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Institute of Physics, Maria Curie-Skłodowska University

Marek SOWA, Janusz FILIKS, Janusz M. ZINKIEWICZ,
and Juliusz SIELANKO

Recoil Implantation of Al and Cu into Stainless Steel and Ti Atoms into Aluminium Induced by Xenon Ion Beam

Wtórna implantacja Al i Cu do stali kwasoodpornej oraz Ti do aluminium wywołana wiązką jonów ksenonu

INTRODUCTION

In the last twenty years, ion implantation in metals and semiconductors has been applied to studies of physical, chemical and mechanical properties of the surface layers [1, 2, 3]. Many types of elements have been implanted into the metals and the results of the investigation have shown, that ion implantation in metals leads to a significant modification of the surface [4, 5]. The recoil implantation technique — used in this work — allows to obtain the controlled concentration of dopants in the materials. Ion beam mixing is an effective method of producing intermetallic compounds [6]. The advantage of these methods is a relatively short time of irradiation required to produce the desired compositions as against to direct implantation.

Some results of recoil implantation from thin films of In, Ag, Cu and Al into steel during krypton and argon implantation were described in our earlier papers [7, 8].

The purpose of this paper is to determine the depth distributions of aluminium, copper and titanium atoms concentration in the case of Al/steel, Cu/steel and Ti/Al systems respectively, implanted by the xenon ions. The depth concentration profiles were obtained by the SIMS measurements and were compared with the Monte-Carlo computer simulations of the recoil process [9, 10, 11].

EXPERIMENT

In the experiment the surfaces of stainless steel (1H18N9T) and aluminium samples were mechanically polished and chemically cleaned. Thin films of copper and aluminium were deposited on the surface of the steel samples as well as titanium films on the surface of Al samples, using vacuum evaporation technique.

Into such samples, the xenon ions with energy 250 keV and the dose 10^{16} ions/cm^2 were implanted through those thin films at room temperature. The implantation was carried out using the UNIMAS isotope separator at the Institute of Physics, of the Maria Curie-Sklodowska University in Lublin [12].

The thickness of Al, Cu and Ti thin films were comparable to projected ranges R_p of the xenon ions. The R_p values were calculated using the computer program based on the Biersack analytical approximations [13, 14] and are presented together with the standard deviation ΔR_p in Table 1.

Table 1. The projected range R_p and standard deviation ΔR_p of the xenon ions in Al, Cu and Ti samples and the thickness of evaporated layer

Tab. 1. Zasięg najbardziej prawdopodobny R_p jonów ksenonu w warstwie Al, Cu i Ti, odchylenie standardowe ΔR_p oraz grubości naparowanych warstw

Ion/Layer	Xe/Al	Xe/Cu	Xe/Ti
Thickness of evaporated layer [nm]	11.0	13.0	16.0
R_p [nm]	73.4	27.9	52.0
ΔR_p [nm]	9.7	6.4	9.7

RESULTS AND DISCUSSION

The depth distributions of the recoil atoms were determined by means of the SIMS method measurements. The construction of SIMS is based on MI–1201 mass spectrometer with the 90-degree sectoral magnetic field [15].

The measurements of depth distribution concentration were carried out for unimplanted thin films as well as after recoil implantation, see Figures 1 a, b and c.

As can be seen from Figure 1, the recoil implantation effect occurs also during the SIMS measurements, which means that the primary ion beam recoil atoms from evaporated thin film to the substrate. This effect should be taken into account in the interpretation of SIMS depth profiling measurements.

The experimental data were compared with the theoretical calculations of the Monte-Carlo computer simulations of the recoil process. The calcula-

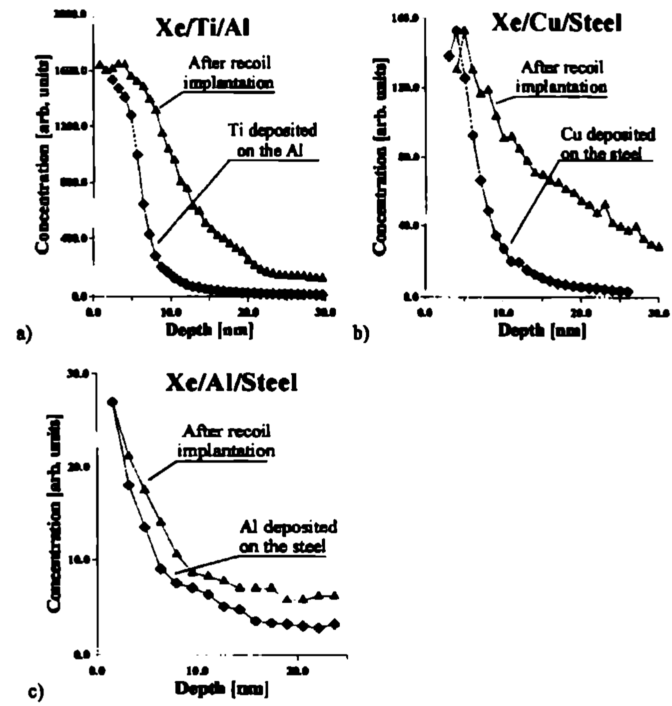

Fig. 1. The SIMS measurements of depth distribution concentration of: a) Ti atoms on Al; b) Cu atoms on steel; c) Al atoms on steel; ♦♦♦ — unimplanted samples; ▲▲▲ — after recoil implantation of Xe ions

Ryc. 1. Pomiary SIMS głębokościowych rozkładów koncentracji: a) atomów Ti w Al; b) atomów Cu w stali; c) atomów Al w stali. ♦♦♦ — próbka nieimplantowana; ▲▲▲ — próbka po implantacji wtórnej

tions were performed using the computer program described earlier [9, 10]. The comparison of the results of computer simulations and the experimental measurements after recoil implantation for Ti/Al, Cu/Fe and Al/Fe systems are presented in Fig. 2a, b and c respectively.

As can be seen from Figure 2, the results on the Monte-Carlo computer simulation agree with the SIMS experimental data within the range about 20%.

The recoil yield coefficient can be evaluated from the measurements data as well as from the Monte-Carlo calculations. The recoil yield was determined as the ratio of the number of atoms introduced from the thin film to the number of implanted Xe ions. The recoil yield values calculated for the Ti/Al, Cu/Fe and Al/Fe systems are equal to 1.59, 1.84 and 2.42 respectively.

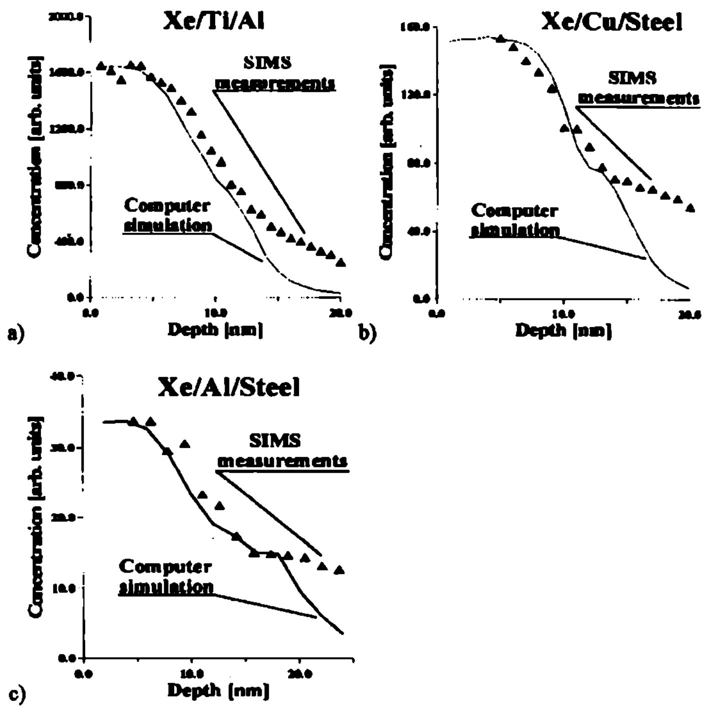

Fig. 2. Comparison of depth concentration profiles of: a) Ti deposited on Al; b) Cu deposited on steel; c) Al deposited on steel after Xe implantation. Solid line — the Monte-Carlo computer simulation; ▲▲▲ — the SIMS measurements

Ryc. 2. Głębokościowe rozkłady koncentracji po implantacji wtórnej: a) Ti naparowanego na Al; b) Cu naparowanej na stal; c) Al naparowanego na stal. Linia ciągła — symulacje komputerowe Monte-Carlo, ▲▲▲ — pomiary SIMS

CONCLUSIONS

The experimental results of recoil implantation of Cu and Al into stainless steel and Ti into Al obtained using SIMS measurements are in relatively good agreement with the results of the Monte-Carlo computer simulations. For the greater depth slight differences between theoretical and experimental data were observed because of the recoil effect during the SIMS measurements. For all samples the recoil yields are greater than one.

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STRESZCZENIE

W niniejszym artykule przedstawiono wyniki wtórnej implantacji aluminium i miedzi do stali oraz tytanu do aluminium bombardowanych wiązką jonów ksenonu. Cienkie warstwy Al, Cu i Ti zostały otrzymane w wyniku naparowania próżniowego i poddane implantacji jonami ksenonu o energii 250 keV i dawce 10^{16} jonów/cm^2. Rozkład głębokościowy atomów wbitych w powierzchnię podłoża z warstwy naparowanej został określony na podstawie pomiarów SIMS. Następnie dane doświadczalne zostały porównane z obliczeniami komputerowymi symulującymi zjawisko wtórnej implantacji z wykorzystaniem metody Monte-Carlo.