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Nano structural properties of stainless steel for Ultra high vacuum chambers

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Abstract: The morphologies and topographies of the two different type of stainless steel (304 L and 316 L) have been studied with using Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD) techniques. The main aim is the nano structural evolution of these samples. The obtained results show that the deformation behavior of the 316 L stainless steel depends to the treatment duration. We suggest 316 L stainless with higher Mo constant should be used for the future ultra high vacuum chamber (UHV) due to their less fracture surfaces.
Key Words: Nano structure, Ultra high vacuum, Stainless steel, SEM and XRD technique.

1. Introduction

In last decades, extensive research has been focused on the synthesis of low – dimensional nano structures [1-8]. In this view, the stainless steel samples are anisotropic nano crystals and their attractive properties make them the suitable material for the wide range of UHV applications.

The type of stainless steel being processed is the determining factor when selecting the most effective passivation process. In fact, the stainless steel structure and their fractural surfaces are all a function of the type of alloy being processed. However, many efforts have been made on the fabrication of UHV chambers with less leakage current and small atom penetration. It is so necessary for growing the ultra thin film without any impurity and dirty, because, as an example, the existence of 1 born atom in 100 000 silicon atoms can cause the electrical properties enhance to 1000 times respect to just pure silicon. It means that small dirty and impurity can strongly change the nano structural properties of ultra thin film down to 1-2 nm [9-21]. Therefore, the fabrication of a chamber which can stand so low pressure for growing ultra thin film is a key point for researchers in nano devices area. We thus consider two kind of stainless steel (304 L and 316 L) and study their surface morphology and topography with using SEM and XRD techniques. Our results indicate that 316L-stainless steel due to its less fractural structure can be used for the next UHV chamber generations.

2. Experimental procedure and details

The stainless steel samples (3cm×1cm) were polished from one side to ensure asmooth surface. We rinsed them with ethanol and put them in an ultrasonic bath for one hour. The cleaned samples may be oxidized with oxygen molecules in the media or make bonds with carbon atoms, we cleaned them one more by passing current through the samples several times. Otherwise, the existence of ultra thin or thin layer of oxide layer on the sample surface can change the quality of the film grown inside the UHVC.

For cleaning the sample and getting ultra high vacuum, we baked the chamber before the experiments in which after baking the background pressure can be down 10^{-12} Torr.

Earlier, measurements with a residual gas mass spectrometer in the line of the beam, has shown that a very low proportion (about 5 percent) of oxygen and carbon is produced with this setup. Typical pressures in the chamber during experiments into the vacuum chamber were around 5×10^{-7} Torr. Indeed, nanotechnology and modern society demand better and more sophisticated materials for engineering as well as nano opto-electronic applications.In these area the dominate research topics are color marking on stainless steel, corrosion resistance and annealing elements [5].

The secondary and backscattered electron images were measured with a 24 voltage and 20000 magnifications.

The material used in this work are 304 L and 316 L stainless steel plate of 20 mm thick, The chemical compositions which contain of 316 L and 304 L are (mass %)0.019 C and 0.019 C, 17.07 Cr and 17.07 Cr, 11.95 Ni and 11.95 Ni, 2.04 Mo and 1.04 Mo, 1.68 Mn and 1.68 Mn, 0.35 Si and 0.35 Si, and a tiny Cu, respectively. The structural evolution of samples is characterized by using Mazandaran university XRD (X-Ray Diffraction) technique with $Cu_{k\alpha}$ radiation ($\lambda = 1.5406 A^{\circ}$) scanning at a rate of $1^{\circ}\min^{-1}$ for 2θ ranging from 10° to 70° (see an example XRD pattern in Fig .1).

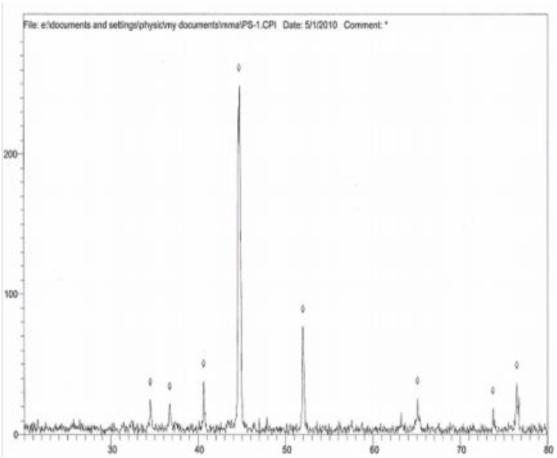

Fig 1.a.XRD pattern of sample 316 L -S.S with Mo constant

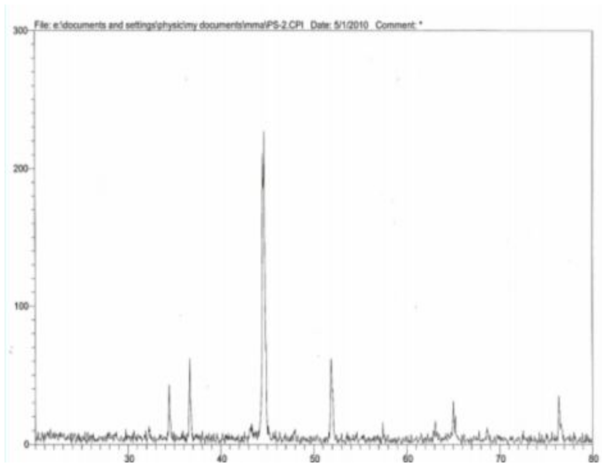

Fig 1.b.XRD pattern of sample 316 L -S.S without Mo constant

The average grain size can be deduced from Scherer equation [8]:

$$D = \frac{K\lambda}{\beta c \cos\theta} \qquad (1)$$

Where D is the crystallite size of Mo thin films, kα is a constant (0.94), λ is the wavelength of X-ray ($Cu_{k\alpha}$ = 1.5406 A°), β is the true half- peak width, and θ is the half diffraction angle of the centered of the peak in degree. The results are shown in figures 2 and 3 that as temperature increase, the Mo crystallites grows.

There are diffraction line broadening of six Bragg reflection peaks of Fcc- Fe (111),(200),(220),(311),(222) and (400) in terms of the Scherrer equation . Figures 3 and 4 (SEMs) show 304 . L (left) and 316 L (right) stainless steel images which are gotten with Tehran- Science and Research Islamic Azad University SEM technique

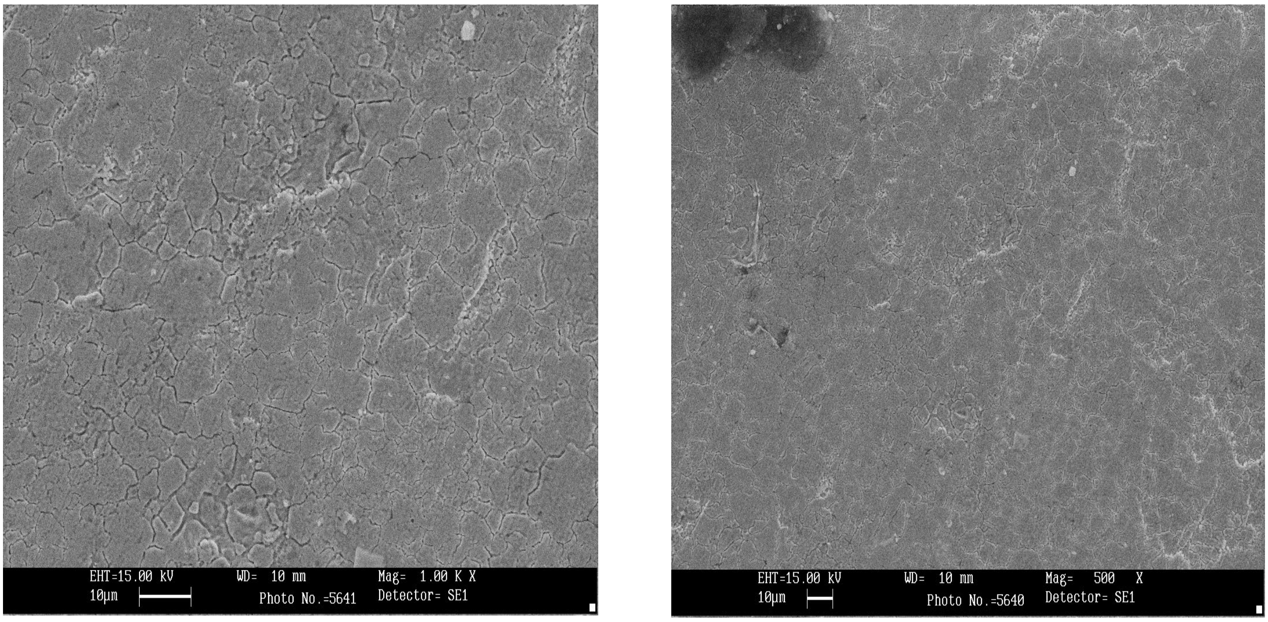

Fig 2. SEM images of 304 L

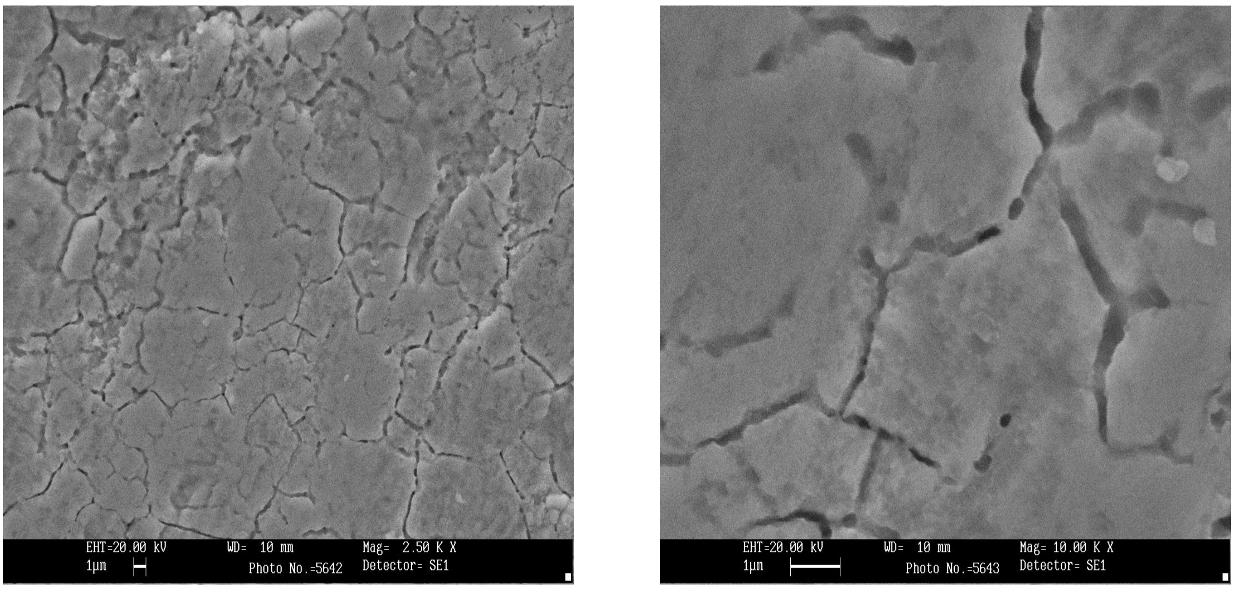

Fig 3. SEM images of 304 L after treatment

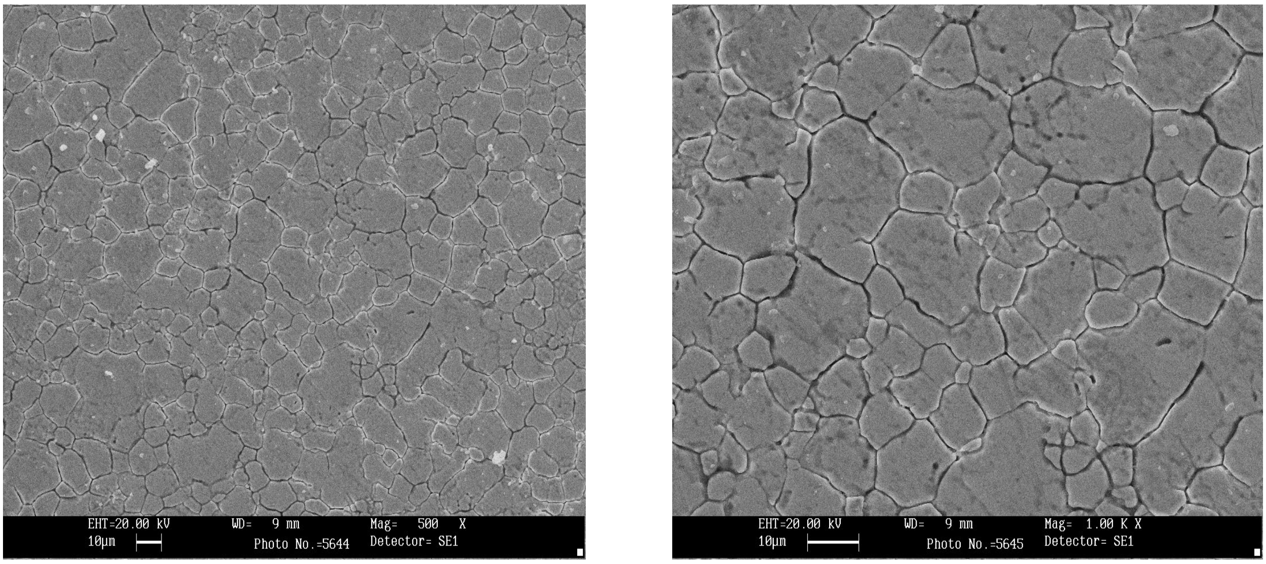

Fig 4. SEM images 316 L stainless steel

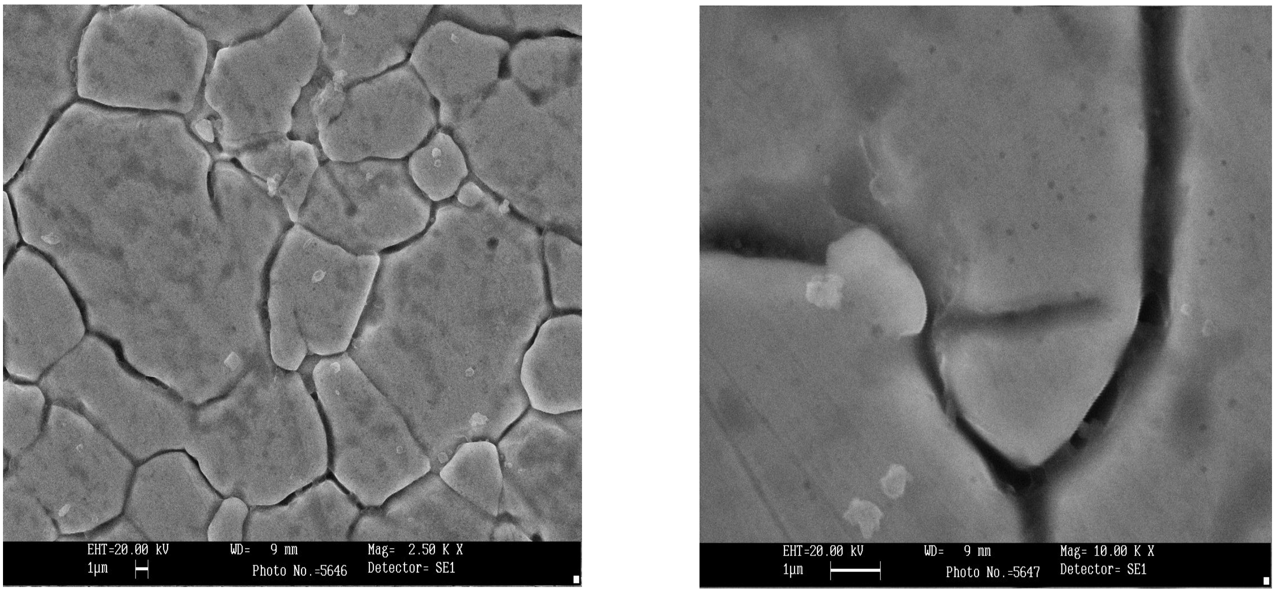

Fig 5. SEM images 316 L stainless steel after treatment

SEM images of 316 L- stainless steel samples show less cracks respect to 304 L- stainless steel sample, meaning the leakage current and small atom penetration through the 316 L- stainless steel are reduced due to more Mo content of 316 L - stainless steel and maybe the plastic deformation near to 316 L - stainless steel surface. It makes that 316L-stainless steel is more stable to local shear than that 304 L - stainless steel, which in turn cause transfer of pieces of deformed material which are further deformed and mixed with counter face material.

In as shown in Figs.2, 3 and 4, multidirectional mechanical loads onto 316 – stainless steel, just like what occurs in the transfer layer of wearing materials, large and rapid deformation may be induced by adding more Mo content, which results in rapidly grain refinement.

Conclusions

The morphology SEM images of stainless steel indicate that 316 L - stainless steel should be used for designing and fabricating of UHV chamber. By adding higher Mo content, a nano thickness film covers the stainless steel surface and prevents atom penetration and leakage current through the stainless steel samples.

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