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Research Paper

Investigation the ion Argon and Nitrogen effect on the transport characteristics of implanted Tantalum interfaces of multilayers

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Keywords

Tantalum, Transport, Interface, Nitrogen

Abstract:

The present paper examines the influence of ion type on the transportation through the structures. The interfaces of structures have been created through the ion implantation process. The interfaces consist of Tantalum layers that undergo bombardment by Argon and Nitrogen ions. The energy of the ion has been taken into account at 30 keV. The outcomes have been obtained at varying doses under room temperature conditions.

In order to study the morphology of the ion implanted rough thin films, the Atomic Force Microscopy analysis applied. The average value of roughness calculated. Reducing the transmission probability is the main result of the structures rough interfaces. The obtained results illustrate that the produced interfaces by Argon ion implantation, were rougher than Nitrogen ones. Moreover in both two cases, the peak to valley ratio reduces. Additionally, as the dose of Nitrogen ion increases, the current density decreases as a function of voltage.

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1. INTRODUCTION

The Tantalum based thin films have been considered in the various field and researches [1], because it has various properties such as high corrosion resistance, mechanical properties, and low density [2-4]. The different experimental and theoretical works show that the Oxygen, Argon, Carbon, and Nitrogen ion implantation improved the surface of tantalum samples [5-6]. The ion implantation process and growth conditions affect the morphology of the implanted interfaces and the mechanical, electrical, and optical produced samples [7-9]. There are many experimental and theoretical rerseraches which they studied the transport properties through Tantalum based thin films [10]. Also, the effect of roughness and the morphology of Tantalum based surfaces have been investigated on the performance of electrical devices [11, 12].

The numerous approaches use to produce the rough interfaces [13]. The impact of rough surfaces/interfaces investigated on the structures electrical conductivity [14, 15]. The ion implantation process causes to roughening the resulted interfaces/surfaces [10-12]. Here, the effect of two different types of ions (Argon and Nitrogen) has been investigated on the transport characteristics of thin films Tantalum created which have been applied in the multilayer structures. The transmission probability and current density have been investigated.

2. MATERIALS AND EXPERIMENTAL DETAILS

In this section the ion implantation process on tantalum samples which done in Plasma Physics Research Center (PPRC), Science and Research Branch, is illustrated. A graphic schematic of ion implanter is showed in Fig .1. The details of process are as following; the sample which cut into 1 cm \times 1cm and 0.58 mm thickness exposed to nitrogen ion implantation. The Nitrogen and oxygen ions lands on sample vertically and their energy and doses of (99.999%) were 30 keV and 1×10^{17} to 10×10^{17} ions/cm² at ambient temperature.

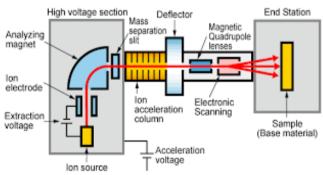


Fig. 1 Schematic of ion implanter

The ion bombardment which cause to heat transferring, room temperature extended a maximum steady value of 100 °C. The variety of ions doses has been considered to cover the whole the surface of sample evenly. It is praiseworthy to detail the characteristics of the samples prior to implantation. To achieve a glossy sample, the items are polished and subsequently cleaned using alcohol and acetone with an ultrasonic system. The nitrogen ions extracted (devoid of selection the mass) were accelerated to a maximum energy of 30 keV in the accelerating column and post-acceleration process. The nitrogen ions were implanted into the surface of tantalum samples that were positioned normally with the ion source.

The structure or composition of samples can be characterized by different approaches. Here, the XRD analysis has been used. The current densities and ion beam energy have been considered fixed during implantation process for all samples. The table 1 shows the parameters which are used ion implantation.

Sample	Fluxes (ions/cm ²)	Time(s)
S_1	1×10^{17}	360
S_2	3×10^{17}	470
S ₃	5×10 ¹⁷	700
S ₄	7×10^{17}	1120
$\overline{S_5}$	10×10 ¹⁷	1600

Table 1. The factors of ion implantation procedure.

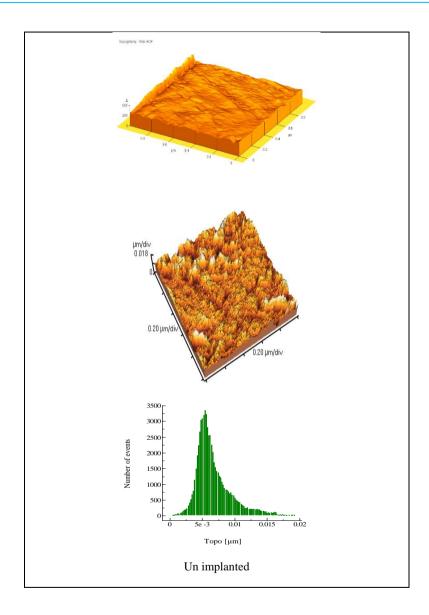
3. MEASUREMENTS AND DISCUSSION

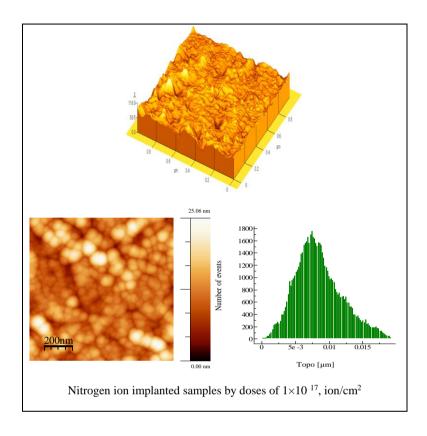
The structural properties and composition of the tantalum samples have been investigated with different methods. The implantation-induced modification of surface roughness is studied employing an atomic force microscopy (AFM). SPM Auto Probe CP, Park Scientific Instruments to investigate the morphology and roughness of the surface, performed atomic force microscopy (AFM). AFM was carried out in a non-contact mode and in the scanning area of 1 lm2 with a low stress tip of less than 20 nm radius.

In order to study the topography and roughness of the surface, AFM analysis in contact mode and scanning area of 1 lm 2 were used.

3.1 SURFACE MORPHOLOGY STUDY BY ATOMIC FORCE MICROSCOPY

Fig.2, displays 3 dimensional AFM surface images of Tantalum based films earlier and afterward Nitrogen and Argon ion implantation.





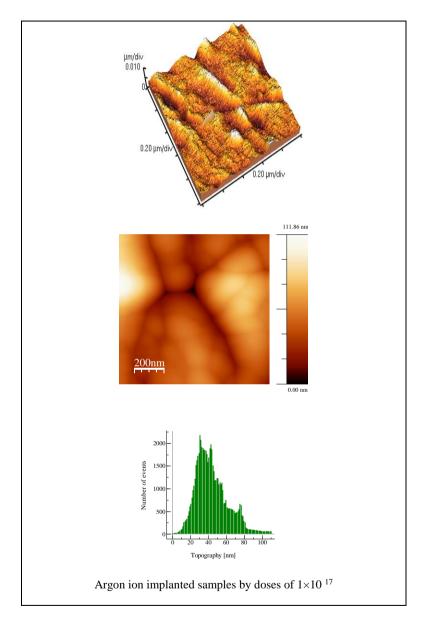


Fig. 2 3D images of un-implanted sample and Nitrogen and Argon ion implanted samples

The AFM analysis images show the shape and the grain size of a $1\mu m \times 1\mu m$ scan area which change with nitrogen ions dose. Table 2 and Table 3, for all samples

present the roughness effect earlier and later of Argon and Nitrogen implantation of ion, respectively.

Table 2. Roughness before and after Argon implantation for all samples.

Tubic 2. Itoughness serore and areer in gon implantation for an samples.						
	Un-	S1	S2	S3	S4	S5
	implant					
Dose	0.0	1×10^{17}	3×10^{17}	5×10 ¹⁷	7×10^{17}	10×10 ¹⁷
RMS roughness (A°)	22.3	7.52	41.10	95.30	50.30	7.52
Average roughness (A°)	15.7	5.64	32.80	69.70	41.30	29.7

Table 3. Roughness before and after Nitrogen implantation for all samples.

	Un-	S1	S2	S3	S4	S5
	implant					
Dose	0.0	1×10 ¹⁷	3×10 ¹⁷	5×10 ¹⁷	7×10 ¹⁷	10×10 ¹⁷
RMS roughness (A°)	1401	22.1	18.9	59.9	23.6	4.0
Average roughness (A°)	41.9	61.9	50.3	17.1	76.3	10.5

Fig. 3 shows the samples roughness versus ion doses for two different ions; Argon and Nitrogen $\,$

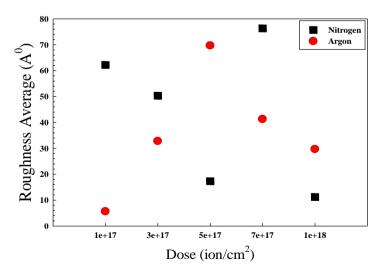


Fig. 3 The roughness average values of samples versus of ion doses

3.2 TRANSMISSION PROBABILITY AND TRANSPORT PROPERTIES

The value roughness average is one of the parameters which described the surface roughness. Thus, calculation of transport properties have been done to achieve comprehensive information about the type of interfaces. Here, the roughness effect on the transport properties of Tantalum based samples (which they produced by two different ions types implantation) has been studied. Based on the transfer matrix method and nearly free electron mass, the transport properties of whole samples have been investigated. The detailed descriptions can be fined in Refs [17, 19].

Fig. 3 shows the portion of scattering because of rough Tantalum thin films which have been used in the five layers' structure. The initial and final interfaces of these structures are regarded as rough. Resonant tunneling occurs as the incoming electrons energies equal the energy of the lowest quasi-bound energy level within the wells. [19]. This is the origin of peaks and valleys in the transmission probability curves.

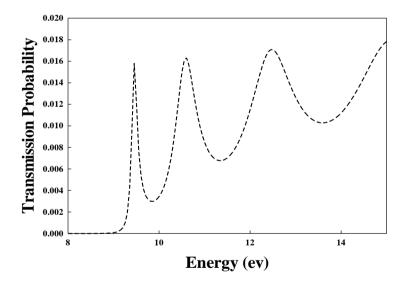


Fig. 4 The transmission probability versus the electron energies for Un-implanted Tantalum thin film

In the present work, the five layers structures have been considered. Their interfaces are Tantalum based surfaces which have been implanted by Argon and Nitrogen ions with different doses. Consequently, it is intriguing to examine how the type of ions influences the transport characteristics of these structures.

In the Fig. 5, the portion of scattered of transmission probability has been shown to compare the effect of ion types on the transmission probability. Moreover, the electron scattering procedure able to generate the additive rise and fall resonance energies and the resonant peaks in transmission probability have not the maximum value (1).

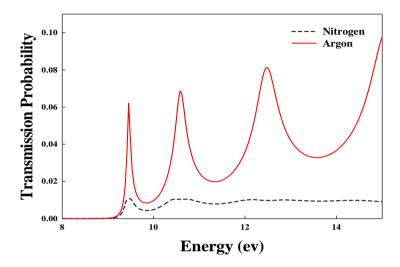


Fig. 5 The transmission probability versus incident electron energies for structures with Nitrogen ion implanted (dotted curve) interfaces, and Argon ones

As it can be seen, the scattering portion of transmission probability of structures with the interfaces that produced by Argon ion implantation is more than the Nitrogen one. To examine the impact of the ion type on the creation of rough interfaces, the current-voltage (I-V) characteristics have been analyzed. In Fig. 6, the current density versus voltage has been plotted for un-implanted interfaces. With increasing the applied voltage (v), the current value extents a maximum gradation and then at higher values of voltage, the current density drops in the area of Negative Differential Resistance (NDR) [17]. The results present that the current-voltage characteristics show negative differential resistance [12-15].

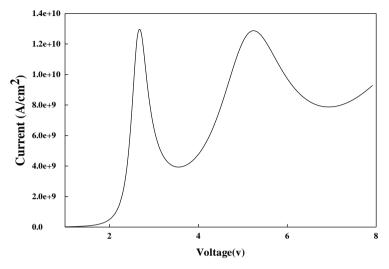


Figure 6 The current density versus the bias voltage for un-implanted case

In Fig. 7, the effect of interface roughness (which have been produced by Argon and Nitrogen) has been shown on the current density. These results can be explained with the results of Fig. 3.

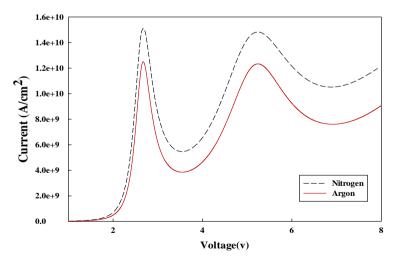


Fig. 7 The current density versus the bias voltage for two cases of Argon and Nitrogen ion implanted interfaces

The scattering portion of probability in the case of Argon ion implantation is more than Nitrogen one. The current density is also less than the Nitrogen case. Moreover, in two cases, as a result of scattering process, the peak of resonant tunneling current declines. Also, the valley current increases and the peak to valley ratio (PVR) reduces. Fig. 8, shows the current density versus the bias voltage to describe the effect of two rough interfaces which have been produced by two doses of Nitrogen ions.

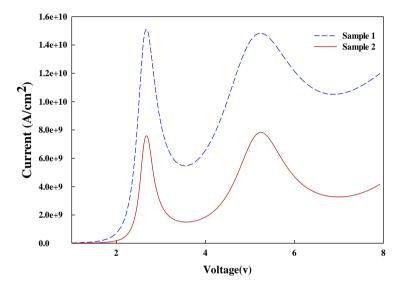


Fig. 8 The current density versus the bias voltage for two cases; 1×10^{-17} (dotted curve), and 3×10^{-17} , ion/cm² Nitrogen doses

Based on the results, the current density has been reduced by increasing the ion doses. This is because of that the interfaces become rougher. These results can be used in the electronic devices fabrication [15].

4. CONCLUSION

In the present study, the effect of ion types (Argon and Nitrogen) implantation has been investigated on the tunneling structures transport properties. The AFM analysis has been used to describe the roughness of produced samples, and the values of average roughness have been calculated. The likelihood of transmission reduces due to the uneven interfaces. The rough surfaces have been developed through the ion implantation method. The scattering procedure causes to decrease the current peak of resonant tunneling, and the PVR ratio also declines.

The prepared samples by Argon ion implantation are rougher rather than Nitrogen cases. Additionally, as the doses of Nitrogen ions are raised, the current density diminishes in relation to voltage.

5. ACKNOWLEDGEMENTS

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