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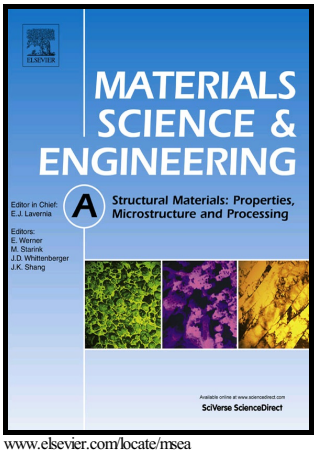

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Mechanical properties of electrodeposited amorphous/crystalline multilayer structures in the Fe-P system

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Abstract

Amorphous/crystalline multilayer structures of Fe-P alloys were deposited electrochemically using the single bath technique. Hall-Petch behavior of microhardness with respect to sublayer thickness was observed down to a sublayer thickness of 15 nm. For thinner sublayers, a hardness plateau was obtained. The transition at a sublayer thickness of 15 nm coincides with the loss of the multilayer structure as observed in transmission electron microscopy. The transition is a possible result of a change in the amorphous to crystalline sublayer thickness ratio and the interface roughness development during the deposition process. Additionally, crack deflection at the interfaces was observed for the layered structures with small sublayer thickness in microbending experiments.

Keywords: electrodeposition; multilayer; hardness; Hall-Petch behavior; iron alloys

1. Introduction

Lamellar structures with lamella widths in the submicron to nanometer regime have attracted much attention due to their unique properties, for example concerning magnetism [1-3] or mechanical strength [4]. The mechanical strength is generally observed to increase with decreasing lamella thickness for crystalline structures. This is equivalent to the Hall-Petch behavior in bulk materials [5, 6]. Indeed, the size dependency for lamellar structures is well described in many cases using the Hall-Petch equation with the sublayer thickness instead of the grain size [7-10]. In other studies, a linear behavior of hardness or yield stress as a function of the reciprocal sublayer thickness was observed [11, 12]. Independent of the exact relationship of strength and sublayer thickness, no further increase or even a decrease of strength is observed below a certain sublayer thickness, which is typically between 2 and 50 nm [8-10, 13]. Various explanations for this phenomenon, which are mainly based on a change of deformation mechanisms on the nanometer scale, are discussed in literature [9, 10].

On the contrary, no clear dependence of the strength on the layer thickness is reported for amorphous layers [14]. This can be attributed to the different deformation mechanism of amorphous