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Abnormal Kinetic Properties of Grain Boundaries in Al Doped with Pb: Grain Boundary Motion and Thermal Extraction of Pb

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Abstract. Measurements of grain boundary migration under a constant driving force in bicrystals of Al alloyed with small amounts of Pb are presented. The temperature dependence of grain boundary mobility is characterized by a steep rise of both migration activation enthalpy and preexponential mobility factor at a specific temperature which depends on misorientation. This behavior is attributed to a wetting phase transition in the grain boundary. An extraction of Pb from the bulk to the surface of the sample during cooling is found. This phenomenon is attributed to the interaction of vacancies with impurity (Pb) atoms.

1. Introduction

Most recent data reveal that the solubility of Pb in Al is extremely small [1]. It is well known that impurities with low solubility strongly segregate to grain boundaries, thus affecting their kinetic properties. The current experiments were initially a part of a systematical investigation into the influence of solute atoms on grain boundary motion. However, first results revealed that in the case of pure Al doped with 20 ppm Pb the system consisted of Al with small inclusions of Pb, which are liquid at temperatures above the melting point of lead. Grain boundary migration in this system was characterized by some unusual phenomena. These phenomena are addressed in the current paper.

2. Experimental

Tilt grain boundaries with rotation axis <111> and misorientation angles 38.2°(Σ7) and 40.5° were chosen for the current study, as they possess special properties, e.g. minimum and maximum migration activation enthalpy and pre-exponential factor for Σ7 and 40.5°<111> boundary respectively, which makes them the most mobile boundaries in pure aluminium although in different temperature ranges [2].

To measure the grain boundary mobility specially prepared bicrystal specimens were used, which contained a curved grain boundary. The grain boundary motion proceeds under a constant driving force $p=\sigma/a$, caused by the grain boundary surface tension σ, where a is the width of the consumed grain. An X-ray diffraction technique was utilized for locating and tracking the grain boundary position. The measured quantity was the grain boundary velocity v, which relates to the parameter of interest, the boundary mobility m, by $v = mp$. For the sake of convenience we use the reduced mobility

$$A \equiv v \cdot a = m \cdot \sigma = A_o \exp\left(-\frac{H}{kT}\right), \tag{1}$$