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4D GRAIN GROWTH STUDY BY LABORATORY DIFFRACTION CONTRAST TOMOGRAPHY

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Summary: Using a novel laboratory diffraction contrast tomography (LabDCT), a non-destructive, 4D study was conducted to investigate the 3D grain structural evolution during grain growth. Information of both the morphology and crystallographic orientation for the grains is obtained. The capability of applying LabDCT for detailed study of grain growth is demonstrated, promising to provide the necessary 4D experimental evidences for further understandings of grain growth.

1. INTRODUCTION

The microstructure evolution during grain growth in terms of grain size distribution and texture is important because they have strong influence on the mechanical, thermal and electrical properties of metallic materials [1]: widely known applications are silicon electrical steels and devices for power current based on T_c superconductor compounds. Extensive studies have been conducted on grain growth, both experimentally and by theoretical modelling. Most of the experimental evidences in previous studies are collected with 2D, static characterization techniques and thus are insufficient for accurate description of the grain growth behaviour, which is essentially a dynamic process with 3D structural evolution.

The technique of X-ray diffraction contrast tomography (DCT) has been shown to be capable of mapping grain structure and orientations non-destructively in 3D, which therefore allows 4D characterization of temporal changes in crystallographic grain structure over time [2]. The novel laboratory-based X-ray diffraction contrast tomography system (LabDCT), operating on a commercially available X-ray microscope (XRM), enables the wider accessibility and routine use for the non-destructive, time-evolution studies necessary for the understandings of dynamic microstructural evolutions [3].

Here we will present a 4D study of the grain growth behaviour using LabDCT. Essential information of microstructural evolution, including both morphology and crystallographic orientation of the grains, is revealed. A comprehensive analysis of the grain growth kinetics on both global and local scales is presented to manifest the full capability of LabDCT in advancing the understandings of grain growth.

2. EXPERIMENTAL METHOD

The material used in the present study is Armco iron with very low carbon content. The initial sample was cold-rolled to 75% reduction in thickness and then annealed at 880°C for 5 days to obtain an average grain size of approximately 75 μm. The microstructure consists of only polygonal ferritic grains without carbides.

The as-treated sample was then scanned on a laboratory X-ray microscope (ZEISS Xradia 520 Versa with

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LabDCT module installed). The scan was conducted using a polychromatic divergent X-ray beam, configured in a Laue focusing geometry, with 181 projections in each DCT scan. (Detailed experimental setup and explanation of LabDCT can be found in reference [2]). Two annealing steps, 18 hrs and 21 hrs at 880°C, were subsequently done and after each annealing treatment, the sample was scanned of the corresponding volume to track the microstructural evolution. The data was processed and reconstructed with the GrainMapper3D analysis package developed by Xnovo Technology Aps.

3. RESULTS

Examples of the reconstructed data are shown in Figure 1. Figure 1(a) shows the reconstructed sample volume at the initial state and after the subsequent annealing treatments and (b) shows the morphology evolution for a few selected grains during annealing. The reconstructed data includes information of the grain morphology such as the grain location within the sample space, the grain size as well as the shape of the grain. An analysis of the grain size evolution over annealing treatments is conducted, for a general description of the grain growth kinetics. Based on the obtained crystallographic orientations for the grains, the textural evolution was investigated, and the local boundary migration behaviors during grain growth were analyzed in correlation with the grain boundary misorientations.

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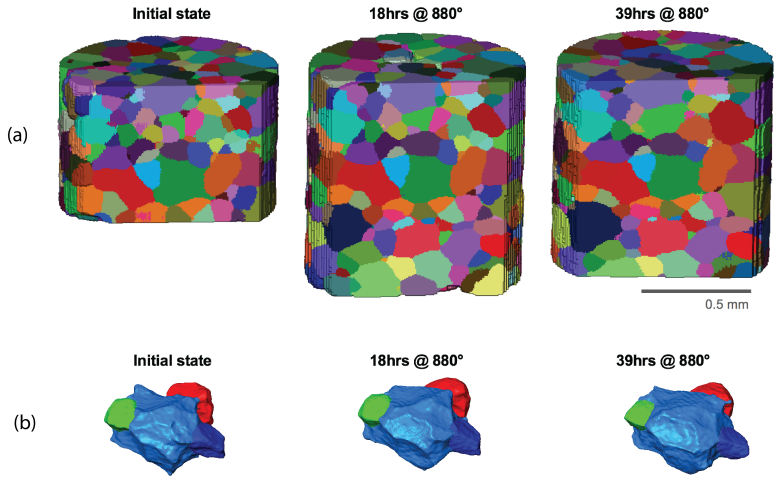

Figure 1: (a) Reconstructed sample volume of the initial state and the corresponding volume after annealing treatments; (b) The evolution of morphology for four selected grains over iterative annealing. The grains in (a) and (b) are colored with grain ID.