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Texture and Evolution of Recrystallization in Low Carbon Steel Wire

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Abstract. The effect of cold wire drawing on texture of industrial low carbon steel wire was investigated. On the other hand, the mechanism of recrystallization of drawn-wire was studied during different isothermal annealing below 723 °C. The structural evolution of wire was studied by optical microscopy, SEM, EBSD and X-Ray diffraction. From this study, a fiber texture was observed in deformed wire. However, a recrystallization reaction occurs after critical temperature during annealing.

Introduction

The low carbon steels have very extensive applications in the industrial fields. For example a production of an industrial low carbon steel wire by cold wire drawing has a large application. This process is one of the oldest metal forming processes. The structure of drawn-wire after a series of section reduction, is characterized by a regular orientation of the grains « texture ». Numerous studies [1,2,3,4,5] show two kinds of texture in the wire : the first one called standard, the other one called cylindrical fiber texture. These two kinds of texture are observed in FCC or BCC materials as copper, aluminum or steel, whatever the diameter (10mm to 0.1mm) of the drawing wire process. However, the state of hard-drawn wire is unstable from a thermodynamic point of view. Heating of this type of material brings about a process of regeneration and recrystallization that restores all the properties featured by the metal before deformation. It is found that during the annealing, the cold rolled structure of a low carbon steel undergoes recovery and recrystallization processes. Recovery involves the annihilation of point defects and dislocations, the arrangement of dislocation into lower energy configuration and the formation and grain growth of subgrains [6]. Different kinetics control the recovery and the recrystallization and therefore the degree of overlapping will depend on the annealing temperature and on the material. The problem of texture formation during recrystallization has been studied for a long time. Firstly recovery takes place and this is then followed by nucleation and growth of strain free grains. This leads to the final texture of the material being derived from both nucleation and subsequent growth [7].
The purpose of the present work is to investigate the recrystallization texture of industrial low carbon steel wire. This work is the complement of the last study of the same material [8].

Experimental procedures

The material used in this study is a commercial low carbon steel wire containing approximately 0.05 wt. % of carbon (initial section S_o = 6.00mm). . Different techniques have been used for this investigation : Optical Microscopy (OM), Scanning Electron Microscopy (SEM) observations were performed on longitudinal and transverse cross-sections after etching with nital . Specimens were prepared for Electron Back Scatter Diffraction (EBSD) analysis in the standard manner. A

Zeis 940 SEM with a tungsten filament is used. The SEM device is coupled with the automatic OIM^{TM}(Orientation Imaging Microscopy) software from the TSL Company. X-ray diffraction (XRD) was used to examine the change in preferred grain orientation by using C_o K_α radiation. The rate of wire drawing is : $\varepsilon = (S_o - S) / S_o$
with S is final section. For this work, a large number of drawn-wires specimens were chosen (from 27 to 85 % of section reduction). For the study temperature effect on structural evolution in drawn-wires, our materials have been annealed at different isothermal temperatures (200, 300, 400, 500 and 600 ° C).

Results and discussion

In the first part of this paper, the microstructures of drawn- wires are presented, but in the second part we were analyzed the recrystallization reaction observed in heated drawn-wires.
Microstructure of drawn-wires:
Optical observations performed on longitudinal and transverse cross-sections of drawn-wires are illustrated in figure 1. The regular orientation of the grains (texture) caused by cold drawing process is clearly observed in longitudinal sections, but, grain refinement is developed in transverse cross-sections.

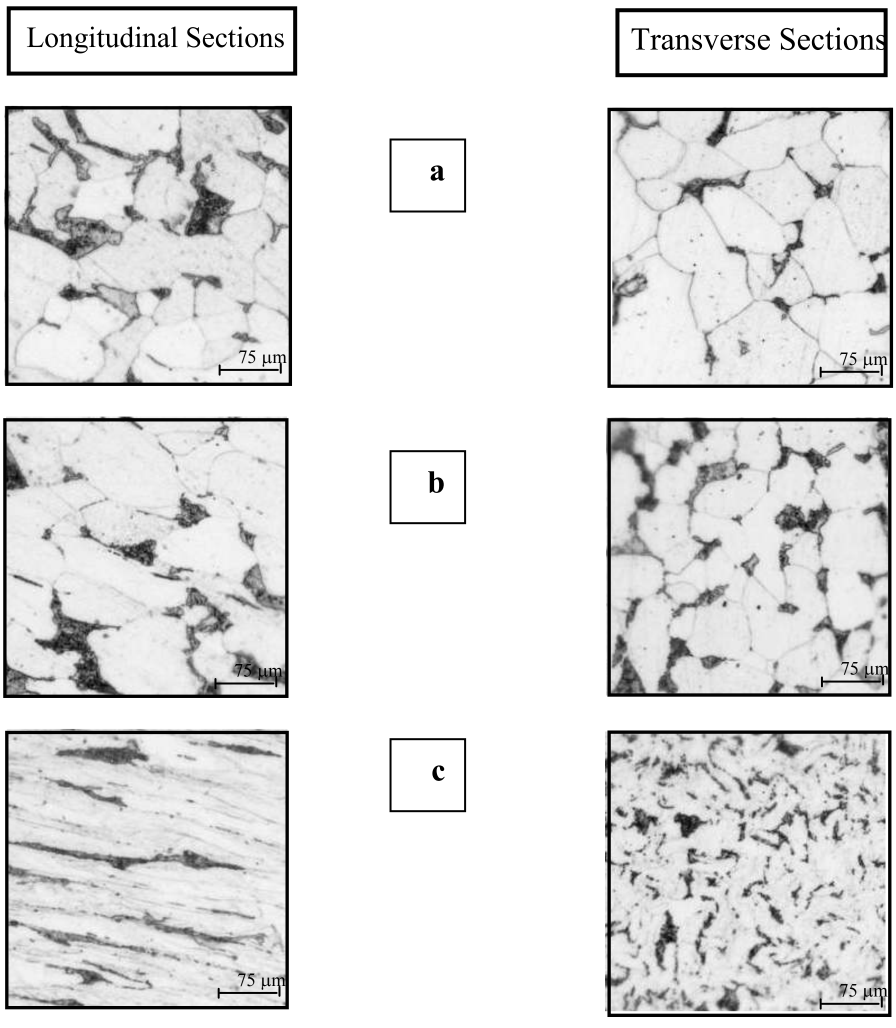

Figure 1. Optical images in the longitudinal and transverse sections of low carbon steel wire after cold wire drawing : a) ε = 27,75 % , b) ε = 43,75 % and c) ε = 80,50 % .

On the other hand, SEM observation (Fig.2) shows elongation of colony of pearlite along the axis direction of drawing. XRD results obtained from drawn-wire show the <110> fiber texture in the ferrite phase (Fig.3).

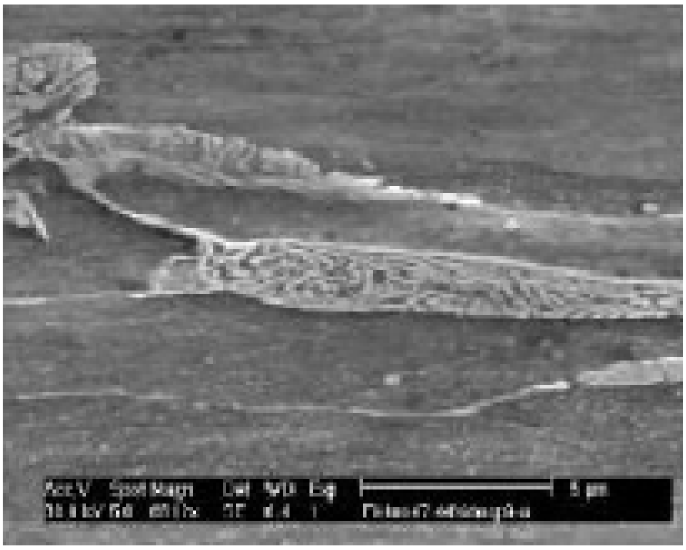

Figure 2. SEM observation in the longitudinal section of low carbon steel wire after reduction (ε = 43,75 %) by cold wire drawing.

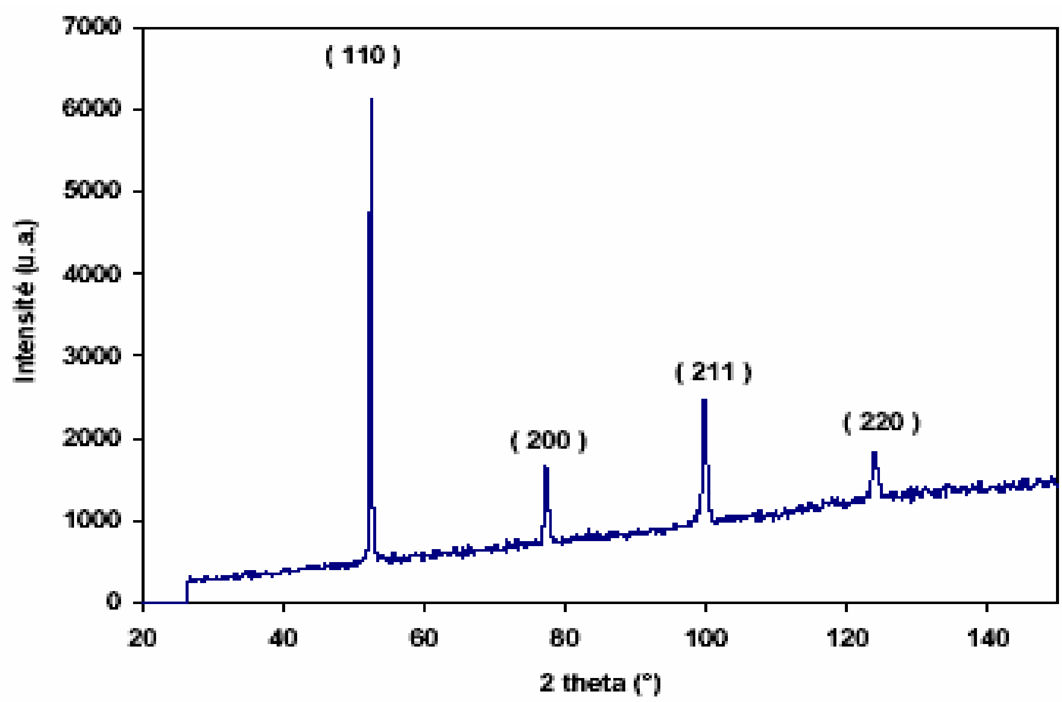

Figure 3. XRD spectrum of low carbon steel wire after reduction (ε = 43,75 %) by cold wire drawing.

Microstructure and textures evolution during isothermal annealing:
Firstly, we have observed a recrystallization reaction on all drawn-wires, only at temperatures (600 and 500°C). Consequently, we can say that a critical temperature of this alloy is about 450°C. Figure 4 and 5 illustrate the evolution of the microstructure, Inverse Pole Figure (IPF) calculated with the harmonic method and grain size of the wire for two annealing temperatures. It is clear that texture (Fig.4b and 5b) is mainly by <101> fiber. We note, that elongated grains are almost replaced by the newly formed equiaxed grains (Fig.4a and 5a). We notice that the variation of the grain size is also evaluated near the surface and in the core of a wire (Fig.4c and 5c).

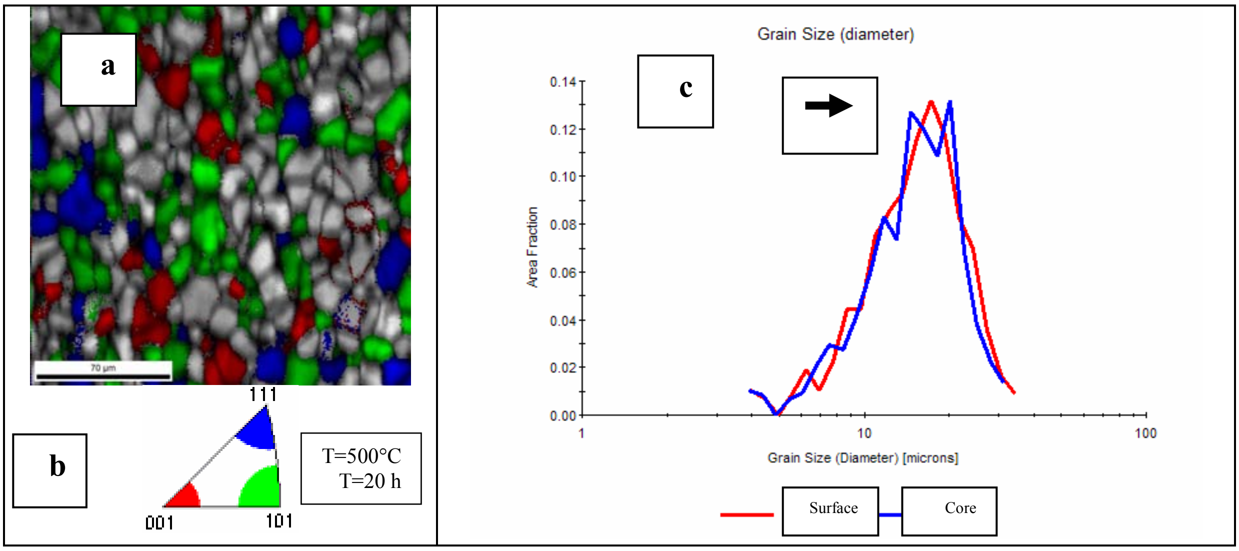

Figure 4. Low carbon steel after reduction (ε = 43,75 %) by cold wire drawing and followed by annealing at 500°C for 20 hours: a) Microstructure , b) IPF calculated from EBSD measurements and c) evolution of grain size in the core and near the surface of a wire.

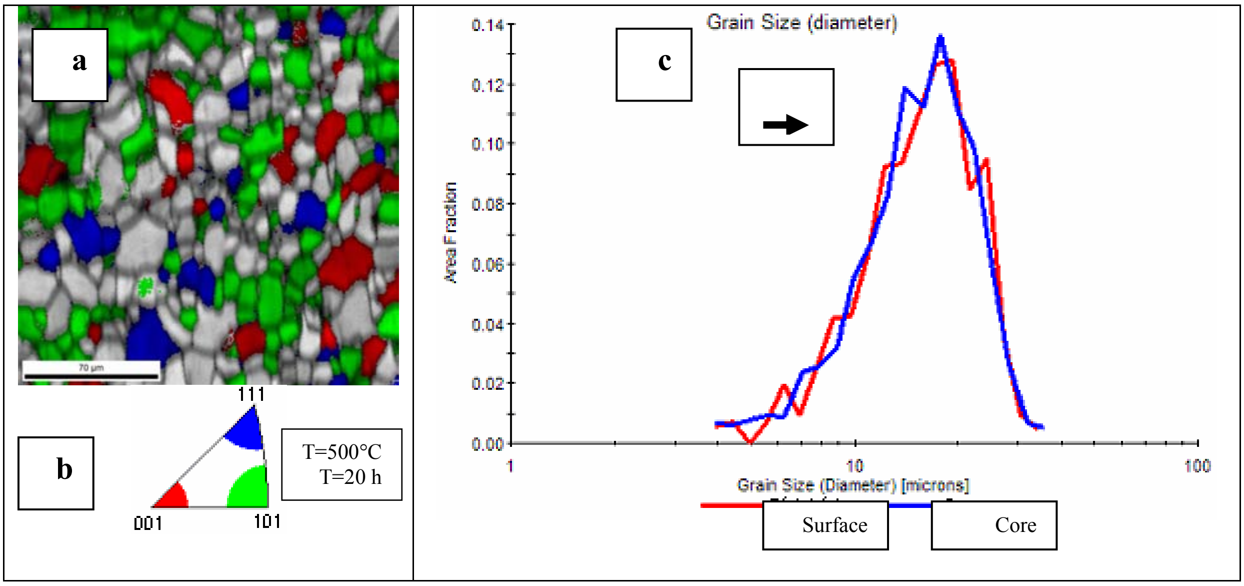

Figure 5. Low carbon steel after reduction (ε = 43,75 %) by cold wire drawing and followed by annealing at 600°C for 20 hours: a) Microstructure , b) IPF calculated from EBSD measurements and c) evolution of grain size in the core and near the surface of a wire.

The grain size is the same for a wire but it differs from drawn-wire to another, (Fig.6) this depends on the rate of section reduction in the word, the finer grains are obtained for the higher reduced wires. This is attributed to the increased amount of nucleation sites when the deformation is increased, due to the higher amount of deformation. The histogram of figure 7 confirms the <110> texture orientation for different rate of reduction either near the surface or in the core of a wire.

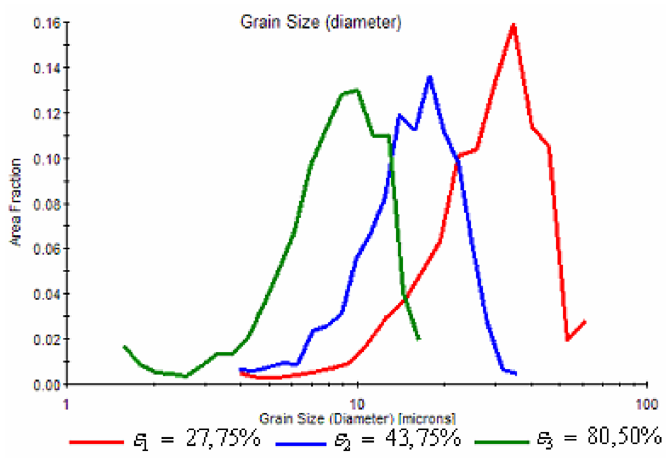

Figure 6.Variation of grain size of low carbon steel after annealing at 600°C of reduced drawn wire.

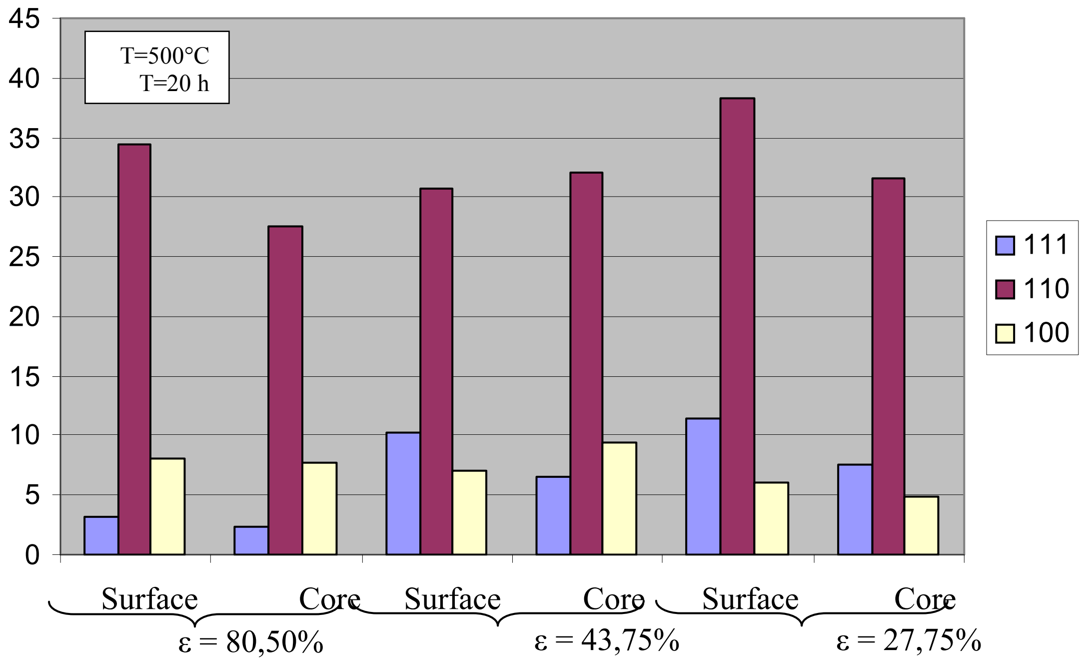

Figure 7.Histogram of grains orientation after annealed at 600°C for 20 hours of low carbon steel drawn -wires

Conclusion

Our investigation represents a contribution to the study of mechanism of recrystallization during different isothermal annealing in the industrial low carbon steel drawn-wires. We have found that a recrystallization reaction develops above the critical temperatures (400°C) and it's characterized by <110> fiber texture.

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