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Structural Refinement, Recrystallization and Grain Growth Phenomena in an Accumulative Roll Bonded Nickel Sheet

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Abstract

The thickness of the lamellar band (LB) structure that is generated in an accumulative roll bonded nickel sheet represents the degree of structure refinement. The LBs reach a saturation in thickness after several roll bonding cycles due to adiabatic heating that balances the dislocations generated during rolling. The thermal restoration process starts with the rearrangement of dislocations and boundary migration. At the initial stages of thermal restoration, LBs with all the orientations in the deformation texture grow by the so-called continuous recrystallization process. However, in the latter stages, growth becomes orientation selective and dominated by S and copper orientations. Finally, grain growth after recrystallization results in the preferred growth of Cube-oriented grains to the full layer thickness of the ARB sheet, thereby generating a strong Cube texture. Thus, grain growth yields a final texture similar to that generated in conventionally rolled and annealed nickel sheets.

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Keywords: nickel; recrystallization; grain growth; accumulative roll bonding

1. Introduction

Severe plastic deformation (SPD) is a simple processing method for generating nanostructures in malleable metals/alloys. In this method, metal blocks undergo high levels of plastic strain, whereby substructural refinement takes place on the nano-scale and the overall strengthening occurs via the so-called Hall-Petch mechanism [1]. Several SPD methods have been investigated in laboratory-scale processing. Among them equal channel angular processing

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(ECAP), high pressure torsion (HPT) and accumulative roll bonding (ARB) are widely investigated [2]. There are two broad challenges with these SPD techniques, there is: (a) a refinement limit for a given metal and (b) a tendency towards thermal restoration/coarsening (recovery, recrystallization, etc.) of the nanostructures. In this investigation, a structural refinement limit is demonstrated in a commercial purity nickel after ARB processing.

Briefly on ARB processing, two sheets of similar dimensions are surface cleaned, stacked and rolled together to ~50% reduction in thickness. Because of the high rolling loads generated from the large thickness reduction in a single pass, the sheets experience good surface bonding [3,4]. The bonded sheet is then cut into two for repeating the second roll bonding cycle by an identical procedure. Thus, the bonded sheets maintains the original thickness while the number of layers increases exponentially with the number of ARB cycles. This process can be carried out repeatedly depending on the work hardening behaviour of the material. Within each bonded layer a unique nanostructure forms known as lamellar bands (LB). LBs appear as a stack of high angle boundaries at 50-200 nm repeat distances [5-7]. These boundaries consist of dense dislocation walls and are aligned parallel with the rolling plane of the sheet. The interior of a typical LB consists of mesh/cellular structures of dislocations, depending on the extent of recovery. In this investigation the refinement limit of the LB structures and the recrystallization and grain growth textures are investigated in commercial purity nickel.

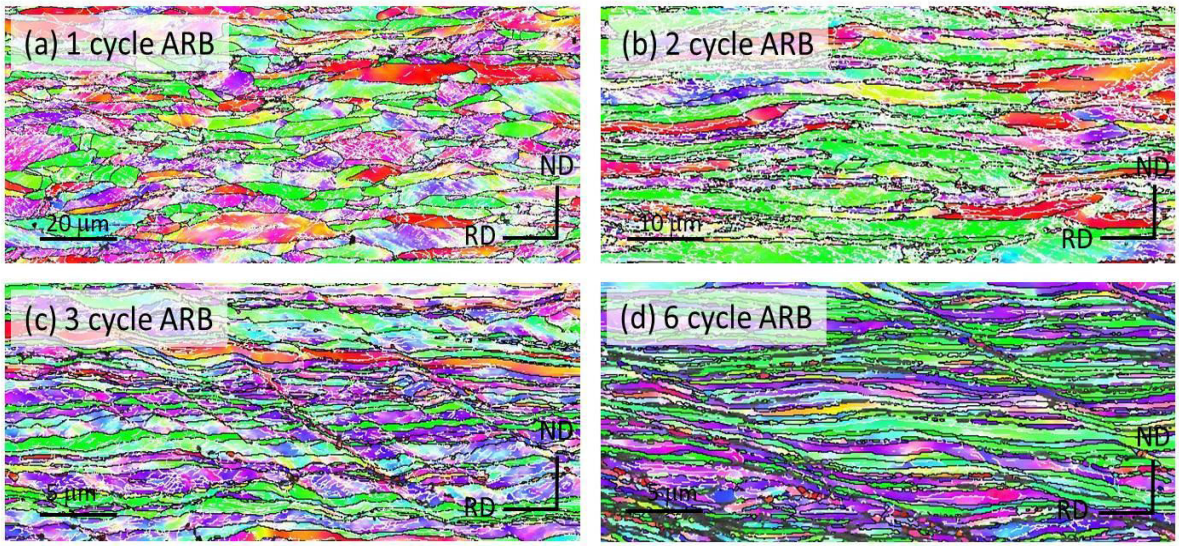

Figure 1: EBSD-measured orientation maps on the RD-ND sections showing the HAGBs and LAGBs as black and white lines, respectively: (a) one, (b) two, (c) three and (d) six cycle ARB samples.

2. Experimental

For preparing sheets for ARB processing, 1 mm thick sheets of commercial purity nickel were cut into a rectangular shape. The sheet surfaces were wire brushed and tightly stacked together using steel wires to avoid relative movement/slipping during roll bonding. The roll bonding was conducted by 50% reductions in thickness in a single pass for up to ten ARB cycles. The RD-ND cross-section of the sheets was mechanically polished to the final fineness with colloidal silica. Microstructure and texture analysis was conducted using scanning electron microscopy (SEM), transmission electron microscopy (TEM) and an Oxford electron back scatter diffraction (EBSD) facility attached to