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Short Communication

Effect of sputtering input powers on $CoSi_2$ thin films prepared by magnetron sputtering

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Abstract

$CoSi_2$ thin films were prepared by radio frequency magnetron sputtering using $CoSi_2$ alloy target. Effect of sputtering input powers on characteristics of $CoSi_2$ thin films was researched by X-ray diffraction (XRD), transparent electron microscope (TEM), energy dispersive X-ray analysis and four points probe, etc. It was shown that the deposition rate increased lineally, the selective sputtering of silicon was strengthened, the (1 1 1) texture increased, and the resistivity decreased when the input powers were increased.

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Keywords: $CoSi_2$; Sputtering input powers; Grain diameter; Resistivity; Magnetron sputtering

1. Introduction

The $CoSi_2$ thin films have been widely researched for ohmic contacts, low resistivity gates and local buried interconnects in ultra-large-scale integrated device (ULSI) [1]. Epitaxial $CoSi_2$ can be formed on Si(1 0 0) by molecule beam epitaxy (MBE) [2] or Ti-interlayer mediated epitaxy (TIME) [3]. $CoSi_2$ thin films can also be prepared by annealing of co-deposition thin films of cobalt and silicon [4–6]. In comparison to epitaxial thin films, the thin films of co-deposition are not epitaxial and have lower thermal stability than epitaxial thin films. But the method of co-deposition features lower stress and can control the ratio of Cobalt and silicon [1]. On the other hand, co-deposition must be adopted when solid phase reaction is not suitable to be adopted [7]. Co-deposition such as co-puttering and co-evaporation has been reported by some articles [4–6] and the method of co-deposition using $CoSi_2$ alloy target was reported seldom [7].

Parameters of preparation such as temperature and type of substrates and the sputtering powers, etc. have effects on the structure and properties of thin films. Of these parameters, the sputtering power is an important factor [8–10], which has influence on the structure, such as texture [8], and properties of thin films.

In the paper, we will investigate the effects of the sputtering input powers on characteristics of the $CoSi_2$ thin films prepared by radio frequency magnetron sputtering using $CoSi_2$ alloy target.

2. Experiments

Cobalt disilicide thin films were fabricated by sputtering $CoSi_2$ alloy on (1 0 0) Si wafer for 30 min at the sputtering power of 100–300 W in ANELVA SPC-350 magnetron sputtering system. The silicon substrates were cleaned and stripped of the native oxide in diluted HF solution. It was cleaned in de-ionized water and thereafter inserted into the deposition chamber. The base pressure in sputtering system was lower than 4×10^{-5} Torr, and the deposition was carried out in 1.6×10^{-3} Torr high pure argon. There was no intentional substrate heating, and therefore the substrates remained below 85 °C. Four-point probe were used to investigate resistivity of thin films. The thickness was

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obtained with profile meter and the compositions by the energy dispersive X-ray analysis.

X-ray diffraction (XRD) was carried out to investigate the structure of thin films. From an analysis of XRD line broadening the contributions due to crystallite size and lattice strain (also named as microstrain) can be determined [11]. The broadening due to crystallite size (β_c) and lattice strain (β_e) are represented by

$$\beta_c = K\lambda/D\cos\theta, \quad \beta_e = 4\varepsilon\tan\theta.$$

The total broadening is the sum of these contributions, and by setting K equal to unity the following relationship holds

$$\frac{\beta\cos\theta}{\lambda} = \frac{1}{D} + 4\varepsilon\frac{\sin\theta}{\lambda}. \tag{1}$$

In the above equation λ is the wavelength of the X-ray radiation, θ the Bragg angle, and ε the strain. From Eq. (1) a plot of ($\beta\cos\theta/\lambda$) vs ($\sin\theta/\lambda$) is a straight line with a slope of 4ε and an intercept of $1/D$. Then the grain diameter D and microstrain can be derived from the analysis of XRD.

The samples for TEM were deposited on the single-crystal KCl for 2 min. The sample was melted in deionized water and the thin films was put on the brass net coated with a thin carbon for TEM. The result of TEM was compared with the results of XRD.

3. Results and discussion

Fig. 1 shows the relationship between the sputtering input powers and the deposition rates. It can be seen that the deposition rates increase with the powers increased. The content of silicon in thin films is shown in Fig. 2. The percentage of silicon is a little higher that the content of silicon in stoichiometric $CoSi_2$, and the silicon concentration in thin films increases with the sputtering powers increased. Some researches [12,13] about the sputtering of $CoSi_2$ showed that silicon had the high sputtering yield than cobalt when $CoSi_2$ thin films were sputtered. This is in accordance with our results. After the silicon is sputtered, the surface atomic density of cobalt in the target is increased, which make cobalt has more chance to be sputtered. Then the sputter yield of cobalt is increased. So the content of silicon in thin films prepared by magnetron sputtering using $CoSi_2$ alloy target is just a little higher than that in stoichiometric $CoSi_2$. The preferential sputtering of silicon was determined by the primary and secondary effects during sputtering [12,14]. The primary effects are those related to the individual sputtering events, which are determined by the energy of the ion, the mass of the ion and target, and its surface energy, etc. The secondary effects, which include segregation, radiation enhanced diffusion and redistribution, etc. affect the atomic concentrations in the surface and near-surface regions. The deposition rate is increased with the sputtering input power, which signifies radiation enhanced diffusion is strengthened with the power increased. The rich cobalt in the surface target would diffuse more quickly into the bulk at the higher powers, which make surface atomic density of cobalt is decreased higher. Then the content of silicon in thin films is increased with the sputtering input powers.

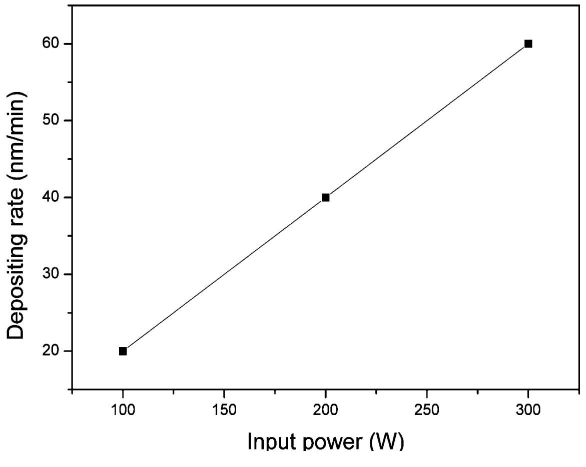

Fig. 1. Relationship between the input powers and deposition rates.

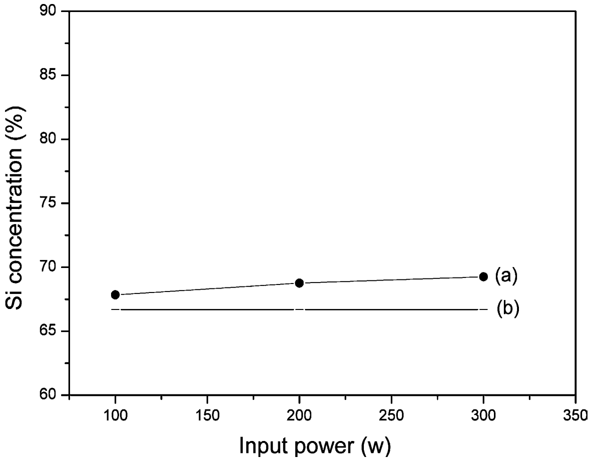

Fig. 2. Silicon concentration in the thin films sputtered at different powers (a) and stoichiometric $CoSi_2$ (b).

Fig. 3 shows the XRD patterns of $CoSi_2$ as-deposited thin films deposited at 100–300 W. I(1 1 1)/I(2 2 0) of the samples prepared on silicon substrates by 100, 200 and 300 W, are 0.74, 1.11 and 2.56, respectively. These values are all higher than 0.46 of $CoSi_2$ powders, which signifies that (1 1 1) texture exists in thin films prepared by magnetron sputtering using alloy target. And the texture increases with the rising powers. Knuyt et al. [15] proposed a model to explain the texture evolution in PVD thin films, which supposes the only driving physical process for the texture evolution is the tendency of the surface to evolve towards a situation of lower surface energy. The model can be expressed as:

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