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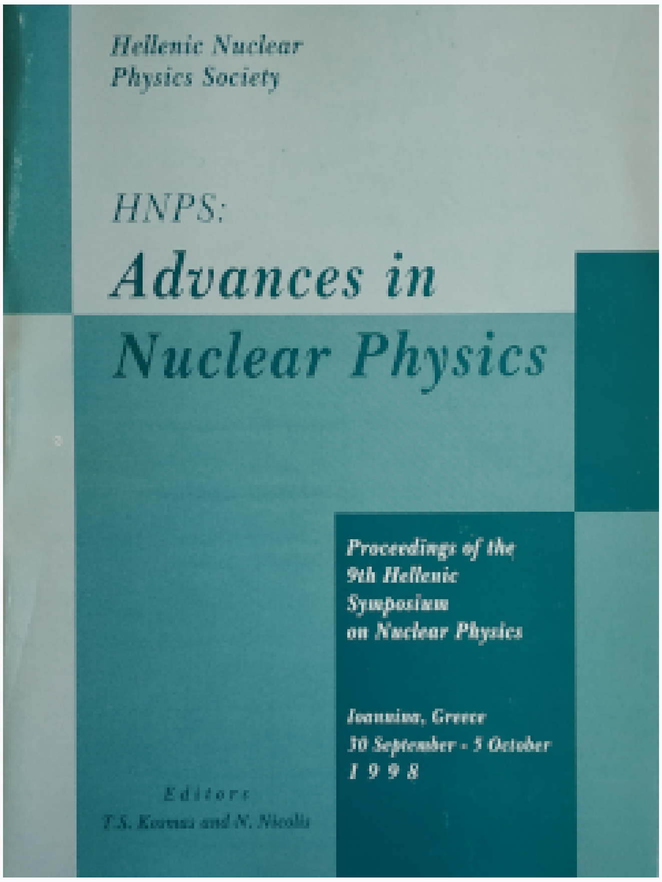

Heavy-ion RBS characterization of multilayer TiNx-SiO2-Si structures

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Heavy–ion RBS characterization of multilayer $TiN_x - SiO_2 - Si$ structures

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Abstract

Multilayer structures consisting of $TiN_x - SiO_2 - Si$ layers operating as MOS devices were constructed and tested for their electrical properties. RBS measurements were performed for the characterization of the structure of the devices. The results show a correlation between the structure found by RBS and the electrical performance of the devices.

1 Introduction

The Rutherford Backscattering Spectroscopy technique (RBS) has been established as a powerful tool of Ion Beam Analysis (IBA) in profiling and characterization of multi - layer structures in a variety of materials [1–3]. In the present work, the RBS method was applied on the characterization of materials consisting of layers of Titanium Nitride and Silicon Dioxide on a substrate of high purity n-type Si, in a Metal-Oxide-Semiconductor (MOS) arrangement.

Titanium nitrides are novel class of materials which are characterized by metallic behavior, low special resistivity, chemical stability and outstanding mechanical properties. They meet a lot of applications in modern electronics as electrodes for gates, diffusion barriers, ohmic junctions and restoring devices.

The samples were manufactured in the University of Thessaloniki using the reactive magnetron technique. A number of 10 MOS devices were fabricated with different parameters of fabrication (polarization potential of the substrate and temperature of development of the TiN film), in order to determine the optimum parameters for the best results. Measurements of the capacity and resistivity of the devices were conducted to correlate the manufacturing parameters with the electrical performance. Then, RBS measurements were carried out to correlate the structure of the device with the manufacturing technique and the electrical performance.

2 The RBS Technique

Rutherford Backscattering Spectroscopy is based on the simultaneous measurement of the energy loss of the projectile and the scattered particle and the reaction yield, after scattering at back angles ($\Theta = 160° - 170°$). The energy of the beam is kept low enough as compared to the Coulomb potential between the projectile and the target so that the reaction mechanism is Rutherford type scattering. The width of the observed plateaux is related to the combined energy loss of the projectile and the scattered particle and leads to the determination of the thickness of the layer, while the yield is related to the concentration of the particular element (Fig. 1).

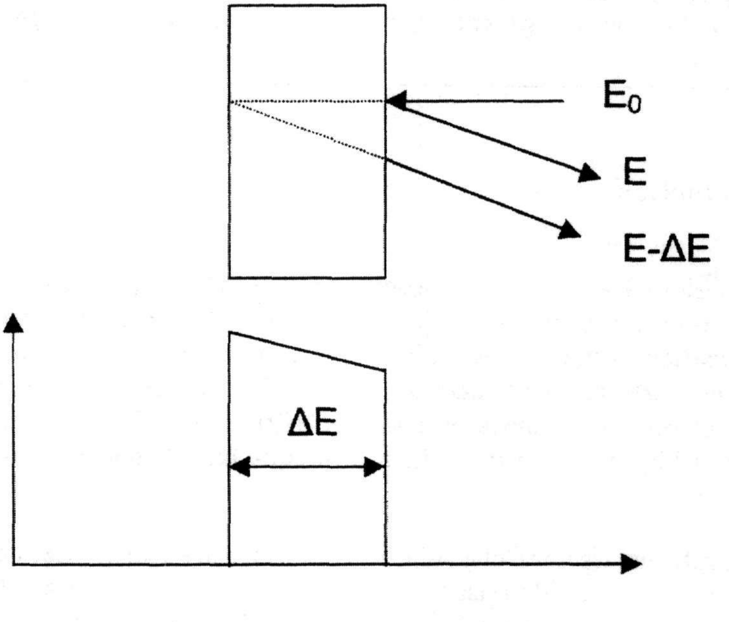

Fig. 1.

Usually, RBS measurements are carried out using ^4He beams at energy 1.2 - 2.0 MeV. It has been shown though [3] that the utilization of a heavy ion beam as projectile (HIRBS) provides superior mass separation, while the depth resolution remains at levels comparable to that of the conventional light ion RBS. Figure 2 shows a comparison of the mass resolution between beams of 10 MeV ^{12}C and 2 MeV ^4He. However, the lowest detectable mass number is higher in HIRBS because elements with mass number lower or around the mass number of the beam are invisible in back scattering.

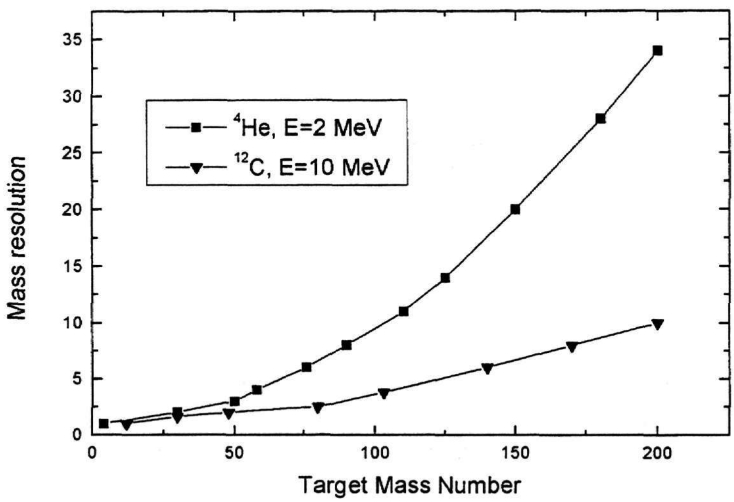

Fig. 2.

In the present work, we utilized a ^{12}C beam at energy 10 MeV for the characterization of the $TiN-SiO_2-Si$ structures. The experiments were performed at the Nuclear Physics Laboratory of the NRCPS "Demokritos", using the TN11, 5.5 MV terminal voltage accelerator. The detecting system consisted of a single Surface Barrier Si detector placed at angle Θ = 160o with respect to the beam. The overall detector resolution was measured by scattering on a thin Au foil and found Γ =90 keV. The beam was well collimated using a two sets of beam collimators and kept at a size of $1 \times 1\ cm^2$.

An RBS spectrum taken with this technique is shown in Fig. 3. Since the beam was ^{12}C, the elements ^{14}N and ^{16}O contained in TiN and SiO_2 are not visible, because their mass is similar to the mass of the projectile and their backscattering energy is very low. The Ti plateau is pronounced at the end of the spectrum while the Si contained in the intermediate layer of SiO_2 forms a "shoulder" before the Si continuum, which is too small to bare any

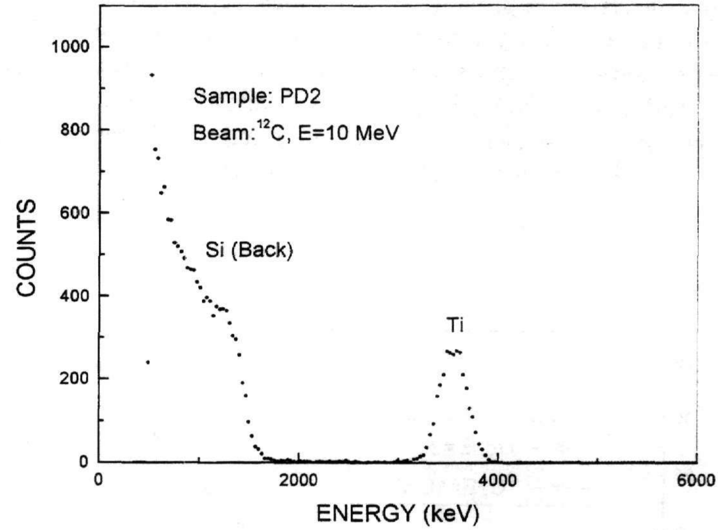

Fig. 3.

information. The tails at both high and low energy part of the Ti plateau represent the isotopes of Ti with mass numbers 46 (8%), 47 (7.5%), 49 (5.5%) and 50 (5.3%) since the most abundant isotope ^{48}Ti counts for only 73.7% of the natural Ti. This separation was made possible by the increased mass resolution of the ^{12}C projectile (Fig. 2).

3 RBS Analysis and Results

For the analysis of the experimental spectra, computer simulations were performed using a home made simulation named TINA [4]. This code is written in standard FORTRAN 77 and uses the Ziegler - Biersak - Littmark Stopping Power Coefficients [5] for the calculation of the energy loss. The overall error of the calculation is 10% following the quoted error on the parameters used.

Figure 4 presents the RBS spectrum of the sample PD2, which is characterized by good electrical behavior, together with the simulation performed. The spectrum is reproduced assuming a surface density of 40 $\mu g/cm^2$ for the layer of TiN and 22 $\mu g/cm^2$ SiO_2 and no interference or diffusion between the layers. The simulation reproduces the experimental spectrum in a good way. The simulation also indicates that the Si contained in SiO_2 should not be observed and the thickness of SiO_2 is less than the depth resolution of the experiment.

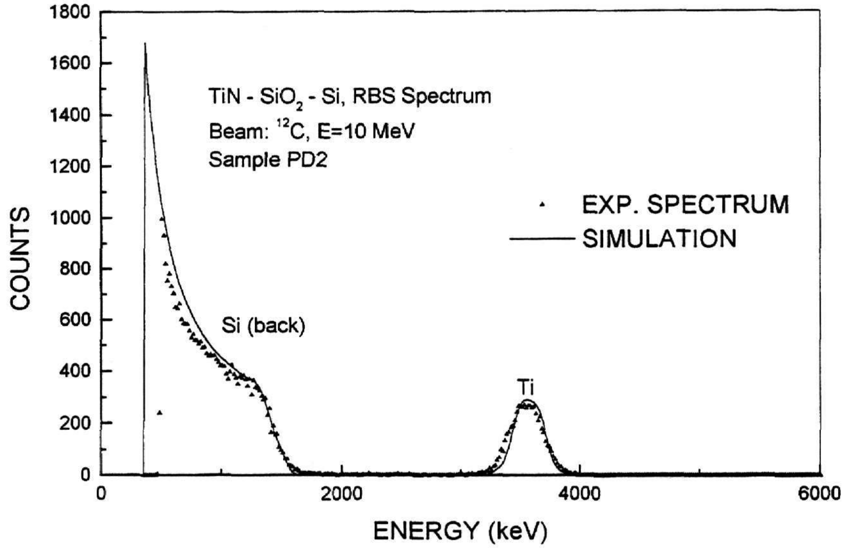

Fig. 4.

All the well behaving diodes in the electrical measurements produced similar RBS spectra, with no signs of structural damage or interference between the layers. On the contrary, all the diodes with poor electrical performance showed evidence of structural damage during manufacturing. As an example, Figures 5 and 6 show the RBS spectrum of the devices PD9 and PD7, which are characterized by high leakage currents. For comparison, in these figures the experimental spectra of the samples PD7 and PD9 are overlaid by the experimental spectrum of the sample PD2 which is characterized by good structure. The spectrum of the device PD9 is not reproduced by the simulation and shows a deficit of Titanium, particularly in the back side, which is a sign of contamination by a light element, probably Oxygen. The spectrum of the sample PD7 shows that the front face is completely destroyed and contaminated by a light element as Oxygen or Carbon.

4 Discussion

A number of 10 MOS devices were manufactured and characterized by the Rutherford Backscattering Spectroscopy technique. The results show that samples with poor electrical behavior, suffered structural damage in the TiN layer. Also, samples with good layer structure were found to exhibit good electrical behavior. Some of that damage can be attributed to Oxygen contam-

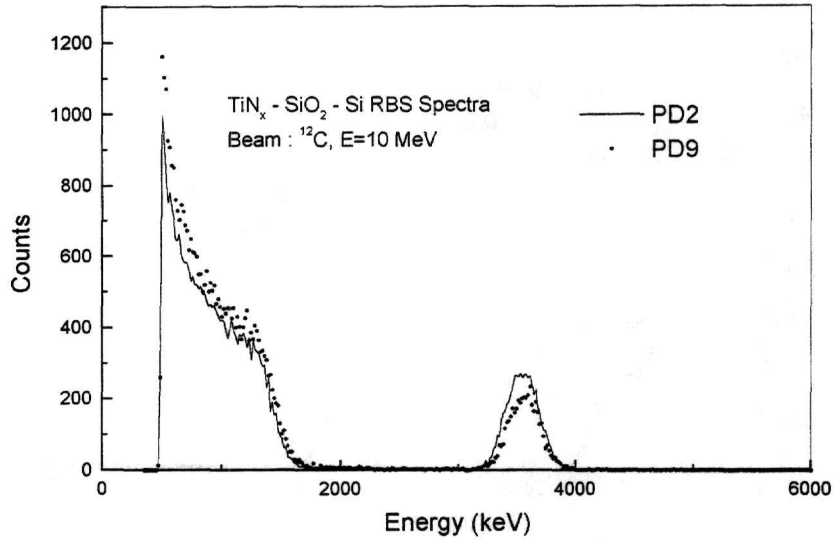

Fig. 1.

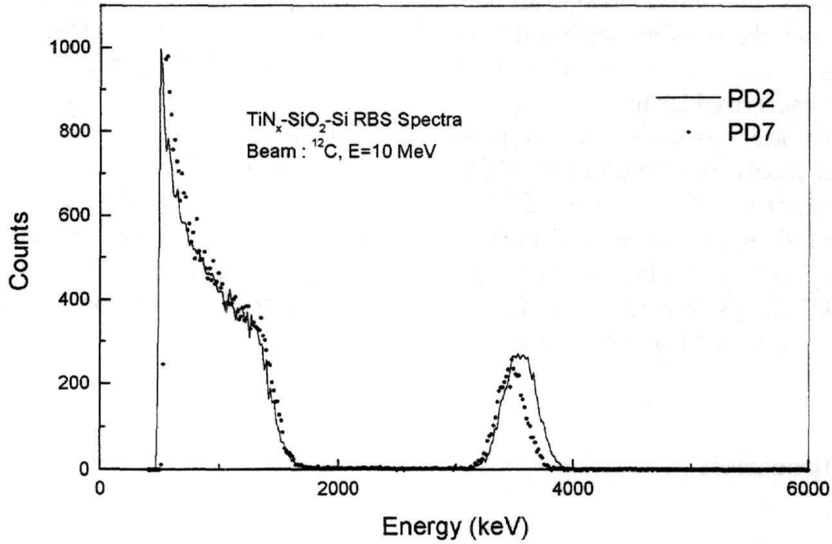

Fig. 2.

ination during fabrication. A correlation between the structure of the layers found by RBS and the deposition conditions used during fabrication, shows that the best results were obtained when the devices were manufactured at room temperature with an applied surface bias of -40 Volt.

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