Intermetallics 101 (2018) 87–98

Contents lists available at ScienceDirect

Intermetallics

journal homepage: www.elsevier.com/locate/intermet

Effect of annealing on the microstructure and texture of cold rolled CrCoNi medium-entropy alloy

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ARTICLE INFO

Keywords:
High-entropy alloy
Thermomechanical processing
Annealing
Microstructure
Texture
Twinning

ABSTRACT

The microstructure, texture and mechanical properties of medium-entropy ternary CrCoNi alloy after cold rolling and annealing were investigated. The cold rolled material shows a heavily fragmented microstructure coexisting with fine scale shear bands. The deformation texture is a α-fibre with a spread between the Goss and Brass component. This type of texture during cold rolling is direct evidence of a low stacking fault energy of the CrCoNi alloy. Annealing at 700 °C yields a fully recrystallized ultrafine grained microstructure with a large fraction of annealing twins. Annealing twins play a significant role in the evolution of the annealing texture. They lead to the emergence of new orientations which have first order twin relationship (60° < 111 > rotation) with the α-fibre rolling texture components. Typical brass recrystallization texture BR {236} < 385 > component does not develop during recrystallization unlike in other low SFE alloys such as brass, Ag and Cu alloys. New prominent twin related orientations are retained with increasing annealing temperature due to the hindrance of preferential growth of certain crystallographic orientations. Tensile tests show that this alloy exhibits ultra-high strength and good ductility.

1. Introduction

Nowadays, multi-component alloys have aroused considerable interest in the materials science and metallurgical community [1–20]. The equi-atomic multicomponent alloys and their derivatives are usually referred to as high-entropy alloys (HEAs). The alloy design strategy of HEAs mainly depends on the maximization of the configurational entropy. When the number of principal elements in the alloy increases beyond five, there is a significant reduction of the free energy of the system due to the contribution of a high configurational entropy [5]. The configuration entropy of mixing usually is greater than 1.5 R (R – universal gas constant). On account of that, in many instances HEAs are stabilized as a simple solid-solution phase [5].

The present study is motivated by recent research on medium-entropy alloys (MEAs) [21–25]. MEAs are composed of two to four constituent elements in equi-atomic proportions and have a configurational entropy in between 1 R and 1.5 R. Initially, Wu et al. [26] studied the thermo-mechanical processing behaviour of a family of face-centred cubic (fcc) multi-component equi-atomic alloys, especially the phase stability and microstructure evolution during recovery, recrystallization and grain growth. The ternary CrCoNi MEA was found to be harder than the quaternary CrFeCoNi alloy. Gludovatz et al. [21] reported that CoCrNi MEA has fcc structure with excellent strength-ductility balance as compared to CrMnFeCoNi HEA. Besides, Laplanche et al. [24] found that this MEA exhibits higher yield strength, work hardening rate and earlier activation of nanotwins compared to the quinary HEA. Their results clearly indicate that solid solution hardening in these equiatomic alloys (MEAs and HEAs) mainly depends on type and combination of alloying elements, but certainly does not depend on the number of alloying elements [24].

The precipitation behaviour of quinary CrMnFeCoNi HEA was studied in detail [27–30]. The single phase fcc structure after severe plastic deformation followed by low temperature annealing was decomposed into multiple phases consisting of a Mn–Ni, a Fe–Co and a Cr-rich phase [13]. Stepanov et al. [29] reported Cr-rich sigma and Cr-rich bcc second phase formation after cold rolling and subsequent annealing at 600°-

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https://doi.org/10.1016/j.intermet.2018.07.014
Received 4 May 2018; Received in revised form 24 June 2018; Accepted 26 July 2018
0966-9795/

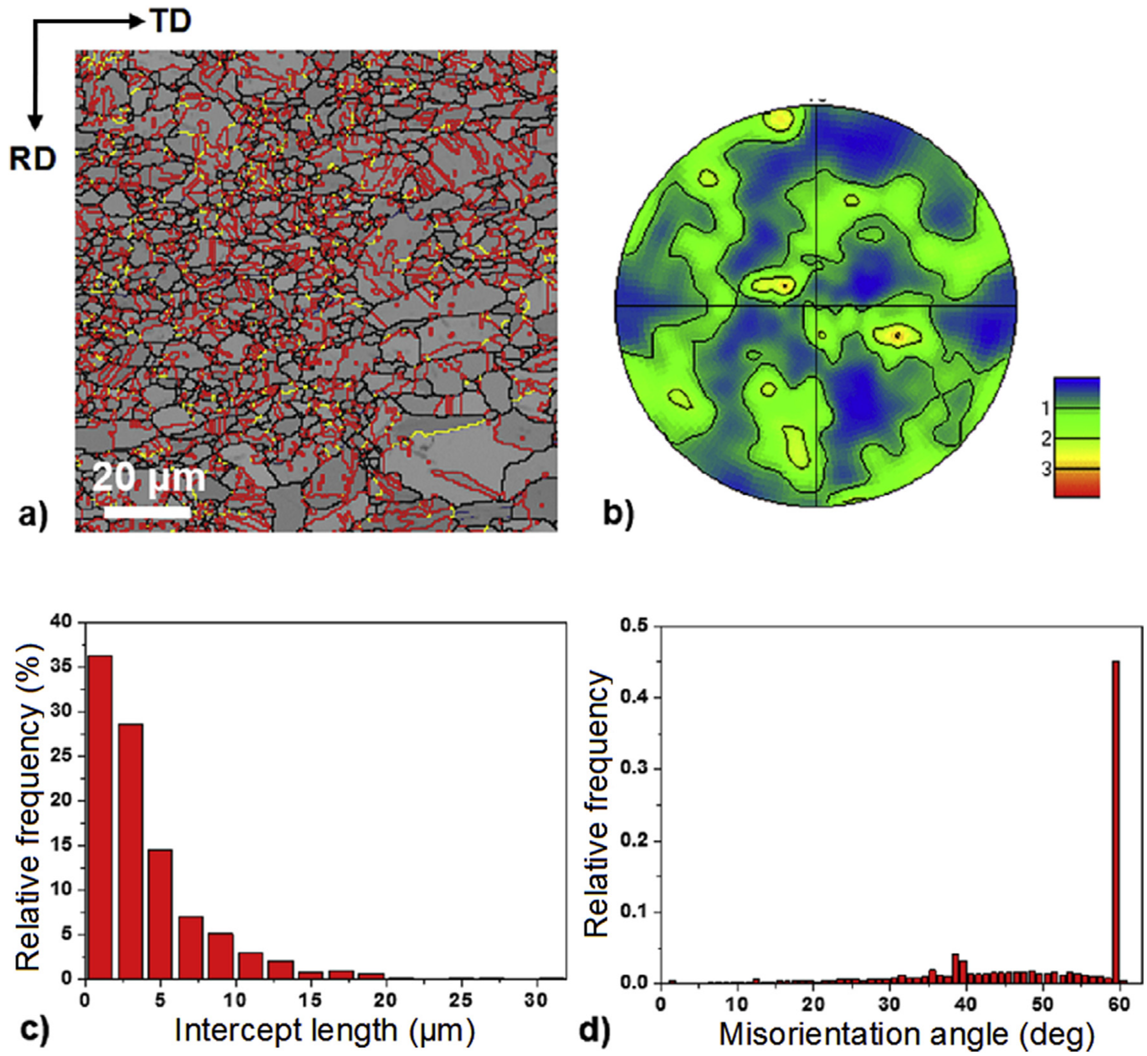

Fig. 1. A) Image quality map superimposed with the grain boundaries, b) corresponding (111) pole figure, c) grain size distribution and d) misorientation angle plot of starting material before cold rolling. (black lines in the GB map: HAGBs, red lines: Σ3 twin boundaries, yellow lines: Σ9 twin boundaries; intensities in the pole figure given in multiples of a random distribution). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

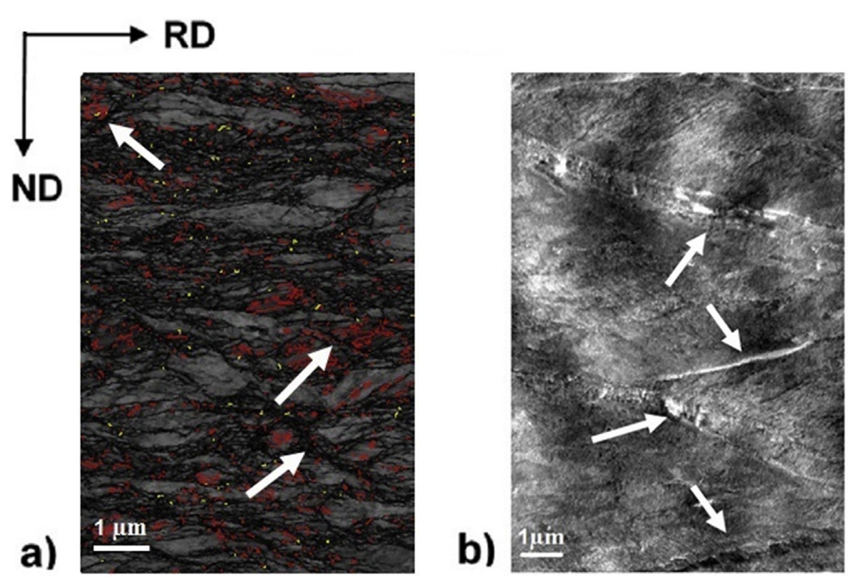

Fig. 2. A) Image quality map of 90% CR material superimposed with Σ3 and Σ9 TBs and b) back scattered electron image of 90%CR material. Fine scale shear bands are marked with arrows in (a and b).