5 - 11 Optimization of Al Film Deposited by DC Magnetron Sputtering

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Silicon micro-strip detector is a position sensitive semiconductor detector with excellent performance in energy and spatial resolution. The chip-making processes mainly include cleaning, oxidation, lithography, etching, ion implantation, annealing, and metallization. Metallization is an important step to provide contact electrode. Several metal materials can be used as electrode, such as Au, Ag, Cu, Al. Considering the cost, electrical properties and good adhesion, the metal film deposited on the silicon micro-strip detector developed by the Institute of Modern Physics (IMP) at Lanzhou is chosen as Si-Al alloy with only 1% of Si.

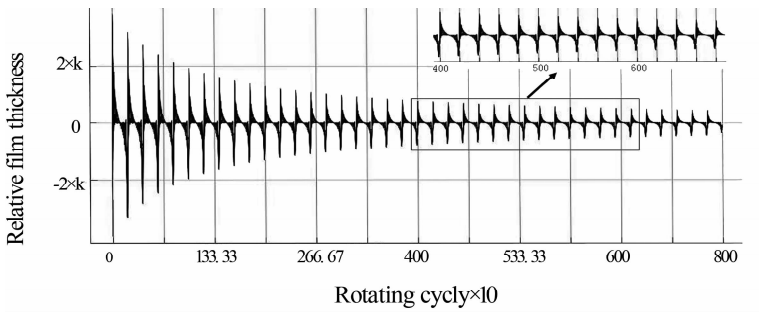

Fig. 1 Simulation on the relationship between the thickness-ununiformity and the wafer rotating cycle. The target horizontally moving period is fixed to be 2 min.

There are many preparation methods for Al film coating, such as the evaporation and the sputtering. Because of the low temperature, high deposition rate and good adhesion, magnetron sputtering has become one of the most widely used techniques[1, 2]. During the development of the silicon micro-strip detector at IMP, the Al film is deposited by a single target magnetron sputtering coating apparatus JB500 produced by HuiYui vacuum company at Shenyang. This coating apparatus has an active target area of 240×60 mm^2, and the target (Si-Al alloy in our work) can be moved in the horizontal direction within a range of ± 100 mm. The substrate holder can be rotated, which could handle the silicon wafer of 4 inch size.

To optimize the Al-film uniformity on thickness[3], both the target moving horizontally and the wafer rotating method had been used in our experiments. Keeping the target moving speed fixed, the total coating time fixed, but the wafer rotating speed changed, the thickness ununiformity was simulated, and the result was shown in Fig. 1. It can be concluded that the ununiformity will fluctuate when the rotating period increases, but the envelop of the curve will shrink gradually. Experiments on the ununiformity changing with wafer rotaing speed were also tested, and the results were listed in Table 1. A rough conclusion can be derived that the ununifomity will be maintained within 5% if the substrate rotating speed is set to be more than 63 Hz, which could match our experimental request.

Table 1 The ununiformity of the thickness derived from experiments

Substrate rotating cycle (Hz)	63.53	61.6	53.7	53.5	50.57	50.36
Film thickness-ununiformity	3.74%	5%	4.48%	3.5%	5.88%	6.66%

We found out that the Al film sputtered on the silicon wafer sometimes was pale, like mist on it . A detailed research were carried out, and it's found that mist mainly came from the water contamination and/or the turbulence of the working gas. Some measures as following were thus chosen[4].

1. Before the coating apparatus starts work, the coating chamber must be baked while pumping until the vacuum pressure was higher than 4×10^{-4} Pa. This could reduce the water contamination effectively.

2. Keep the substance around the wafer substrate as few as possible. This can reduce the gas blocking during sputtering and make the gas move smoothly. For example, we took away the shutter from coating chamber, and as a result, the mist on the film got thin obviously or even disappeared.

After the careful selection of the target moving period and substrate rotating period, a good quality of Al film had been coated on the silicon strips of the detector chip. It adheres to the silicon substrate tightly,

and lays a solid foundation for the good performance of the silicon strip detector.

References

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[4] http://www.2ic.cn/html/35/t-343435.html.

5 - 12 Progress on Portable Rapid Detection Device for Measuring Content of ^{40}K, ^{238}U and ^{232}Th in Minerals

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A portable rapid detection device with four isolated single-channels which is used to measure the γ spectra of ^{40}K, ^{238}U and ^{232}Th in minerals has developed by the crystal detector group of IMP at present. Each channel in the device is mainly composed of four parts, such as the radiation detector with CsI(TI) crystal, the high quantum efficient PMT, the subsequent electronics and the counter. The specific nuclide will be identified by measuring its corresponding characteristic γ ray. The window with suitable ULD(Upper limit discriminator) and LLD(Lower limit discriminator) are chosen for a single channel of the device through PC control software (or hardware) to measure the full-energy peak counts of the characteristic γ ray. ^{40}K, one of the three natural potassium isotopes with an enrichment of 0.012%, can be identified by tracing its decaying γ-ray of 1.461 MeV from ^{40}K to ^{40}Ar. As for ^{232}Th and ^{238}U in minerals, the decay chains from thorium series or uranium series have kept in long-term equilibrium, and the γ rays of 2.615 MeV from ^{208}Tl decay and 1.764 MeV from ^{214}Bi decay could be used as the characteristic γ lines for the tracing of their parent nuclides ^{232}Th and ^{238}U respectively.

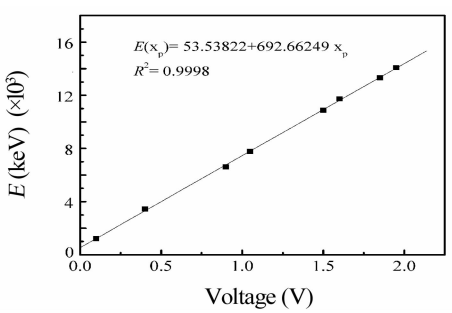

Fig. 1 Linear fitting between the γ ray energy and the threshold voltage.

Calibration has been carried out with the standard γ rays of ^{137}Cs, ^{60}Co, ^{152}Eu and ^{207}Bi source. Keeping the window between LLD and ULD fixed as 0.1 V, we increased the LLD threshold step by step from 0.05 to 3.0 V, and the energy spectra were thus derived. Each γ-ray full-energy peak is uniquely designated to a threshold voltage. The relationship between the standard γ ray energies and their corresponding threshold voltages were plotted in Fig. 1, which is in good linearity. From the interpolation or extrapolation from Fig. 1, we deduced that the central threshold voltage level for ^{40}K, ^{238}U, ^{232}Th were 2.03 V, 2.47 V and 3.69 V respectively for the specific γ rays of 1460.8, 1764.4 and 2614.5 keV. A standard potassium sample has been tested by the detection device, and the threshold voltage corresponding to the γ ray of 1460.8 keV from ^{40}K decay, was just consistent with the derived value of 2.03 V.

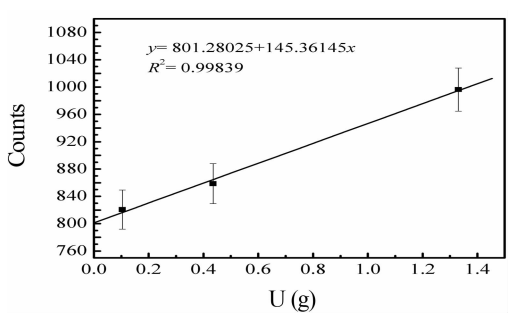

Fig. 2 The count of standard uranium samples vs the weight of ^{238}U content.

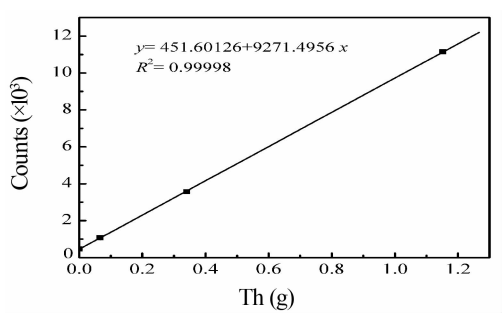

Fig. 3 The count of standard thorium samples vs the weight of ^{232}Th content.