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The electron-spectroscopic Investigations of the epitaxial $CoSi_2$ films on silicon

B. E. Egamberdiev, A.T.Rakhmanov, A. S. Mallaev, A.A Rashidov

Tashkent State Technical University department of Metrology, standardization and certification , st. University 2, Tashkent, 100095, Republic of Uzbekistan

ABSTRACT: This work is devoted to the study of the electronic structure, optical properties and electric resistance of the epitaxial layers $CoSi_2$/Si produced in the ultrahigh vacuum conditions (p=10^{-7} Pa) by the molecular beam epitaxy method on Si surface (111). It has been shown that the forbidden zone width of solid $CoSi_2$ films is 0.5-0.6 eV and there are two maximal of the electron state density in the valence zone. These films have the low specific resistance (p=20-25 μΩ.cm).

KEYWORDS: silicon, epitaxial, structure, vacuum, electron, zone, temperature, spectroscopy, CoSi2, molecular beam epitaxy method,electron-spectroscopic , silicid,peaks,spectra,films.

I. INTRODUCTION

The good structural concordance of *Si*, $CoSi_2$, CaF_2 and hence the growing of multi-layer systems from the layers of those materials combination are the first prerequisite to create devices wits unique specifications. The creation of the *Si*-$CoSi_2$-*Si* epitaxial structure allows the manufacturing of new type of ultrahigh frequency devices, e.g., transistors with metallic and permeable base. The main principle of such transistors creating is based on the change of the semiconductor base to the material having low electric resistance close to the metal one. In this respect, the more suitable material proved to be $CoSi_2$ films [1-4].

II. RELATED WORK

By now the regularities of the $CoSi_2$ film epitaxial growth on the Si single crystal surface have been studied. The optimal conditions of producing the uniform films have been determined, the type and parameters of the lattice, as well as the electric physical properties of these films have been investigated.

In the article the results of epitaxial CoSi2 / Si (111) formed by MBE, TFE and RA. Cobalt silicide layers grown on substrates such as Si doped by phosphorus-4,5, Si doped by boron -7.5, Si doped by boron -10. The growth of the films produced in ultrahigh vacuum MBE installation. Before epitaxial growth surface of the substrates were subjected to chemical cleaning and special cleaning vacuum. Detailed description of the installation of the MBE and purification methods contained in [5]. The thickness of the deposited cobalt in all cases was 100 Ǻ, meanwhile, CoSi2 film with thickness about 380 Ǻ was formed. The one-step processes were studied and a two-step growth. With two-stage increase in the growth of the film took place in two stages with different modes of growth.

This work is devoted to the study of the electronic structure, optimal properties and electric resistance of the epitaxial $CoSi_2$/*Si* layers produced in the ultrahigh vacuum conditions ($p=10^{-7}$ *Pa*) by the molecular beam epitaxial method on *Si* surface (111). The optimal growth temperature is T=850 *K* and the optimal ratio of flows *SiCo* is 2:1. The films of the thickness d=50-500 Ǻ have been studied [5]. The studies were conducted by Auger electron spectroscopy (AES), secondary ion mass spectrometry (SIMS), photoelectron spectroscopy (PES) and high energy electron diffraction (HEED).

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III. RESULTS AND DISCUSSION

Before the measurement of the $CoSi_2$ films were annealed in the ultrahigh vacuum conditions ($p=10^{-7}$ *Pa*) at T=900-1000 *K* for 3-4 hours. After the treatment on the HEED pictures taken for the films with $d>150$ Å the bright sharp point reflexes on Laue arcs were detected, that corresponds to the pure atomic smooth surfaces.

The photoelectrons spectra for the *Si* (111) and $CoSi_2$ films ($d=200$ Å) measured at $h\nu=10.8$ *eV* are given in fig. 1.

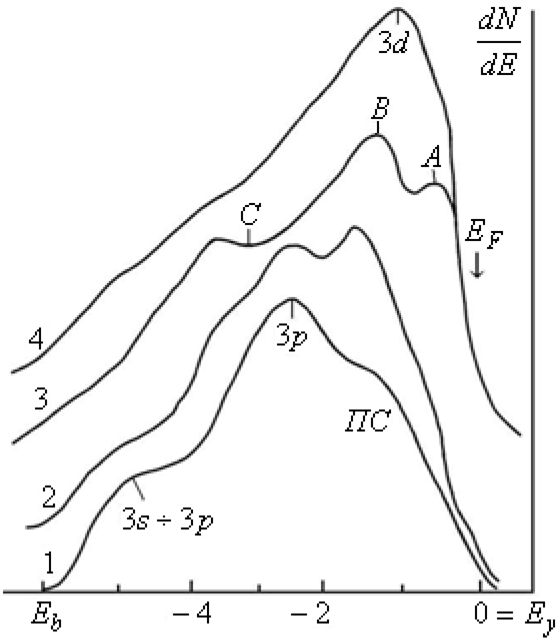

Fig 1. The photoelectrons spectra for the *Si* (111) and $CoSi_2$ films ($d=200$ Å) measured at $h\nu=10.8$ *eV*.

The abscissa axis is the electron binding energy E_b taken relative to the Fermi level E_F. It is seen that the shape and position of the main peaks for *Si* and silicide are visible distinguished from each other. In the pure *Si* case the presence of peaks (*B*, *C*, *E*) is explained by the electron excitation from 3*p*, 3*s* states of valence electrons and from the surface states. Both the 3p electrons and the surface states apparently take part in the formation of peak A. In the $CoSi_2$ case the presence of peak B is connected with the electron excitation from the generalized (3*p-Si* and 3*d-Co*) state, and peak C from the 3s state of *Si*.
The parameters of the energy zones for *Si* and $CoSi_2$ defined according to the photoelectron spectra (fig. 1) are given in table 1.

Table 1

Sample	Zone parameters, *eV*				
	ϕ	φ	E_g	χ	V_s
Si	5.1	4.7	1.1	4.0	0.3
$CoSi_2$	4.9	4.9	0.5	4.4	–

Table 1. Zone and energy parameters of Si and $CoSi_2$.

It can be seen from table I that from *Si* to $CoSi_2$ the decreasing (2 times) of the forbidden zone width E_g, the straightening of the zone band and some increasing of the electron affinity value occur.

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The value of the both photoelectron ϕ and thermo electron φ work functions for *Si* and $CoSi_2$ do not sharp differ from each other. For $CoSi_2$ $F\approx\varphi$. *So* it can be supposed that $CoSi_2$ is the degenerated semiconductor with the whole conductivity. The high electric conductivity of *Co* silicide can be due to this fact.

The electric resistance of the $CoSi_2$ films was defined by the 4- probes method [6]. The experimental result had been showed that in the case of the very thin films (d>100 Å) the specific résistance value depends on both thickness and temperature of the film formation and in the solid films case (d>100-150 Å) it depends mainly, on the formation temperature. The value of ρ for the $CoSi_2$ films growing at the different *T* is given in table 2.

Table 2.

T, K	*ρ, μΩ.cm*	
	d≈60 Å	*d≈200 Å*
600	250	110
750	–	50
900	150	20
1000	120	20
1100	–	40
1200	120	70

Table 2. The dependence of ρ on the temperature formation for $CoSi_2$.

So for the film width $d\approx60$ Å the value of ρ becomes higher and even at the optimal formation temperatures it is about 120-150 $\mu\Omega.cm$. That is mainly due to the fact that the film is not solid. The solid films ($d\approx200$ Å) growing at T<700-750 K also have the high resistance. This fact is explained by insufficient ordering of the structure and by the high density of the point defects. The temperature increases of the film growth up to 900-1000 K results the sharp ρ decreasing (20-25 $\mu\Omega.cm$), that is connected with the essential crystal perfection improvement of $CoSi_2$ film. The further formation temperature increases (T>1100 K) is accompanied by the specific resistance increasing. That can be due to both the island film formation and the enrichment of the surface with silicon owing to silicon diffusion through the film.

The optical properties of $CoSi_2/Si$ (100) films have been also studied. For the example the dependence of the light reflection coefficient on the light wave length for the 200 Å thickness film is given in Fig.2. It was shown that within the whole studied range of light wave length λ the k value increases with the λ increasing.

However, for λ<2-2.5 μ the increasing is small and its value do not exceed 10-15%. The considerable *k* increasing occurs beginning with λ=2.5μ, that approximately coincides with the edge of fundamental absorption $CoSi_2$. At λ>2.5 μ the *hv* value becomes less than the forbidden zone width ($E_g\approx0.5$ *eV*) of $CoSi_2$ and

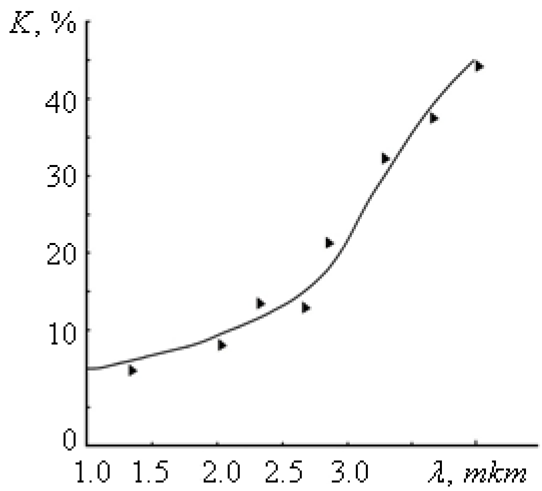

Fig 2. The dependence of the light reflection coefficient on the light wave length for the 200 Å thickness film

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hence the absorption coefficient sharply decreases. Apparently, that results in some increasing of the light reflection coefficient.

IV. CONCLUSION

1. The true information about the electron states density distribution in the valence zone and the energy parameters for $CoSi_2$/ Si films has been obtained.
2. It was shown that the electric resistance of $CoSi_2$ film produced by the molecular beam epitaxy method mainly depends on the thickness and temperature of the film formation. $CoSi_2$ is supposed to be a degenerated semiconductor with whole conductivity. High electric conductivity of *Co* silicide is explained by that fact.
3. The considerable increasing of the light reflection coefficient beginning with λ=2-2.5 μ was explained by the inter-zone transitions absence (fundamental absorption) in $CoSi_2$ at λ>2-2.5 μ.

REFERENCES

[1] A.B.Zotov, B.B.Korobtsov. Poverkhnost. N-12 (1990)p. 5.
[2] R.T.Tung et al., Appl. Phys. Lett. V.55, N-19, (1989) p.3005.
[3] L.Handerbache et al. Thin Solid Films. V.184 (1990) p.317.
[4] J.A.Roth, C. R. Crowell. Application of the silicon/slicide. V.15, N-4 (1978) p.13-17.
[5] B.E.Egamberdiev,B.Ch.Cholliev,A.S.Mallaev,M.E.Zoirova Receiving films $CoSi_2$/Si(100) and analysis of their morphology and stekhmomstriya o metodama MLE,TFE and RE //Surface Engineering and Applied Electrochemistry N1,2007,p.88-92.
[6] A.S.Mallaev"Reserch of mechanism greating silisid Mn_2Si_3,$FeSi_2$,$CoSi_2$,$NiSi_2$ in silicon it is ionic-implanted" Avtoreferat cand.Dis.,Tashkent,2009,p.2