Towards an understanding of microstructural evolution during post deformation annealing of asymmetrically deformed nanostructured low carbon steel

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Abstract

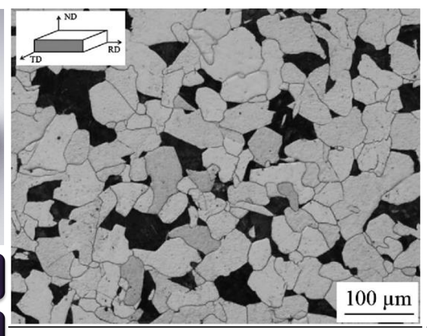
This study investigated the static annealing behavior of nanostructured low-carbon steel fabricated by differential speed rolling (DSR) process. For this purpose, the samples processed by 4-pass DSR at roll speed ratio of 1:4 for the lower and upper rolls, respectively. It was annealed at temperatures ranging from 425 ℃ to 625 ℃ for 1 hour. The deformed samples exhibited a complex microstructure in the ferrite phase consisting of an equiaxed structure with a mean grain size of ~0.4 μm and a lamellar structure with a mean lamellar width of ~0.35 μm. The texture evolved after DSR deformation consisted of components with orientations belonging to the rolling texture and shear texture. After static annealing at temperatures lower than 525 ℃, the aspect ratio of the deformed grains tended to shift toward a unit corresponding to the equiaxed shape, whereas the grains tend to be stable during annealing. In addition, grains with low dislocation densities began to appear due to static recrystallization in the severely deformed ferrite grains at temperatures above 525 ℃, which also help to produce equiaxed grains with ultrafine sizes. The strong fiber texture consisting of α- and γ-components, which formed after deformation by DSR, tended to become weaker and more uniform with increasing annealing temperature.

Introduction

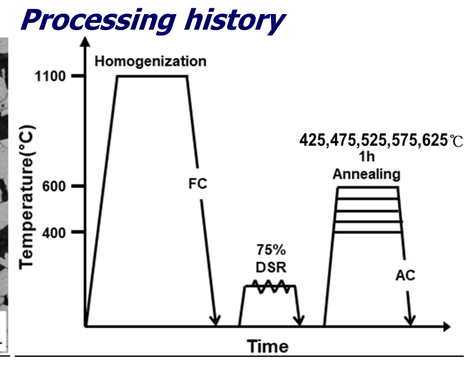
Low-carbon steels

- Good combination of strength & ductility
- Good formability
- Good weldability
- Relatively cheaper than other steels
- Good effect of heat treatment

Experimental



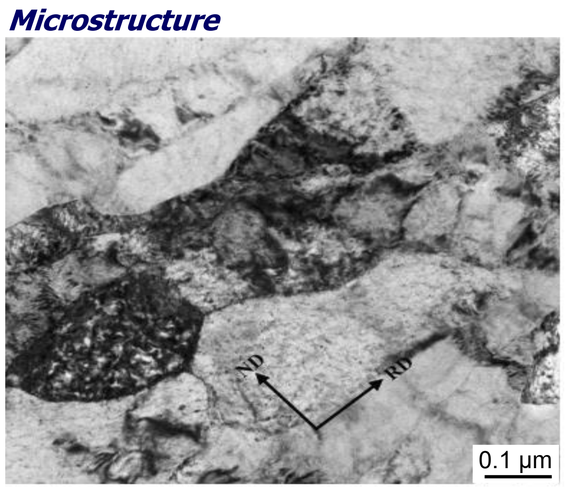
Processing history

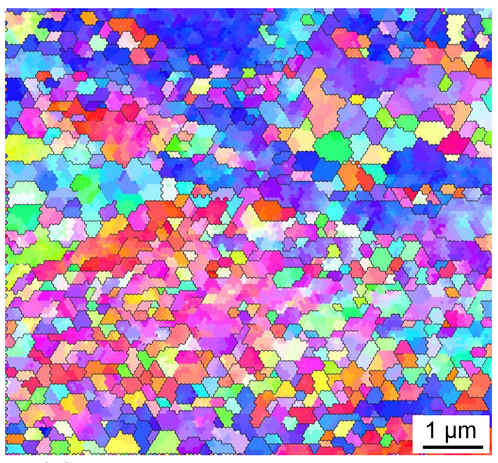


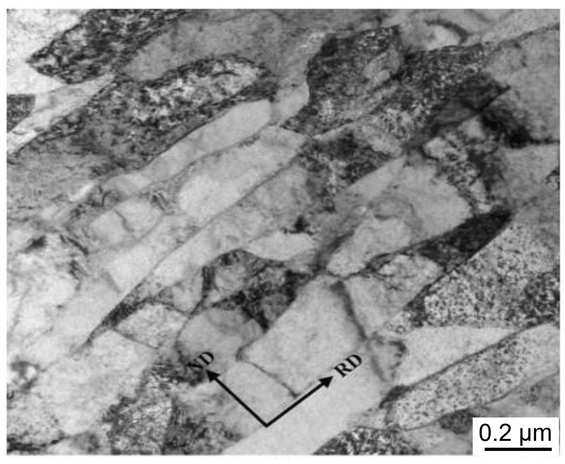
Materials	Low-carbon steels	**DSR**	D_{roll}: 220mm, Roll speed: 5rpm(bottom), 20rpm(top) Reduction: 30%(total: ~75%), 4-pass, Temperature: RT
Composition	0.18C-0.012Si-0.5Mn-Fe (wt.%)		
Phase	α-ferrite, pearlite(~20vol%)	**Annealing**	425,475,525,575,625(℃) for 1hour & Air Cooling
Grain size	~100 μm		

Result : deformed sample

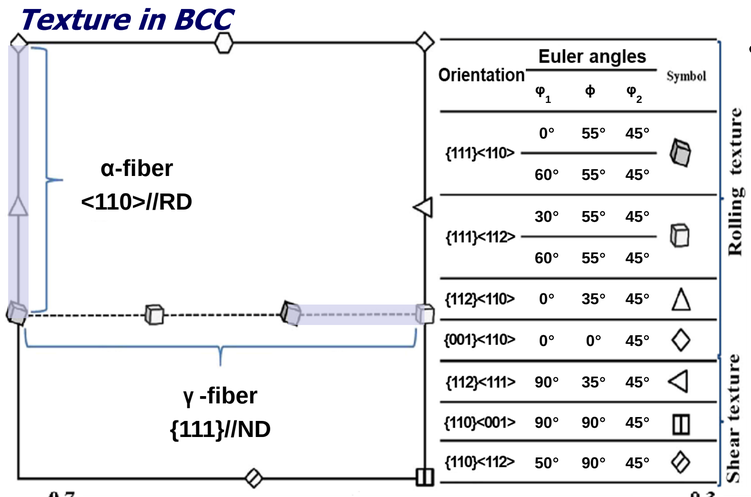
Microstructure



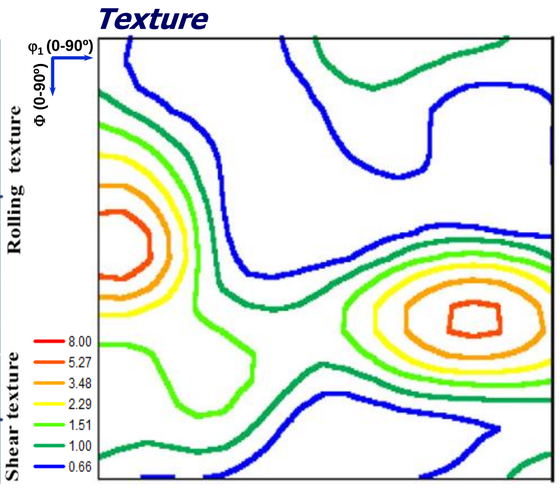


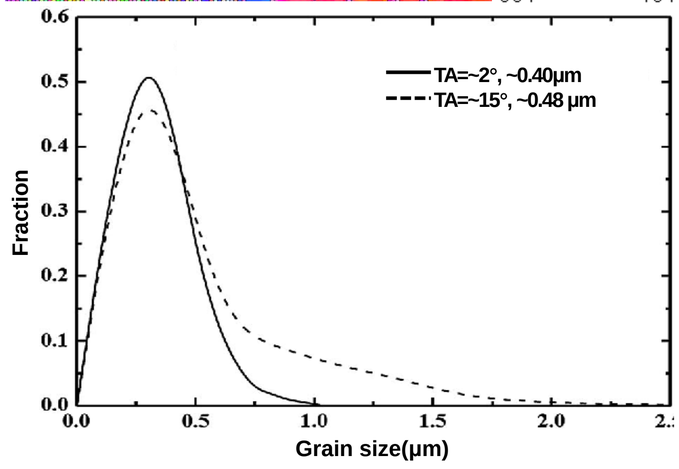


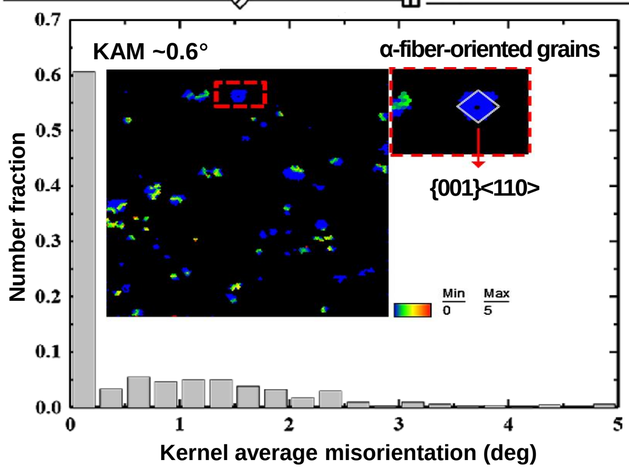
Texture in BCC

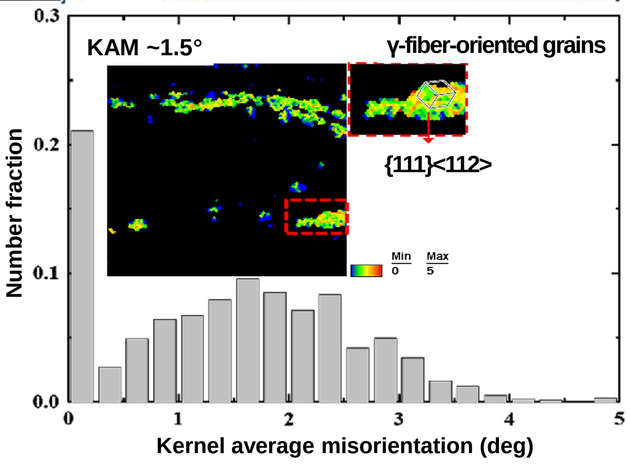


Texture



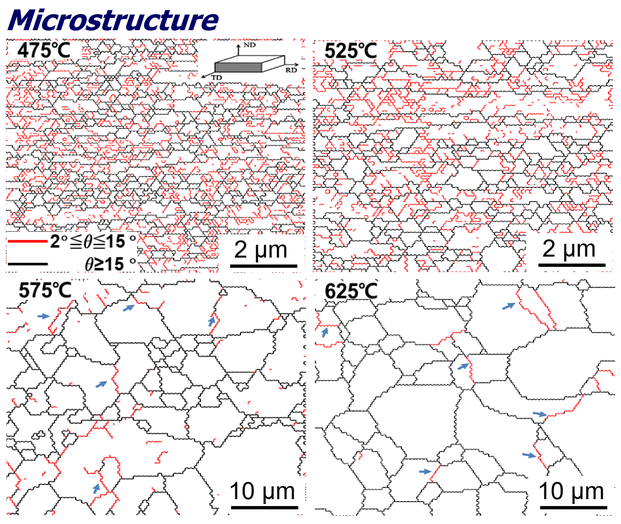


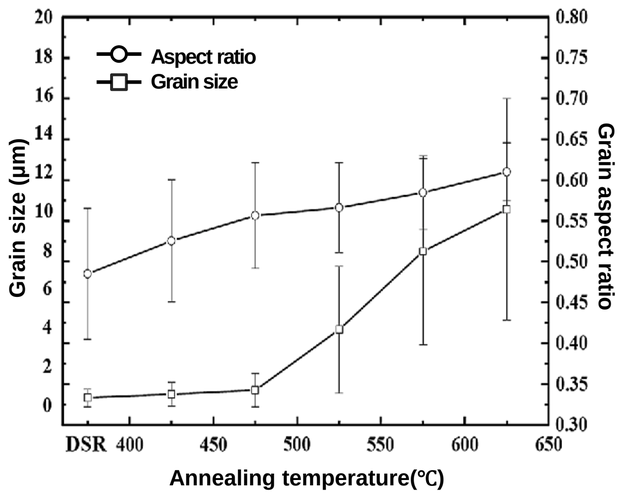




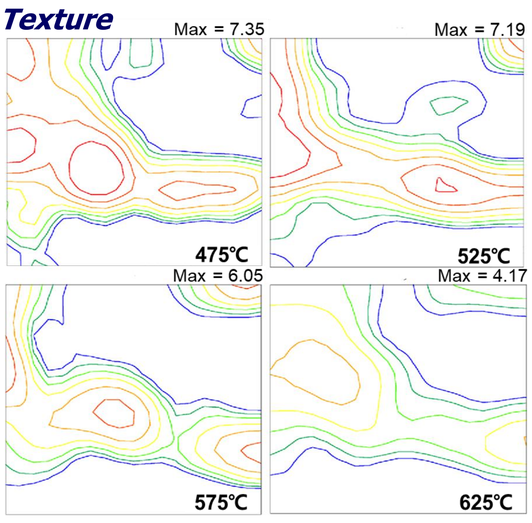
Result : Annealed sample

Microstructure

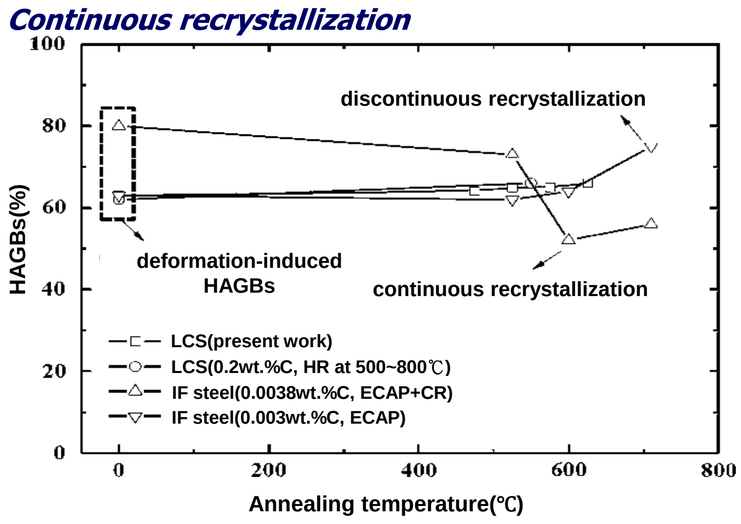




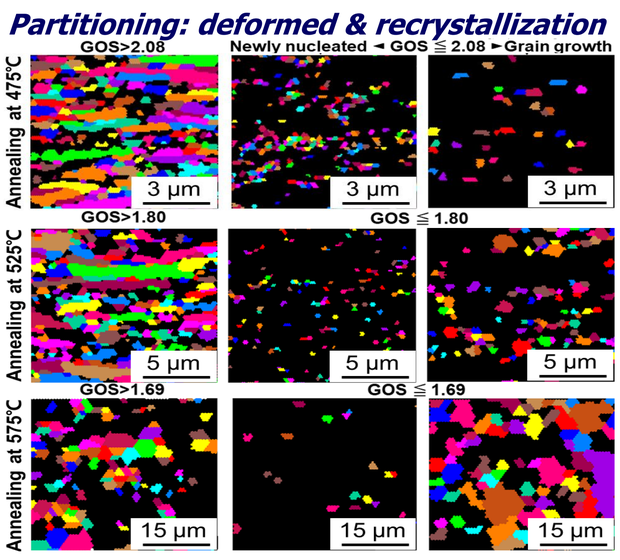
Texture



Continuous recrystallization



Partitioning: deformed & recrystallization



Hardness

Orientation intensity

Summary

The annealing behavior of nanostructured 0.18 wt.% carbon steel samples fabricated by a differential speed rolling (DSR) process was investigated at temperatures between 425 ℃ and 625 ℃ for 1 hour. Deformation by the DSR process at room temperature resulted in a complex microstructure in the ferrite phase consisting of an equiaxed structure with a mean grain size of ~0.4 μm and a lamellar structure with a mean lamellar width of ~0.35 μm. The textures evolved in the LCS sample after 4-pass DSR deformation consisted of components with orientations belonging to the rolling texture and shear texture. During heat treatment at 475 ℃ for 1 hour, an ultrafine-grained microstructure with a ferrite grain size of ~0.8 μm was obtained. The grain boundary misorientation of the ultrafine ferrite grains were evaluated quantitatively, and ~67% of the boundaries were found to be high-angled boundaries of which was similar to deformed and annealed at higher temperatures. The strong fiber textures consisting of a-fibers and γ-fibers, which were formed after deformation by DSR, tended to become more uniform. Also, the grain size and aspect ratio tend to become bigger and close to 1 gradually. These tendencies became more pronounced with increasing annealing temperature. The LCS sample fabricated by DSR showed high thermal stability up to 475℃. Continuous recrystallization during annealing of the DSR-deformed LCS samples coupled with no significant appreciable change in texture and fraction of HAGBs.