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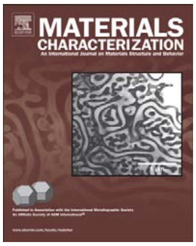

# Effect of martensite to austenite reversion on the formation of nano/submicron grained AISI 301 stainless steel

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ABSTRACT

The martensite to austenite reversion behavior of 90% cold rolled AISI 301 stainless steel was investigated in order to refine the grain size. Cold rolled specimens were annealed at 600–900 °C, and subsequently characterized by scanning electron microscopy, X-ray diffraction, Feritscope, and hardness measurements. The effects of annealing parameters on the formation of fully-austenitic nano/submicron grained structure and the mechanisms involved were studied. It was found that annealing at 800 °C for 10 s exhibited the smallest average austenite grain size of 240±60 nm with an almost fully-austenitic structure.

## 1. Introduction

Austenitic stainless steels are widely used as structural materials for applications requiring excellent resistance to general corrosion in combination with good mechanical properties. These alloys show the best corrosion resistance and ductility among the stainless steels. However, they possess a relatively low strength, particularly yield strength, which limits their structural applications.

Grain refining of austenitic stainless steels is an effective method to increase their strength, while keeping their toughness high. Recently, an advanced thermomechanical process has been developed to produce nano/submicron grain structures in metastable austenitic steels [1–3]. This process includes heavy cold rolling to form strain-induced martensite from austenite, followed by reversion of this martensite to austenite at relatively low annealing temperatures and times. It is established that austenite grains reverted from the deformed strain-induced martensite are very fine, while austenite grains reversed from deformed austenite are relatively coarse [1].

Very few studies have been conducted on the grain refinement of commercial austenitic stainless steels [4,5]. Some researchers [2,4] have reported that martensite can be transformed to austenite with different shear and diffusional mechanisms depending on its chemical composition and temperature range. Johannsen et al. [4] reported that the volume fraction of martensite after annealing was increased with increasing annealing temperature above 750 °C. They showed that at these temperatures, martensite was formed during cooling from annealing temperatures.

The aim of this work was to investigate the martensite to austenite reversion behavior on the formation of nano/submicron grained AISI 301 stainless steel. The reversion of martensite and the precipitation taking place during annealing treatment were also studied.

## 2. Materials and Experimental Procedures

The chemical composition of the AISI 301 stainless steel used in this investigation is given in Table 1. The hot rolled steel strips with an initial thickness of 8 mm were cold rolled to sheets of 0.8 mm thickness. The reduction of each pass was around 0.1 mm. Before each pass, the specimens were cooled

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Table 1 – Chemical composition of AISI 301 used (wt.%).

| C | Mn | Ni | Cr | Mo | Si | Cu | Al | Co | P | S | Nb | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.11 | 0.66 | 6.91 | 16.2 | 0.27 | 0.67 | 0.53 | 0.06 | 0.1 | 0.03 | <0.03 | 0.003 | 0.005 |

in a solution of ethanol and ice brine (about −10 °C). The reversion of martensite to austenite for the 90% cold rolled specimens was performed by isothermal annealing at temperatures between 600 and 900 °C for different times from 1 to 100 min in the furnace. For short time annealing, (10–60 s) a salt solution consisting of 50% $Na_2CO_3$ + 50% NaCl was used.

The microstructures of the specimens were revealed by optical and scanning electron microscopy (SEM Philips X230). The software Clemex was used for grain size measurements based on the intercept method [6]. Almost 100 grains were selected by the software to determine the grain size and the 95% confidence band of the results was reported. The amount of strain-induced martensite was measured by means of X-ray diffraction (XRD, Philips X' Pert with Cu Kα anode) and Feritscope (Fischer, MP30E).

## 3. Results and Discussion

Fig. 1 shows the XRD patterns of the specimens with 90% cold rolling and annealing at 900 °C for times from 1 to 100 min. The XRD pattern of the 90% cold rolled specimen shows only martensite reflections with a preferred orientation along the $(200)_{\alpha'}$ plane. After 1 min annealing at 900 °C, almost all the martensite was reverted to austenite; the intensities of $(110)_{\alpha'}$, $(200)_{\alpha'}$, and $(211)_{\alpha'}$ martensite reflections compared with the cold rolled specimen drastically decreased, and $(111)_{\gamma}$, $(200)_{\gamma}$, $(220)_{\gamma}$, and $(311)_{\gamma}$ austenite reflections appeared. With increasing annealing times, the patterns showed a significant increase in the intensity of martensite reflections with a preferred orientation along $(211)_{\alpha'}$.

Fig. 2 presents variations in martensite volume fraction measured using a Feritscope versus annealing times at different temperatures. During annealing at 600, 650, 700, and 750 °C for times between 1 and 100 min (Fig. 2a), no significant martensite reversion was observed. Fig. 2b shows annealing behavior at 800 to 1000 °C for a time range similar to that of Fig. 2a. Reversion rate at these temperatures was so high that most of the martensite was reverted to austenite after around 1 min. However, at these temperatures, the amount of martensite after cooling increased with increasing annealing time up to 10 min beyond which it remained approximately constant. According to Fig. 2b, the amount of transformed martensite is lower at temperatures of 950 and 1000 °C.

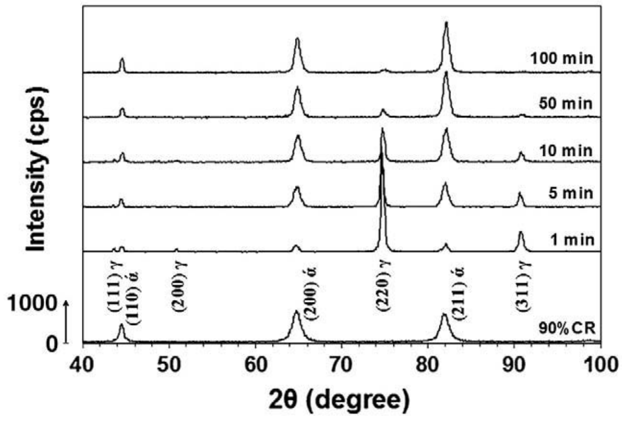

Fig. 1 – The XRD patterns for 90% cold rolled and annealed specimens at 900 °C for different annealing times.

Increasing amounts of martensite during annealing is an unexpected phenomenon that has also been reported in previous studies [1,4,7–9]. As reported in some of these works [6–8], this increase took place at lower temperatures (about 300–400 °C). One possible mechanism proposed to account for this is the recovery and relaxation of the matrix adjacent to the martensite laths that lead to martensite

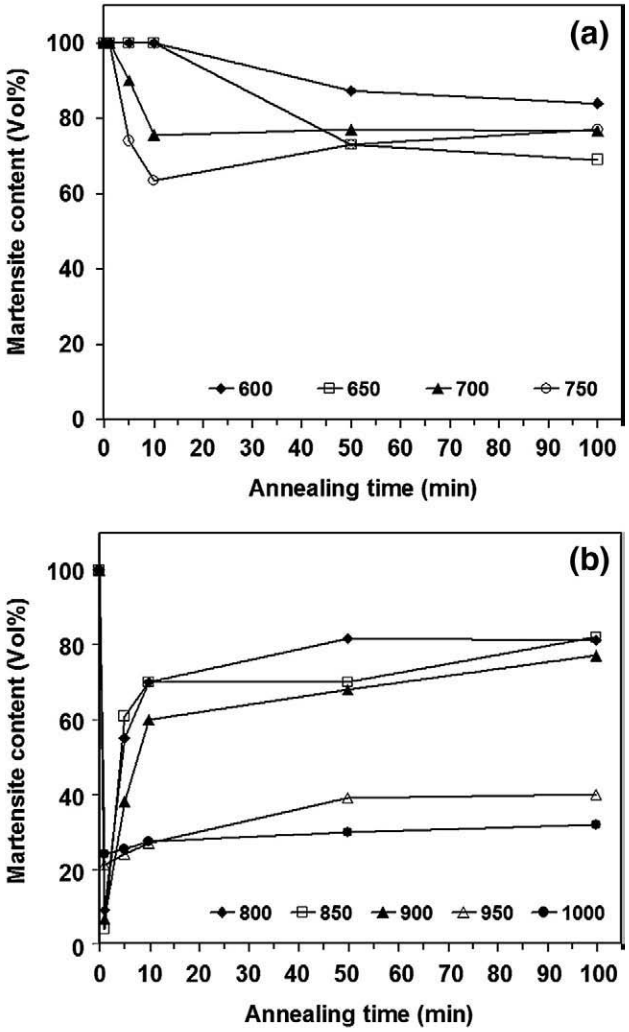

Fig. 2 – Martensite content in the specimens annealed at a) 600, 650, 700, and 750 °C; and b) 800, 850, 900, 950, and 1000 °C as measured by Feritscope.