A Cosserat crystal plasticity and phase field theory for grain boundary migration

Anna Ask, Samuel Forest, Benoit Appolaire, Kais Ammar,
Oguz Umut Salman

PII: S0022-5096(17)30901-8
DOI: 10.1016/j.jmps.2018.03.006
Reference: MPS 3299

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 9 October 2017
Revised date: 2 February 2018
Accepted date: 3 March 2018

Please cite this article as: Anna Ask, Samuel Forest, Benoit Appolaire, Kais Ammar, Oguz Umut Salman, A Cosserat crystal plasticity and phase field theory for grain boundary migration, *Journal of the Mechanics and Physics of Solids* (2018), doi: 10.1016/j.jmps.2018.03.006

A Cosserat crystal plasticity and phase field theory for grain boundary migration

Anna Ask[a], Samuel Forest[a,*], Benoit Appolaire[b,c], Kais Ammar[a], Oguz Umut Salman[d]

[a] *MINES ParisTech, PSL Research University, MAT – Centre des matériaux, CNRS UMR 7633, BP 87 91003 Evry, France*
[b] *Université de Lorraine, CNRS, IJL, F–54000 Nancy, France*
[c] *Laboratoire d'Etude des Microstructures, CNRS/Onera, BP72, 92322 Châtillon Cedex, France*
[d] *CNRS, LSPM UPR3407, Université Paris 13, Sorbonne Paris Cité, 93430, Villetaneuse, France*

Abstract

The microstructure evolution due to thermomechanical treatment of metals can largely be described by viscoplastic deformation, nucleation and grain growth. These processes take place over different length and time scales which present significant challenges when formulating simulation models. In particular, no overall unified field framework exists to model concurrent viscoplastic deformation and recrystallization and grain growth in metal polycrystals. In this work a thermodynamically consistent diffuse interface framework incorporating crystal viscoplasticity and grain boundary migration is elaborated. The Kobayashi–Warren–Carter (KWC) phase field model is extended to incorporate the full mechanical coupling with material and lattice rotations and evolution of dislocation densities. The Cosserat crystal plasticity theory is shown to be the appropriate framework to formulate the coupling between phase field and mechanics with proper distinction between bulk and grain boundary behaviour.

Keywords: Cosserat crystal plasticity, Phase field method, Dynamic recrystallization

1. Introduction

1.1. Scope of the work

The microstructure of a polycrystalline metallic material is characterized by the shape and distribution of differently oriented grains. Macroscopic material properties such as strength and ductility can be tuned by thermomechanical processing which significantly alters the microstructure of the metal at the grain scale through viscoplastic deformation and subsequent (sequential) or concurrent (dynamic) nucleation and growth of new grains.

*Corresponding author
Email address: samuel.forest@ensmp.fr (Samuel Forest)