Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Vacuum 78 (2005) 337–340
VACUUM
SURFACE ENGINEERING, SURFACE INSTRUMENTATION & VACUUM TECHNOLOGY
www.elsevier.com/locate/vacuum

# Radiation damage of Si wafers modified by means of thin layer ion assisted deposition

I.S. Tashlykov[a,*], O.G. Bobrovich[b]

[a]*Department of Common Physics, Maxim Tank Belorusian State Pedagogical University, Sovetskaja Str. 18, 220050 Minsk, Republic Belarus*
[b]*Department of Physics, Belorusian State Technological University, Sverdlova Str. 13-a, 220630 Minsk, Republic Belarus*

**Abstract**

Development of the damage and structure of metal-based-film–Si structures' constructions formed by ion-beam-assisted deposition (IBAD) of thin films onto silicon, using a method in which the metal deposition is accompanied by bombardment by the same metal ions, is considered. The analysis was carried out using the RBS/channeling and TEM methods. The films are found to have uniform thickness, they are amorphous in the interface region and include low scale (~5–10 nm) inserts of metal. It is estimated that concentration of silicon atoms displaced during the IBAD process in the interface region decreases 1.7–3.7 times when a thin layer on the silicon wafer is deposited by physical evaporation before the IBAD process.


*Keywords:* Self-ion assisted deposition; Silicon; Deposited energy density; Thin film

## 1. Introduction

Transition and refractory metal–silicon interactions using the ion-beam techniques have been investigated intensively for the last 15 years because of their great importance for fabrication of semiconductor devices [1,2]. Ion-beam-assisted deposition (IBAD) of metal layers is a promising method for silicide creation because it enables us to perform silicidation directly in a single metal deposition step. The silicidation reaction in this situation, can be considered as a thermal activated process because of the effect of thermal spikes, which is associated with the microscopic temperature within a collision cascade of about 1500–2000 K [3].

In our work, we have fabricated the Me–Si structures by self-ion-assisted deposition (SIAD), and have investigated intermixing of components in the interface region between silicon and metal phases and the structure of the modified surface. It is known that various effects (e.g. ballistic mixing, radiation enhanced diffusion, thermal

*Corresponding author. Fax: +017 226 40 24.
*E-mail address:* tashl@bspu.unibel.by (I.S. Tashlykov).

0042-207X/$ - see front matter 
doi:10.1016/j.vacuum.2005.01.047

spike effects, chemical reactions, sputtering) may contribute to the rate of Me–Si interaction [4–7]; therefore, we investigated the dependence of Me–Si interaction on the SIAD process parameters. We have examined the influence of energy density deposited in the collision cascade (DED) and the procedure of Me–Si structure preparation on intermixing of components, to clarify the role of the above-mentioned processes in the desired structure construction.

## 2. Experimental techniques

Cobalt, zirconium, molybdenum and tungsten layers were deposited on (1 0 0)-oriented silicon wafers by means of SIAD. Deposition experiments were performed using a resonance vacuum arc ion source. Such kind of ion source provides deposition of a thin metal film on a target with ion irradiation. But instead of noble gas ions that are usually used in IBAD, our technique made use of self-ion-irradiation condition. It means that irradiation is carried out using ions of the same species as those used for the deposition on the target. Thus, no noble gases are introduced into the target. The second salient feature of the SIAD method is the increase of the DED under the influence of often heavier than argon metal ions up to 10 or even more electronvolt per atom inside the collision cascade.

The vacuum in the target chamber was about $10^{-2}$ Pa during SIAD of a thin metal film on the silicon. Silicon samples were floated to a negative potential with respect to the source of 5, 7, 15, 20 kV to accelerate the ion species. Thin film deposition rates were between 0.4 and 1.9 nm/min; ion/atom ratios were between 0.02–0.45. Sigmund's approximation [8] was used for the estimation of the DED in the ion beam mixing (IBM) experiments.

The Rutherford backscattering/channeling (RBS/C) technique was employed for the investigation of the target composition and for the study of silicon structure damage. The energy of $He^{+}$ ions was 1.5 MeV, the scattering angle $\Theta = 110^\circ$, and the angles of the entry and escape were $\Theta_1 = 0^\circ$ and $\Theta_2 = 70^\circ$, correspondingly. The energy resolution of the analyzing system was 15 keV. TEM analysis was performed on a JEOL 3010 electron microscope, and applied to the samples prepared by hand tools using a small angle cleavage technique [9].

## 3. Results and discussion

RBS/C spectra of W-deposited and ion-irradiated samples are shown in Fig. 1. The level of the residual damage in the SIAD-treated samples was extracted from the aligned spectra of backscattered ions number 1–4. Since ions that are channeled can only be scattered by atoms that are displaced from the lattice site, the aligned spectra essentially replicate the profile of the interstitially displaced atoms (we neglect a flux peaking effect for two reasons: firstly, very thin layers are analyzed, and secondly, sufficient severely damaged crystals are investigated). Increase in the yield in the aligned spectrum corresponds to an increase in the damage or the number of displaced atoms. In our experiment, we observe that the damage increases with the accelerating voltage from 7 to 20 kV, (curves 1–3 in Fig. 1). This fact could be expected, but the most peculiar phenomenon observed here is the increase of yield of the aligned spectra behind the damage peak under the influence of ion energy,

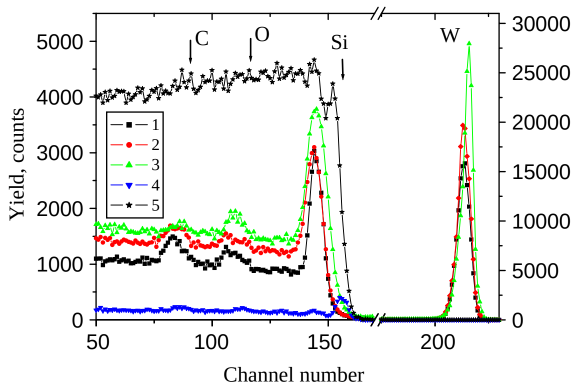


Fig. 1. RBS/C spectra of W–(1 0 0) Si samples constructed by means of SIAD at accelerating voltages: 1—7 kV, 2—15 kV, 3—20 kV, 4—virgin Si, 5—random Si.