaner then dried using a hairdryer. NiCrO deposition uses DC plasma sputtering. The sputtering parameters used were variations in the ratio of Ar: O₂ gas that is 60:40, 70:30, 80:20 and 90:10, voltage 2.5 kV, current 15 mA and pressure 2.7 x 10⁻² Torr.

The X-Ray Diffraction test is carried out to ensure the phase formed on the thin layer is NiCrO. Characterization of optical properties was carried out using a UV-Vis Spectrometer. From the UV-Vis test results obtained the spectrum of the relationship between transmittance and wavelength (λ), then the refractive index value of the thin layer is calculated by the Swanepole Equation [11] (equations 1 and 2):

\[ N = 2n_s \left( \frac{T_m - T_m^*}{T_m T_m^*} \right) + \frac{n_s^2 + 1}{2} \]  
\[ n = \sqrt{N + \sqrt{N^2 - n_s^2}} \]  

After the refractive index is determined, the thickness of the layer can be calculated using equation 3:

\[ d = \frac{\lambda_1 \lambda_2}{2 (\lambda_1 n_2 - \lambda_2 n_1)} \]  

the value of the coefficient of absorption of thin films (α) can be calculated using equation 4:

\[ \alpha = -\frac{1}{d} \ln T \]

Using the Tauc plot method the gap energy (Eg) of the thin film can be determined by extrapolating the energy(hν) as abscissa and (αhν) as an ordinate until cutting the ordinate axis, the value of Eg is obtained ordinate axis, the value of Eg is obtained. The value of hν is determined using equation 5:

\[ hν = h \frac{c}{λ} \]

3. Results and discussion
Based on the results of measurements using UV-Vis spectrophotometry, the spectrum of light transmitted over a wavelength range of 310 nm to 900 nm is shown by a graph of the relationship of transmittance values to wavelengths of NiCrO thin films for various of time and the ratio of gases shown in figure 4.3 and figure 4.4. Changes in the peak and valley of the transmittance indicate the optical presence of the thin layer of photon energy passing through it.
The XRD pattern of NiCrO films deposited using sputtering on a glass substrate is shown in Figure 1. XRD analysis shows that the film is polycrystalline from a cubic NiCrO structure at an angle of 30.44°, 43.58°, and 63.34° orientation NiCrO (002), NiCrO (113) and NiCrO (044). The XRD sample pattern shows that the crystallinity of the film deposited increases with the amount of oxygen. The optical transmittance spectrum of the thin film is presented in Figure 2. Based on Figure 2 it can be seen that decrease value transmittance caused because NiCrO thin layer absorbs the energy that runs through it. Grain size items very affect the number of transmitted light. Size items more and smaller cause value transmittance big so are the others. In addition, the arrangement of the formed atomic particles also affects the transmittance value. Based on the variation of gas ratio data, it can be seen that the more argon gas composition causes a decrease in transmittance. This is because argon gas as a gas sputter is tasked with bombarding at the target until the target atom is released and attached to the substrate. So that the more argon gas, the more atoms that are layered on the substrate. The number of atoms deposited on the substrate causes more photons to be absorbed so that the transmittance is smaller.

![Figure 1. XRD pattern of NiCrO thin film.](image1)

![Figure 2. Spectrum of optical transmittance of NiCrO thin films.](image2)
Figure 3 shows the results of the calculated gap energy of thin film as a function of argon and oxygen gas ratio. Based on Figure 3 the variation of the gas ratio affects the energy gap change. The more oxygen gas the energy gap tends to increase. This is because the more oxygen added affects the amount of NiCrO crystals formed. This shows the crystal structure affects the gap energy change as a function of the amount of oxygen gas added. The energy gap increases with the increasing intensity of NiCrO formed.

![Figure 3](image_url)

**Figure 3.** Effect of gas variations on the gap energy of the thin film.

4. **Conclusion**
The deposition using the DC sputtering technique has successfully formed a thin layer of NiCrO. Based on the results it can be concluded that the variation of the ratio of argon gas and nitrogen affects the formation of NiCrO crystals and gap energy. The amount of oxygen gas more and more Energy gap is increasing followed by an increase in the amount of NiCrO formed.

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