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In-situ TEM investigation of diffusion of nano-scale liquid Pb inclusions on dislocations and in bulk aluminum

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Abstract. Diffusion of nano-sized liquid Pb inclusions in thin aluminum foils is investigated using *in-situ* transmission electron microscopy (TEM). Free diffusion of the inclusions in the bulk and diffusion constrained by dislocations trapping is studied. The motion of trapped Pb inclusions is spatially confined in close proximity to the dislocations. The diffusion coefficients of free motion of the inclusions are determined using Einstein's equation. The diffusion coefficients of trapped inclusions were obtained using an equation based on Smoluchowski's analysis of the Brownian motion of particle in a harmonic potential. The agreement of the diffusion coefficients of free and trapped inclusions indicates the same underlying microscopic mechanism, and no strong influence from dislocations. The microscopic mechanism controlling the mobility is discussed.

Introduction

Nano-sized inclusions of Pb in Al is an appropriate system for *in-situ* TEM studies [1,2]. The high mobility of liquid Pb inclusions in Al allows to investigate quantitatively the diffusion of such inclusions either free in the bulk or attached to defects [3,4]. This provides a means for analysis of the microscopic mechanisms controlling the mobility using the available diffusion models for bubble diffusion [5,6]. The influence of the defects on the mobility can be investigated as well.

The study of the mobility of nano-sized liquid Pb inclusions in Al can be useful for understanding the kinetic behaviour of noble gases bubbles, which impacts the lifetime of construction materials used in the nuclear power industry [7]. Unexpectedly, the mobility of noble gases bubbles is rather low in these materials, and quantitative TEM studies of their kinetic behaviour are difficult.

This paper presents *in-situ* TEM studies of diffusion of nano-sized liquid Pb inclusions, both free and trapped by dislocations, in thin aluminum foils. The results related to the diffusion of the trapped inclusions are analyzed in terms of Smoluchowski's analysis of Brownian motion of particles in a harmonic potential [8]. The microscopic mechanism governing their mobility is discussed on basis of the obtained results.

Experimental procedure

The Al samples containing nano-sized Pb inclusions for TEM studies were prepared from ribbons of Al-Pb dilute alloys obtained by rapid solidification from a temperature above the Al-Pb liquid immiscibility gap. The samples were subsequently annealed in an Ar atmosphere to equilibrate the microstructure. *In-situ* TEM studies of diffusion of the inclusions were carried out in a 200 kV Phillips CM 20 microscope using a Gatan single tilt heating stage. The observations were recorded