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Effect of Spheroid Anneal 810°C and Double Annealing at 400°C to The Mechanical Properties and Microstructure of SUS 304 Thin Metal Foils for Sensor and Electronic Application

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Graphical abstract

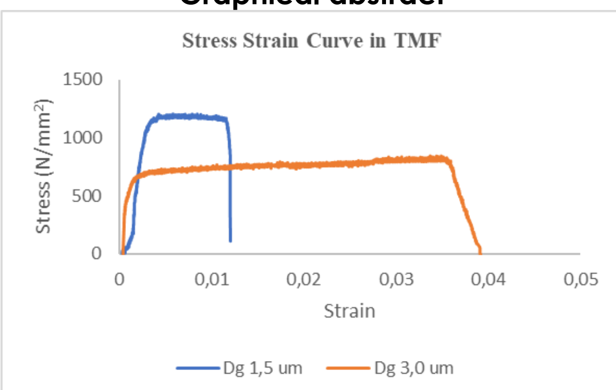

Figure 1. Graphical Abstract

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Abstract

The stainless steel thin metal foils have wide application, especially for electronic industries. The problem hindered are high cost for mass production, the effect of phase transformation to the mechanical properties still not clear. The change of microstructure in austenitic stainless steel (ASS) after double annealing at 400°C and spheroid anneal treatment at 810°C in thin metal foils (TMF) of SUS 304 were studied experimentally, including Scanning Electron Microscope – Electron Back scaterred Difraction (SEM – EBSD) and five stages of the uniaxial tensile stress state. The martensitic phase transformation (MPT) and grain misorientation (GMO) compared each other both in fine grains and coarse grains. The MPT occur in ASS SUS 304 TMF. The GMO occur in SUS 304 Thin Metal Foils. The GMO spread homogeneous in fine grains and spread inhomogeneous in coarse grain. The GMO volume fractions in fine grains spread homogeneously. The GMO volume fractions in coarse grain spread inhomogeneously.
Keywords: Martensitic phase transformation (MPT); Grain Misorientaion (GMO); SUS 304 Thin Metal Foils.

Abstrak

Baja tahan karat ultra tipis memiliki aplikasi yang luas, khususnya untuk industri elektronik. Problem yang muncul pada logam ultra tipis adalah efek transformasi fasa yang berpengaruh pada sifat mekanik dan biaya produksi massal yang masih mahal. Baja ultra tipis di anil dua tahap pada suhu 400°C dan diberi perlakuan spheroid anneal pada suhu 810°C selama satu jam, sampel kemudian ditarik sebanyak lima tahap dan struktur mikro diamati menggunakan Electron Back Scaterred Diffraction - Scanning Electron Microscope (SEM-EBSD). Transformasi fasa martensit (MPT) dan grain misorientation (GMO) dibandingkan baik di butiran halus maupun di butiran kasar. GMO tersebar homogen pada butiran halus dan tersebar tidak homogen pada butiran kasar. Transformasi fasa martensit (MPT) terjadi pada SUS 304 ultra tipis.
Kata kunci: Transformasi Fasa Martensit; Grain Misorientation; Logam Ultra Tipis SUS 304.

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1.0 INTRODUCTION

The wide application of stainless steel is a very wide in the electronic, biomedical, bio assay, opto electronic and food industries. ASS SUS 304 TMF has corrosion resistance, excellent in formability, high in strength and ductility (1,2). The demand of microparts is increasing unabated in this decades (2,3). The microforming technology still has challenge in high cost mass production, size effect and limitation of materials product (1,3,4,). When ASS SUS 304 TMF subjected by deformation in plastic condition such as uniaxial tensile test, the MPT or and GMO occured in ASS SUS 304 TMF. (1,3). The MPT occur from the movement of slip band intersection each other during deformation in plastic condition such as uniaxial tensile test stress state (1,6,7,8). Uniaxial tensile test in ASS affect on the work hardening occurence that enhance the strength and plastic instability of ASS (1,3,5). The chemical composistion, strain path, grain size (Dg), strain rate and strain level affect to the occurence of MPT and GMO in ASS. The MPT affect to the surface hardening in ASS SUS 304 TMF (9). The occurence of MPT may affect to the surface roughness behavior (1,9). Strain induced martensitic transformation in stainless steel occured after plastic deformation (1,7,9). The dependency between microstructure in locally area and deformation – induced surface roughness need to be explained (1,7,9,13). Study of the surface roughness in TMF with the Dg lower than 10μm is needed (1,7,5,9,13). The MPT has an effect to the behavior of surface roughness of ASS TMF (1,9,11,12,13). The microstructure change may occure in ASS TMF at high strain level, because the slip band movement increase at high strain level (1,6,8,13).

However, effect of heat treatment to the MPT and GMO behavior in ASS SUS 304 TMF still unclear yet. The aim of this study was to explain the effect of spheroid anneal and double annealing to the MPT and GMO area fraction. In this work and study, ASS SUS 304 TMF were subjected by uniaxial tensile test step by step until five cycles. The MPT and GMO studied, measured and analyzed using SEM-EBSD.

2.0 METHODOLOGY

The quantity of chromium element in ASS SUS 304 TMF is high as explained in table 1. The highly amount of chromium element in SUS 304 TMF make the materials easier to transform from austenite to become MPT after deformation in plastic condition such as uniaxial tensile test.

Table 1. Chemical composition of TMF of SUS 304

	C	Si	Mn	P	S	Ni	Cr
Min						8,00	18,00
Max	0,08	1,00	2,00	0,045	0,030	10,50	20,00
	0,05	0,39	1,10	0,030	0,004	8,03	18,01

The samples of SUS 304 TMF were cleaned using ethanol and ultrasonic vibrations simultanously. The duration of cleaning was 30 minutes. The SUS 304 TMF were subjected by uniaxial tensile test step by step until five stages. The calculation of surface roughness and the microstructure investiagted and analyzed. The uniaxial tensile test used Shimadzu Tensile Machine AG – IS 50 KN fabricated by Shimadzu Corporation. The capacity of tensile machine was 50 KN. The surface roughness investigated using Keyence Confocal Laser Microscope (VE 8800, Keyence Co). The behavior of surface roughness and the microstructure change investigated in point A,B,C and D as shown in figure 1 (1).

The change of microstructure in ASS SUS 304 TMF investigated after uniaxial tensile test with the strain rate 1.6 x 10^{-3} mm/s. The change of microstructure investigated in different grain size (Dg) such as fine grains and coarse grains. DVE - 201 video non-contact extensiometer used to observe the elongation during uniaxial tensile test. The surface roughness behavior measured step by step after uniaxial tensile test. The change of microstructure and surface roughness behavior measured at the same place. The change of microstructure measured before and after five steps of the tensile test. The surface roughness measured every steps until five steps during uniaxial tensile test.

3.0 RESULTS AND DISCUSSION

The stress strain show that the strength of the fine grains was higher than the coarse grain, the ductility of the coarse grain was higher than the fine grains (1,2) as shown in figure 1.

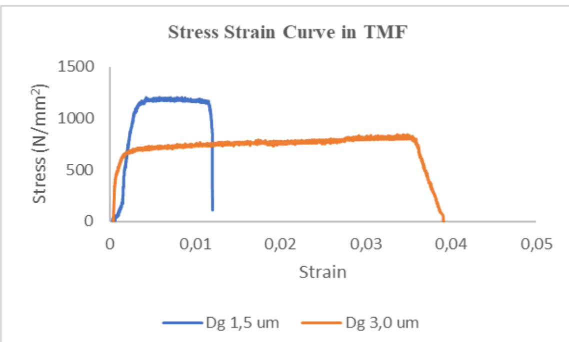

Figure 2. The Uniaxial Tensile Test Result

3.2. Experimental result of microstructure in various strain level

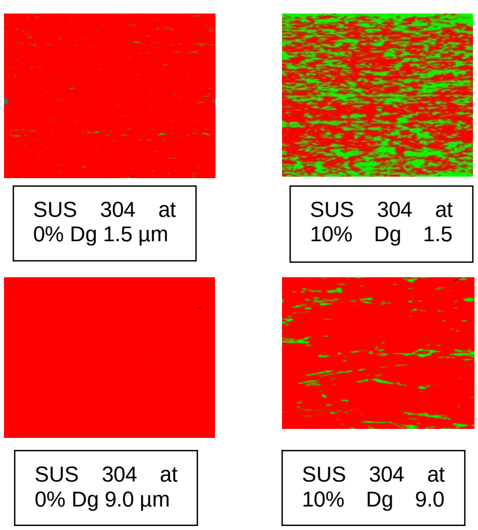

Figure 3. Specimen ASS SUS 304 TMF of Phase Transformation

- FCC meta stable austenite
- Martensite phase transformation (MPT)

According to the figure 2 , the red color is austenite and the green one is martensitic phase transformation (MPT). The phase transformation occur homogeneously in fine grains. The MPT not occur in room temperature of ASS SUS 304 TMF fine grains in room temperature as shown in figure 2a. The MPT spread homogeneously in fine grains as shown in figure 2b. The MPT not occur in room temperature in coarse grain at room temperature as shown in figure 2c. The MPT occur inhomogeneously in coarse grain at room temperature as shown in figure 2d.

The MPT have mechanical properties such hard and strong in the grains (1). The existence of MPT become the key of the mechanical properties of the grains. When the MPT spread inhomogeneous, the grain become inhomogeneous (1,3,5). When the MPT spread homogeneous, the grain become homogeneous (1,3,7). The surface roughening increase lower with the increasing strain level in fine grains compared to the coarse grains (1,3,5). The surface roughening increase higher in the coarse grain compared to the fine grain with the same strain level (1,3,6). The MPT enhance in surface roughening in ASS SUS 304 TMF (1,3,6,7,8). The MPT increase very high and homogeneous in fine grains and in the room temperature. The MPT increase high and inhomogeneous in coarse grain in the room temperature.

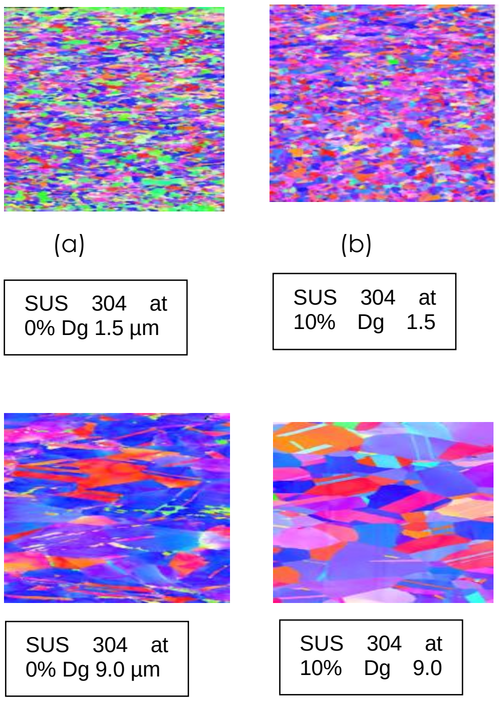

Figure 4. Specimen ASS SUS 304 TMF of Grain Deformation

The initial grain for fine grains are shown in figure 3a. The grain deformation in fine grains are lower than coarse grain a shown in figure 3b. The initial coarse grains are shown in figure 3c. The grain deformation in coarse grains are higher than fine grains as shown in figure 3d. The hardness behavior are explained in the next session.

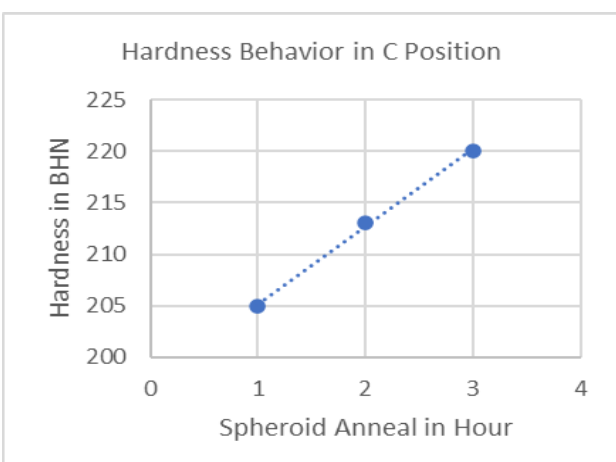

Figure 5a. Hardness in C Position

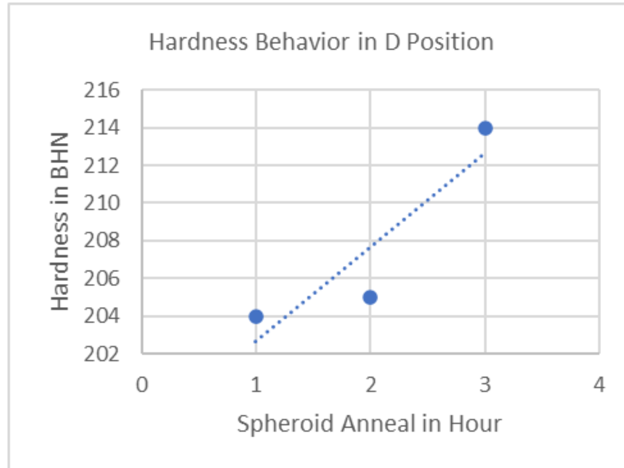

Figure 5b. Hardness in D Position

As shown in figure 4a and figure 4b, the hardness increase with the increasing Spheroid Anneal (SA) time and double annealing. The grain become more spheroid because of increasing SA time and double annealing. When the grain become more spheroid, the hardness increase as shown in figure 4a and 4b. The increasing hardness of thin metal foils (TMF) may have depencency with the surface roughening behavior and formability of TMF.

4.0 CONCLUSION

1. MPT occur in ASS SUS 304 TMF in room temperature both in fine and coarse grains.
2. MPT occur in ASS SUS 304 TMF both in fine and coarse grains.
3. MPT decrease in coarse grains of ASS SUS 304 TMF compared to fine grain with the same strain level.
4. The grain deformation in the coarse grain are more severe than fine grains at the same strain level.
5. The MPT spread homogeneous in fine grains and spread nonhomogeneous in coarse grains in room temperature

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