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Characterization of directionally recrystallized cold-rolled nickel using EBSP

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Scanning electron microscopy (SEM) and electron back-scattered diffraction patterns (EBSP) have been employed to investigate the changes in the microstructure and texture of 90 % cold-rolled nickel when subjected to directional recrystallization. The effects of annealing temperature, hot zone velocity, and temperature gradient ahead of the hot zone on the microstructure were investigated.

Specimens roughly 10 mm x 10 mm x100 mm in size were produced from polycrystalline nickel and cold rolled to 90% thickness reduction. Directional recrystallization experiments were carried out in air using a home-built furnace. The specimens were held stationary and the furnace and associated cooling plates were translated together by a stepper motor. The translation velocities can be varied between 2 mm/h and 600 mm/h. The temperature gradient ahead of the hot zone is controlled by changing the used distance between the cooling plates and the top of the furnace. The temperature gradient was ~270^{o}C/cm. Experiments were conducted with two hot zone temperatures (370^{o}C and 470^{o}C, respectively) and three hot zone velocities (4.5 mm/h, 40 mm/h and 50 mm/h). Microstructural changes in the specimens were investigated using a Zeiss DSM962 scanning electron microscope equipped with an EBSP system operated at 30 KeV. Prior to examination in the SEM the specimen surfaces were mechanically polished and electropolished in a solution containing 14% sulfuric acid, 71% phosphoric acid and 0.75% hydrochloric acid in water at +45^{o}C. Backscattered electron images were also acquired.

SEM/EBSP examinations of nickel in “as received” condition showed that prior to rolling a largely random texture was present. Upon cold rolling however, the nickel developed the texture shown in Figure 1. An orientation map of a cold-rolled nickel specimen subjected to directional recrystallization is shown in Figure 2. The green shades indicate grains within which the <001> crystallographic direction lies parallel to the rolling direction. They make up approximately 70 % of the total area investigated. Grains marked in red exhibited large deviations of the <001> direction from the rolling direction. The alignment of the <100> axes with the rolling direction after directional recrystallization is visible in the contoured pole figure in Figure 3. The cube-texture is typical and was observed for all *annealing temperature – hot zone velocity* combinations investigated. After directional recrystallization, the specimens exhibited in general smaller average grain sizes (between 12 μm and 18 μm) compared to “as-received” condition which had an average grain size of ~21 μm. The only exception was the extreme case of T=470^{o}C and V=4.5 mm/h where the average grain size remained practically unchanged (~22 μm) after directional recrystallization.

In conclusion, directional recrystallization of cold-rolled nickel leads to the formation of a strong cube-texture with the <100> axes aligned parallel to the rolling direction.

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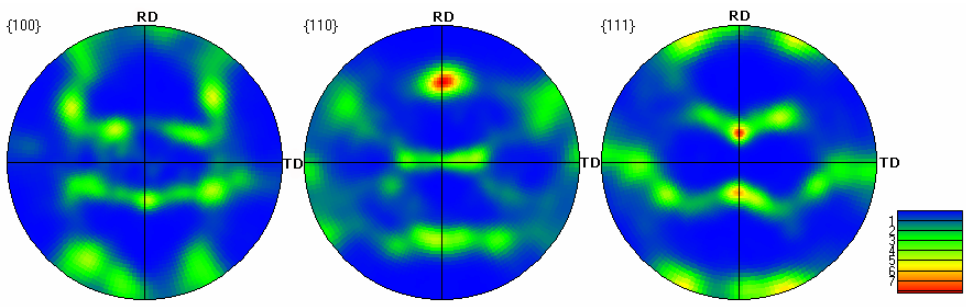

FIG. 1 Contoured pole figures of the rolling texture of nickel rolled to a reduction of 90%. The normal to the rolling plane is at the center. RD represents the rolling direction. The legend indicates the probability (frequency) of a certain orientation of a particular crystallographic axis.

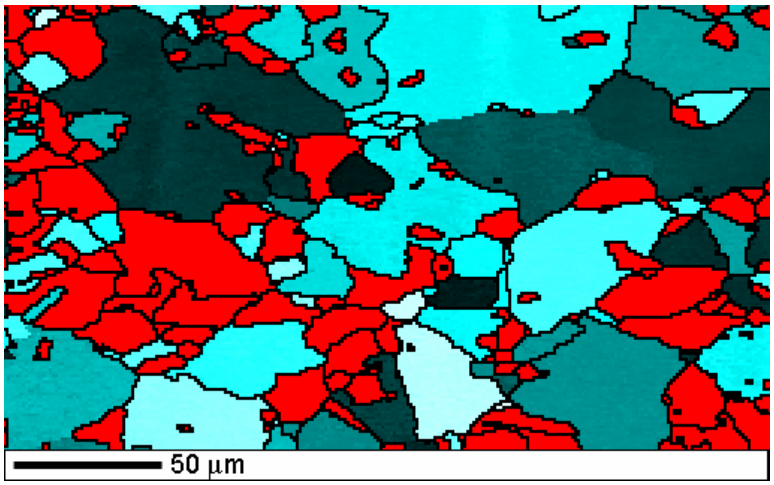

FIG. 2. Orientation map obtained by EBSP analysis of cold-rolled nickel, directionally recrystallized at T=370^{o}C and velocity 40 mm/h. The rolling direction (RD) is orizontal. The grain boundaries were established by the EBSP system based on a 10^{o} misorientation angle.

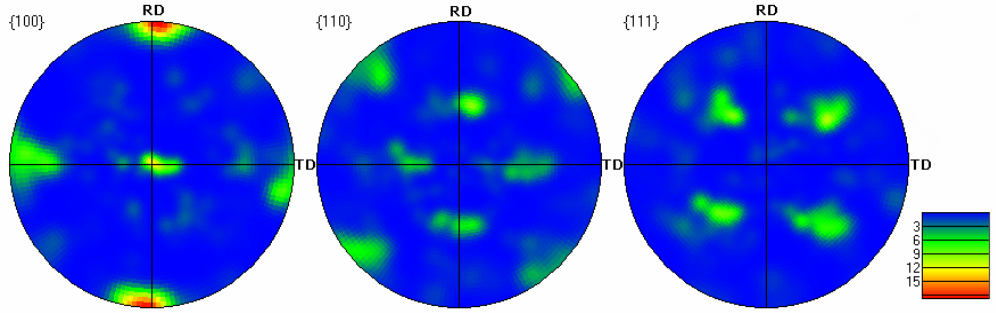

FIG. 3 Contoured pole figures showing the annealing textures of cold-rolled nickel, directionally recrystallized at T = 370^{o}C and 40 mm/h. The legend indicates the probability (frequency) of a certain orientation of a particular crystallographic axis.

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