ION IMPLANTATION PROCESS OF LANTHANUM AND TITANIUM DOPANTS INTO A SUBSTRATE OF $FE_{80}CR_{20}$

Hendi Saryanto[1],Darwin Sebayang[1], Pudji Untoro[2], Tjipto Sujitno[2]

[1]Advanced Manufacturing and Material Centre, Faculty of Mechanical and Manufacturing Engineering
University Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor Darul Ta'zim,
[2]Badan Tenaga Nuklir (BATAN) Indonesia
darwin@uthm.edu.my, untoro@batan.go.id,

Abstract

Ion implantation is the process of depositing a chemical species into a substrate by direct bombardment of the substrate with high-energy ion in such away the changing of physical properties of the solid species, therefore, taken place. The aim of this research is to show the ion implantation process into a substrate $Fe_{80}Cr_{20}$ with Lanthanum and Titanium dopants. Specimens, $Fe_{80}Cr_{20}$ were developed using powder metallurgy technique, Lanthanum and Titanium ions were implanted by using Cockcroft-Walton Type 200 keV/200 µA ion implantor with ion doses of 10^{17} ions/cm^2 and kinetics energy 100 keV. The prediction of thin layer of dopants into surface of $Fe_{80}Cr_{20}$ was performed using a software called TRIM-SRIM simulation tools. The micro hardness test was conducted by the Vickers-micro hardness tester, and the characterization of microstructure was carried out by EDX, and SEM. The ion implantation process was succeeded to deposit the Lanthanum and Titanium dopants into the surface of Fe80Cr20. Predictive models for the effects of post-implantation processing, such as micro hardness, are also discussed in this paper.

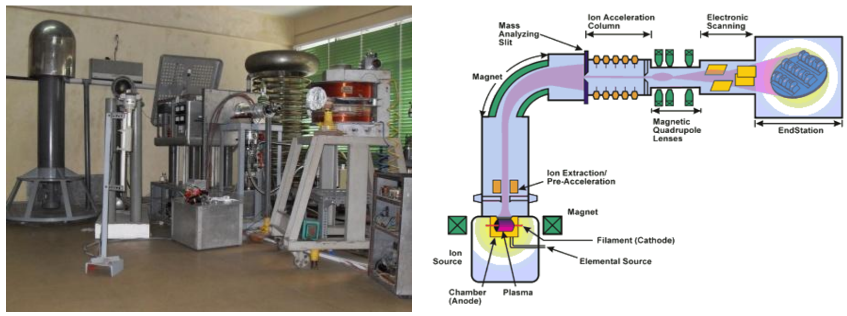
***Keywords**: Ion Implantation, Microstructure, Micro Hardness, SEM, EDX*

1. Introduction

Since the early 1970s the modification of the surface properties of materials, particularly metals, by ion implantation technique, Hardness, wear resistance, coefficient of friction, fatigue strength, film adhesion, and corrosion resistance, had been significantly improved [3]. Ion implantation is carried out through atom placement into a solid substrate by ion bombardment from the range of keV to meV energy level. It had been recognized early that this technique will provides the possibility a wide selection on the atomic species and also on the external control of the number atoms per cm^2 need to be implemented on the specimens. Addition of 'doping' elements such as cerium, yttrium, lanthanum etc. often leads to improved corrosion resistance as well.[1,2,4].

Ion implantation is a technique which offers capability to drastically modify the surface properties of various materials. Ion implantation proceed through ion acceleration at well defined energy (generally in the range 20–500 keV) towards to the material surface. Ions will penetrate the matter and in the first hundreds of nanometers will immobilize after collision with cascades [5].

The surface hardening of steels by using ion implantation method is an efficient and reliable approach that can be used in a large number of industrial applications. Nevertheless, the compound layer developed on the surface reaches hardness values that are well above the core material and also has a large micro-hardness gradient in the interface. This research work presents the comparative results between the surface treatment of Lanthanum and Titanium dopants into a substrate of $Fe_{80}Cr_{20}$ which produced by a Mechanical Alloying process[6], The ion implantation process was performed by Cockcroft-Walton accelerator Type 200 keV/200 μA located in BATAN-Yogyakarta-Indonesia.



(a) (b)

Figure.1. a). The accelerator Ion. b). Schematic diagram of an ion implantation system.

2. Experimental Procedure

2.1 Material

$Fe_{80}Cr_{20}$ Based alloys (produced by Mechanical Alloying process), where the formation process is distinguished on the basis of milling time hours, namely: specimens of $Fe_{80}Cr_{20}$ with milling time 40 hour is called as (*$Fe_{80}Cr_{20}$(40 h)*), $Fe_{80}Cr_{20}$ with milling time 60 hours (*$Fe_{80}Cr_{20}$ (60 h)*) and while for the $Fe_{80}Cr_{20}$ with milling time 80 hours called as (*$Fe_{80}Cr_{20}$ (80 h)*). It is necessary to be noted that all mentioned specimens are treated under a hot compaction process [6].

2.2 Sample Preparation

The samples of $Fe_{80}Cr_{20}$, were abraded with silicon carbide abrasive paper with grit of 100, 220, 400, 600, 800, 1000, 1200, 1500 and 2000 and polished by 0.05 μm diamond paste and ultrasonically cleaned by using ethanol over 30 minutes. Lanthanum and Titanium ions were implanted on one of coupon faces respectively with doses of 10^{17} ions/cm^2 on the area of 8.03 cm^2 and ion beam energy of 100 keV. the current density was maintained at 10 μA. The required time process of ion implantation, then, can be estimated by the following equation (1)

$$D(\text{dose}) = \frac{I\,t}{1.6\text{x}10^{-19}\ q\,A} \qquad (1)$$

Where *D* is the implanting dose, *I* represents the beam current (μA), *t* equals to beam time (s), *q* is the charge state of the ion, and *A* is defined as the striking area (cm^2)[7].

2.3 Analytical methods

The prediction of thin layer of dopants into surface of $Fe_{20}Cr$ was performed using a TRIM-SRIM simulation software. From the result provided from that software, one can calculate the profile depth of Ions through the use of equation as follows (2)

$$x = R_p + \sigma R_p \tag{2}$$

Where, x is the depth of profile of ions, R_p is *ion range and* σR_p is the longitudinal straggling (8).

The characterization of surface area after ion implantation was carried out by a scanning electron microscope (SEM) and Energy-dispersive X-ray spectroscopy (EDX). Experiments for hardness measurement were performed with a Micro Hardness Testing device under load conditions of 490.3mN. The indentation time was maintained for 10 seconds for all specimens. Hardness measurement of each specimen was carried out three times and takes averaged on their values.

3. Results and Discussion

The initial description of an implantation process can be obtained before the actual process was done by using a software TRIM-SRIM simulation tools. The result of the use of that software in term of the concentration depth profile of Lanthanum and Titanium dopants into substrate of $Fe_{80}Cr_{20}$ as depicted the Figure 3.1 and Figure.3.2.

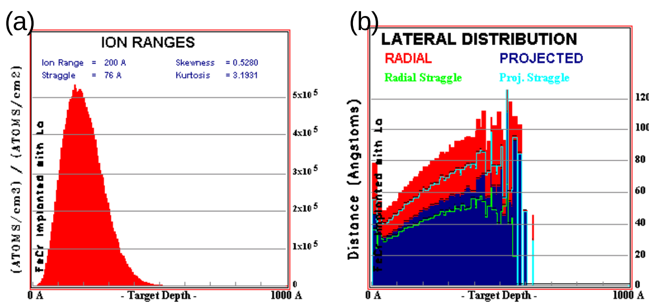


Figure. 3.1. TRIM-SRIM simulation of $Fe_{80}Cr_2$ implanted with Lanthanum,(a) Ion Ranges, (b) Lateral Distribution

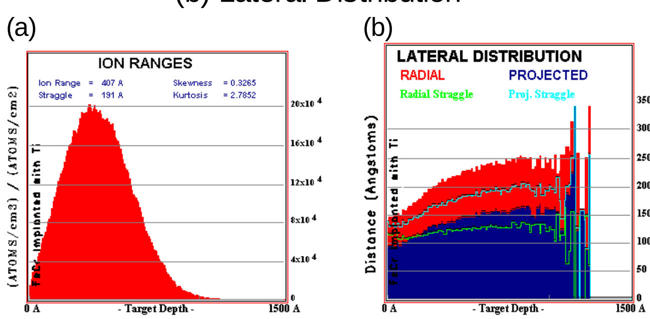


Figure. 3.2. TRIM-SRIM simulation of $Fe_{80}Cr_2$ implanted with Titanium, (a) Ion Ranges, (b) Lateral Distribution

Fig 3.1.a, shows the phosphorous ions (100keV) was formed on $Fe_{80}Cr_{20}$ target. This figure also shows the value of the ion range (R_p) and the longitudinal straggling (σR_p) on the surface area of $Fe_{80}Cr_{20}$ which is implanted with Lanthanum dopant are 200 À and

76 À. While The *ion range* (R_p) and the longitudinal straggling (σR_p) on the surface area of $Fe_{80}Cr_{20}$ which is implanted with Titanium dopant are 407 À and 191 À as shown in the Fig.3.2.a. Target depth at 1000-1500 was setup to allow for obtaining ions in the plots. "(ATOMS/cm3)/(ATOMS/cm2)". Fig.3.1.b and Fig.3.2.b, show the value lateral straggling distance of implantation with Lanthanum and Titanium are 132 À and 52 À respectively

Morphology characterization of lanthanum and Titanium dopants on the surface area of specimens after implantation process are shown in the Fig.3.3 to Fig .3.5. Figure 3.3.a, 3.4.a and 3.5.a, show the microstructure characterization of surface area has been implanted with Lanthanum dopant. While the results of EDX analysis show the existence of the element iron, chromium, and lanthanum on the surface of specimens. Figure 3.3.b, 3.4.b and 3.5.b, show the microstructure characterization of surface area has been implanted with Titanium dopant, while the results of EDX analysis also showed the existence of the element iron, chromium, and Titanium on the surface of specimens.

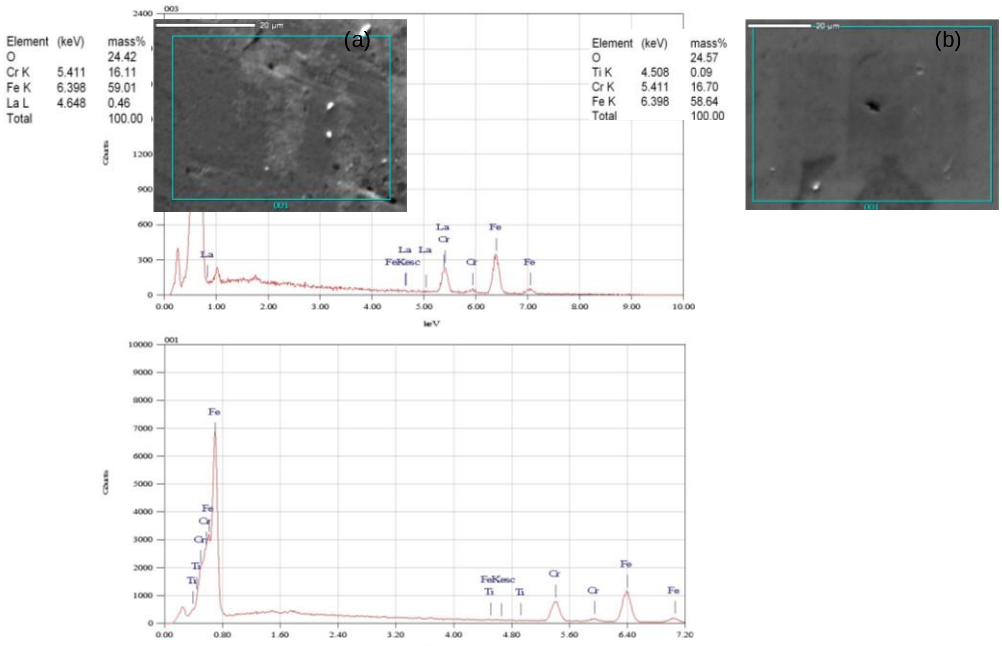


Figure. 3.3. (a). $Fe_{80}Cr_{20}$ 40 h, Implanted with La, (b). $Fe_{80}Cr_{20}$ 40 h, Implanted with Ti

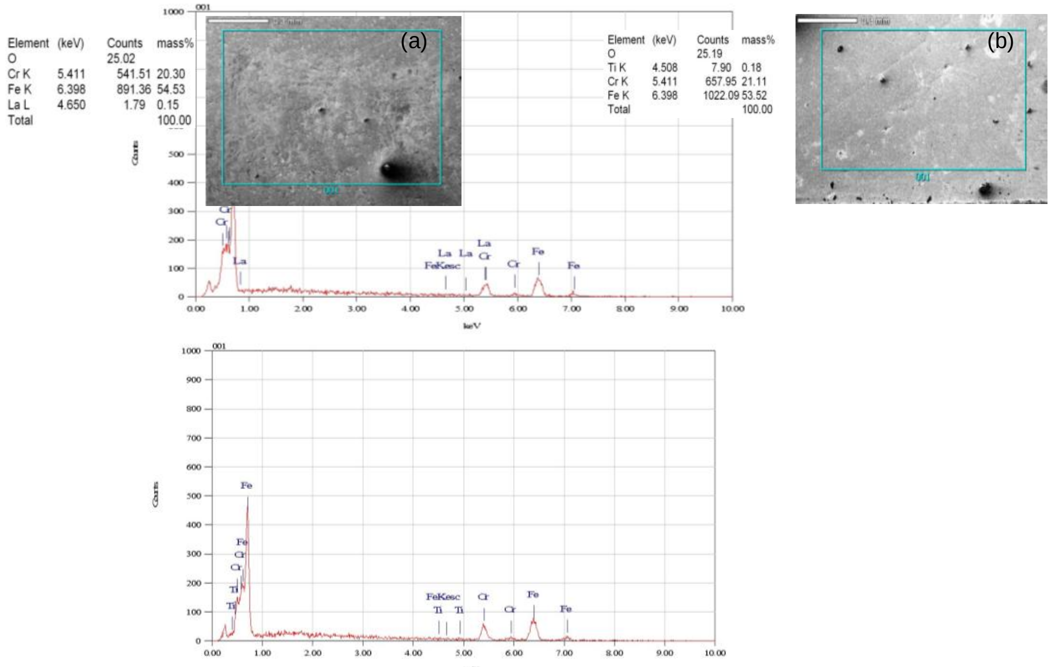


Figure. 3.4. (a). $Fe_{80}Cr_{20}$ 60 h, Implanted with La, (b). $Fe_{80}Cr_{20}$ 60 h, Implanted with Ti

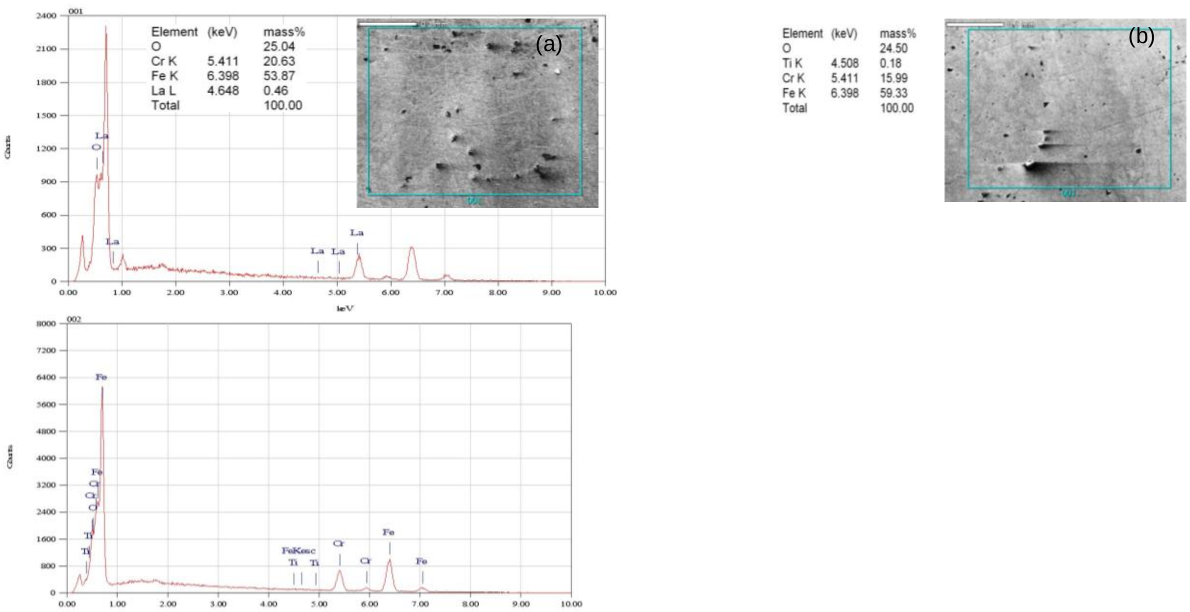


Figure. 3.5. (a). $Fe_{80}Cr_{20}$ 80 h, Implanted with La, (b). $Fe_{80}Cr_{20}$ 80 h, Implanted with Ti.

Fig. 3.6. Show the results of hardness measurement on the surface area of the nine samples.

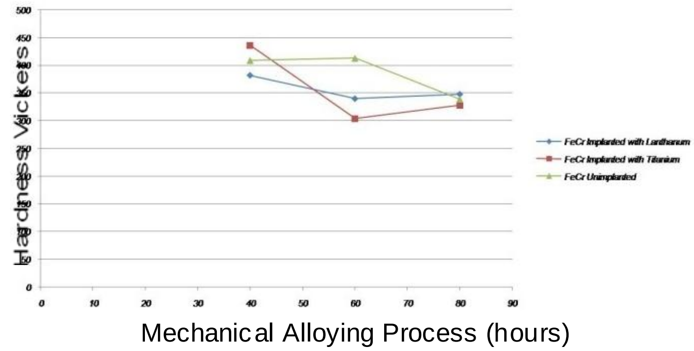


Fig. 3.6. Micro Hardness testing on surface area of $Fe_{80}Cr_{20}$ before and after implantation process

4. Conclusion

Simulation results show the Ion range and the concentration level of dopants ions into substrate of $Fe_{80}Cr_{20}$. Implantation process of Lanthanum and Titanium dopants into substrate of $Fe_{80}Cr_{20}$ with ion doses of 10^{17} ions/cm^2 can be estimated to have 352 À and 789 À depths.

The implantation process of lanthanum and Titanium dopants into substrate of $Fe_{80}Cr_{20}$ with was considered successful. SEM and EDX results prove the presence of Lanthanum and Titanium on substrate of $Fe_{80}Cr_{20}$. This research shows that Implantation process of Lanthanum and Titanium dopants give influence to the surface hardness of $Fe_{80}Cr_{20}$. In addition to this, the surface hardness of $Fe_{80}Cr_{20}$ is also influenced by the crystallographic phases during mechanical alloying process.

5. Acknowledgement

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