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DEPOSITION TECHNOLOGY OF METAL THIN FILM WITH DC-SPUTTERING ARC-12M METHOD

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ABSTRACT

In this paper described the results of testing and measurement of film thickness for target deposition Copper (Cu), Nickel-chromium (Ni50-Cr50) using DC-Sputtering, and shown a strong correlation between film thickness with time deposition by sputtering systems which are linear for each type of target. Characteristic curve is also shown on the pressure conditions of argon (Ar) constant, increasing the value of power from the starting 100 to 300 watts causes deposition while the value added to value of speeds from 350 to 450 watts, the value increased deposition nearly constant speed. And at constant power conditions, the addition of argon gas pressure (Ar) decreases the value deposition speed. By comparing each characteristic curve at the same pressure and power, connection speed deposition value comparison for each type of target are: Copper (Cu) > Chrom (Cr) > Nickel-chromium (Ni50-Cr50).

Key Word: Deposition, Cu, Cr, Ni50-Cr50, DC-Sputtering

INTRODUCTION

To produce a thin film circuit or component, must go through several stages of processing are carried out systematically and repeatedly. Each process has procedures and techniques of making respectively. One of the processes that must be performed on the manufacture of components or circuits, namely the coating of thin film materials (deposition) on a substrate by using a sputtering system [1-3].

Sputtering systems can superimposing various kinds of metal and metal guide (metal alloy) or non-metal on the substrate resulting in a hybrid circuit industry, sputtering system is widely used as one of the major steps to make the thin film layer on the substrate.
Sputtering system is a system that most benefits compared with vacuum evaporation [4-6].

a. Can be superimposed films of metals, alloys, insulators, semiconductors and even magnetic metals.
b. Deposition velocity for each type of material is not much different.
c. Can perform many layer deposition (multilayer) well as the ability coat various types of metals.
d. Film thickness is easier and simpler to be observed and controlled.
e. Adhesion between the film and the substrate surface is stronger.

METHODS

The process of metal and non-metal deposition (Alloy) conducted by Sputtering method. The tools used are Sputtering Machine (Plasma Science ARC-12 M). This tool can be operated in DC Sputtering (for material deposition process that is both conductor) and RF Sputtering (for conductors and non-conductors). In this study conducted a metal deposition Copper (Cu), Nickel-chromium (Ni-Cr) and Silicon Dioxide (SiO_2) with variable time (minutes), power (watts), and the pressure of the carrier gas of argon (Ar) (mTorr).

Sputtering is a process deprived of material from a solid or liquid surface due pounded by high-energy particles to an exchange of momentum (momentum exchange). Target in the form of a coating material (coating material) is placed in the direction of the substrate (Figure 1) in a vacuum chamber with the initial pressure of about 5x10-4 - 5x10-7 Torr. High vacuum conditions herein is intended to suppress the contamination of the gases that potentially pollute at levels as low. During the process, put an inert gas such as argon gas is maintained at a pressure of about 10-3 mTorr.

2.1 Types of operation Sputtering

2.1.1 Sputtering with direct current (DC Sputtering)

Sputtering with direct current (DC Sputtering) or usually called cathode sputtering, working at low pressure and normally uses argon gas (Ar) to produce ions. Referred to as Sputtering with direct current (DC Sputtering) because the voltage that is used to maintain the glow discharge is a direct voltage is high enough among the hundreds of volts to thousands of volts at the second electrode.

At the anode substrate to be coated is placed the film while the target or backing material is placed on the cathode. Both are placed facing each other with a normal direction and between them will be included gas argon (Ar) with a low-pressure glow discharge that will occur when the rated voltage at the second electrode. Ions of argon (Ar) which is charged positipakan hit targets on the potentially negative cathode. Due to high-energy collisions with the atoms of the material to be knocked off the target. The atoms will stick to the substrate and will make the thin film layer (thin film layer) on the substrate.

Before the gas argon (Ar) is inserted into the vacuum chamber, must first meet the initial conditions of pressure (base pressure) between 10-5 - 10-7 torr. The goal is to clean of all kinds of particles and also no longer residual gases such as oxygen in the space. In order to get optimum deposition results.

2.1.2 Sputtering System with radio frequency

On target types isolatort idak can coat the substrate using direct current sputtering system DC-sputtering because the applied voltage is used will prevent the occurrence of neutralizing the positive charge gathered on the surface of the target, while pounded by ions. Accumulation of positive charge would cause a potential difference between the cathode and the anode becomes smaller. As a result, the state of glow discharge can not be maintained even be deadly glow discharge. To overcome that to use voltage alternating with the radio frequency is used is a high frequency because the frequency is called RF sputtering process. Devices using RF sputtering system shown in Figure 1. The radio frequency that is often used in the industries, the field of scientific research and the field is 13.56 MHz. [7-8].

RF-sputtering has many advantages compared to DC-sputtering as an insulating material in addition, this system can also use the target type of conductor, resistor, and dielectric. With the advantages of RF-conductors, resistors, and dielektrik. Dengan advantages of RF-sputtering add functionality and usability of the sputtering system itself so that the system is widely used in the industries of electronics, especially in the field of thin film technology.

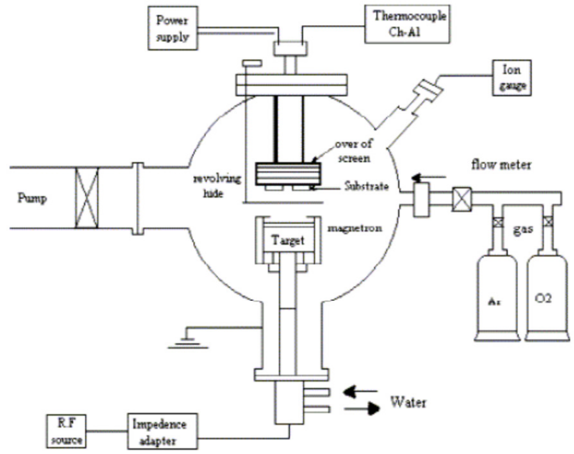

Figure 1. Schematic of sputtering process [7].

The substrate is mounted on the anode, while the material to be deposited or so-called "target material" will form the cathode. Between the cathode with the anode given high voltage (500 V - 5000 V). Unidirectional high voltage difference, will result in ionized argon gas (Ar) produces Glow Discharge, ie continuous plasma formation. Electron source will support the ionization of the inert gas so that the formation of the positive charge of argon around the cathode will be faster.

These ions will bombard the cathode material (target) with high-energy atomic and molecular targets resulting bounce from the surface. Most of these particles will settle on the substrate. The fall of the corner atoms on the substrate surface is different, this will result in a thin film which is flat compared to the evaporation process.

Sputtering method is called DC Sputtering or cathode sputtering. DC Sputtering can only be used for material deposition process that is conductor. As for the non-conductor material (insulator, dielectric) deposition process must be carried out by RF Sputtering, because the potential Aselerasi from DC sources can not be used directly on the surface of the insulator [9-10].

Here, the gas ions reach the surface of the target can not be neutralized because of the unavailability of free electrons. Ion will form positively charged layer on the surface of the target which resulted in cessation of the sputtering process in the absence of Glow Discharge. This problem can be overcome by using alternating voltage at a radio frequency of 13.56 MHz. By RF Sputtering, deposition process can be performed using targets that are insulators, conductors, resistors and dielectrics [11-12].

2.2 On Sputtering deposition Speed

In a sputtering system, deposition speed is affected by the results of Sputtering (Sputtering yield), Sputtering speed (Sputtering rate) and pollutant (Impurity trapping).

Value Results Sputtering (Sputtering Yield)

Sputtering yield value is the number of atoms that bounce off the target by one ion pounder. To analyze the changes that occur in the sputtering process, has been known for the analysis of Sigmund's linear Cascade makes the correlation between ion energy (eV) with Sputtering Yield (atom / ion).

Sputtering analysis of the results is determined by the following equation:

$$S = K\frac{M_i M_t}{(M_i + M_t)}[E/U]\alpha \qquad (1)$$

with:

α = function of Mt / M,

S = the value of the sputtering (atoms per ion)

E = the energy of ion collider (eV)

U = sublimation energy (eV / molecule) α

K = constant of 0.1 to 0.3.

Threshold energy

Threshold energy is the minimum energy possessed ion collider so that ions of the target bounced, so the sputtering process can occur. In the sputtering process, the relationship between the sputtering threshold energy results are as follows:

$$S = \alpha\left(E^{1/2} - E_{th}^{1/2}\right) \qquad (2)$$

$$\alpha = \frac{k}{U}\left[\frac{Z_t}{Z_t^{2/3} + Z_x^{2/3}}\right]\left\langle\frac{Z_x}{Z_t + Z_x}\right\rangle^{0.67} \qquad (3)$$

with:

E = the energy of ions (keV)

k = constant (5.2)

Eth = threshold energy (KeV)

U = sublimation energy (eV per particle)

Z1 = atomic number of the target

Zx = number of gas atoms (ions pounder)

If a gas molecule composed of m number of atoms, the equation becomes:

$$S = m^{1/2} - \left[(mE_{th})^{1/2}\right] \qquad (4)$$

2.3 sputtering Speed (Rate of sputtering)

Sputtering speed is defined as the number of atoms per unit time and broad bounce. At the time of ion current density or flux current (Ji) equals the ion flux q multiplied by the electron charge, the speed sputtering is

$$r_s = \frac{Sj_i}{q} \qquad (5)$$

with:

rs = speed sputtering

Ji = current density (A cm^{-2})

Impurity (impurity trapping)

Gas argon (Ar) is used as ion collider, can contain impurities in the deposition process involved deposited on the substrate. Oxygen go in together with argon gas (Ar) can also react with the atoms on the target so as to affect the resistance layer on a substrate film and adhesivity.

Stages of the process are as follows:

a. Cleaning the substrate

This stage is very important, because it determines the quality of the thin film layer is formed. Impurities existing on the substrate was dissolved with chemical solvents. In order to perfect the cleaning process, the cleaning process is done in Ultrasonic cleaner. The chemicals that are commonly used, among others, is Trichloro Ethylene (TCE), Trichloro ethan (TCA), ethanol, or acetone**.**

b. Sputtering Stage

Sputtering process is performed on the operating mode DC Sputtering, with initial pressure (base pressure) ranges between 10-5-10-6 Torr. Having achieved these conditions included an argon gas (Ar), until it reaches a constant pressure of about 4 mTorr. The supplied power is 100 watts.

Before the deposition process, first performed the etching process of the substrate to be coated. The trick is to reverse the direction of ion collider toward the substrate with a low energy, so it just enough to clear the particles of impurities without damaging the surface of the substrate. This method can increase the power of the adhesive film on the substrate surface. Deposition process is performed using the desired target.

In the sputtering apparatus, as used herein, can be installed three kinds of targets, which are used interchangeably. Sputtering apparatus used herein is equipped with a monitor measuring the thickness (Thickness monitor), the working principle of this thickness gauges is the vibration frequency of the crystal oscillator will change according to the thickness of the resulting films. The more particles deposition process results attached to the crystal, the crystal oscillator vibrations would be lower. This frequency difference is converted as the difference in thickness, which immediately appear on the monitor screen.

3. Results and Discussion

3.1 The film thickness 3.1 Copper (Cu) with time

With the pressure of argon gas (Ar) 15 mTorr and 200 watt measurement data obtained by measuring the time data deposition to a film thickness of copper (Cu).

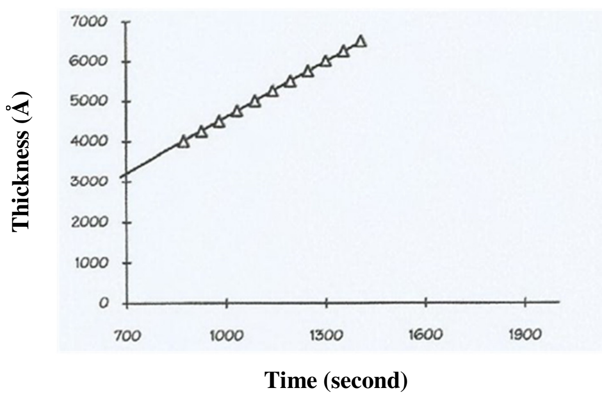

Figure 2. The curve relationship film thickness of copper (Cu) against Time

The film thickness Nickel-chromium (Ni_{50}-Cr_{50}) with time

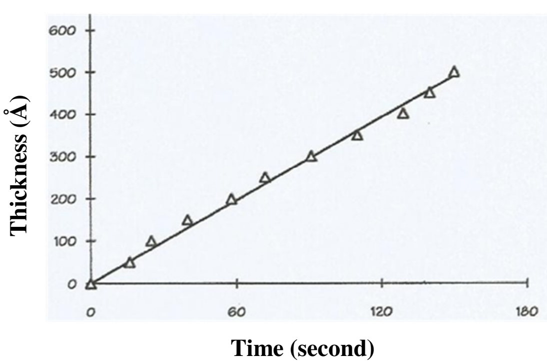

Figure 3. The curve relationship Ni_{50}-Cr_{50} film thickness of the Time

3.2 Effect of the amount of power to the deposition speed

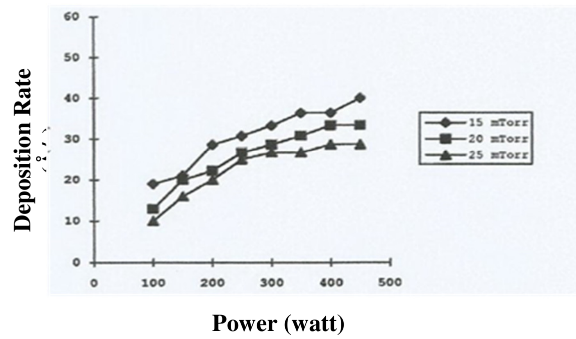

Figure 4. Characteristic Curve Speed for chromium deposition (Cr)

From figure 4 it can be seen that the deposition rate increases with increasing power, especially at 100-300 watts, but to increase the power of 350-450 watts, speed of deposition showed nearly constant value.

Table 1. Conditions deposition process of Cr, Ni_{50}-Cr_{50} and Cu

Base pressure	3 - 4 x 10^{-5} Torr
Power	200 Watt
Gas pressure	15 mTorr
Rotation	8 Rpm
Gun / Shutter	2/2

3.3 Characteristics deposition Speed Copper (Cu)

From the results of measurements and tests during the deposition conducted against targets Copper (Cu), deposition speed for each gas pressure Argon (Ar) and a given power. Cu deposition speed characteristic curve shown in Figure 5.

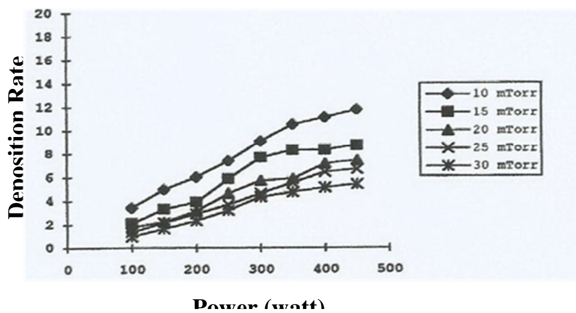

Figure 5. Characteristic curve deposition Speed for Copper (Cu)

4. Conclusions

From the results of the test and measurement of the thickness of the film deposition for a targeted Copper (Cu), chromium (Cr) and nickel-chromium (Ni-Cr) using DC-Sputtering in ARC-12M system, can be summed up as follows:

1. From the characteristic curve in Figure 1-4 shows a strong correlation between the thickness of the film with a deposition with sputtering systems ARC-12M Linear for each type of the target.
2. The characteristic curve in Figure 5, the condition of the pressure argon (Ar) is constant, an increase in the value of power ranging from 100 to 300 watts cause pendeposisiannya speed value while the value of 350 to 450 watts, the value increased speed pendeposisiannya approximately constant. And on the condition of constant power, the addition of argon gas pressure (Ar) decreases the value speed deposition.
3. By comparing each characteristic curve at the same pressure and power, relationships deposition velocity comparison value for each type targets are: Copper (Cu) > chromium (Cr) > Nickel-chromium (Ni_{50}-Cr_{50}).
4. The order of great value deposition speed is determined by the electrical conductivity properties of each target and the relatively large mass of constituent particles.

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