IOP Conf. Series: Materials Science and Engineering **63** (2014) 012156 doi:10.1088/1757-899X/63/1/012156

Nanocrystalline structures and tensile properties of stainless steels processed by severe plastic deformation

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Abstract. The development of nanocrystalline structures in austenitic stainless steels during large strain cold rolling and their tensile behavior were studied. The cold rolling to total equivalent strains above 2 was accompanied by the evolution of nanocrystalline structures with the transverse grain size of about 100 nm. The development of deformation twinning and martensitic transformation during cold working promoted the fast kinetics of structural changes. The development of nanocrystalline structures resulted in significant strengthening. More than fourfold increase in the yield strength was achieved. The strengthening of nanocrystalline steels after severe plastic deformation was considered as a concurrent operation of two strengthening mechanisms, which were attributed to grain size and internal stress. The contribution of internal stresses to the yield strength is comparable with that from grain size strengthening.

1. Introduction

The development of ultrafine grained and/or nanocrystalline structures by severe plastic deformation is one of the most promising methods for obtaining various steels and alloys with superior mechanical properties [1, 2]. It has been shown that the ultrafine grained and/or nanocrystalline structures could be obtained in almost all metallic materials after sufficiently large strains at relatively low temperatures [3]. By now a number of special deformation methods have been successfully utilized for severe straining [1, 4-6]. It should be noted that the effectiveness of deformation treatment for the development of ultrafine grained or nanocrystalline metals/alloys depends significantly on the susceptibility of the processed material to the grain fragmentation/subdivision upon plastic working. The high efficiency of cold working should be expected for processing of metallic materials exhibiting deformation twinning and/or strain-induced martensitic transformation [7-10]. Typical representatives of such materials are austenitic stainless steels. The low values of stacking fault energy in austenitic stainless steels promote the deformation twinning, whereas the metastable austenite experiences martensitic transformation under cold working conditions. Therefore, the austenitic stainless steels can be easily processed in ultrafine grained or nanocrystalline states by using conventional method of metal working without application of any special techniques.

The development of ultrafine grained or nanocrystalline structures is of the utmost importance for austenitic stainless steels. These materials are characterized by relatively low yield strength after ordinary thermomechanical processing [11]. The structural strengthening by means of large strain deformations has been shown as an advanced approach for production of high strength austenitic stainless steels [12, 13]. The aim of the present study is to clarify the mechanisms of structural