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Characterizing the Effect of ECAP on Particle Dispersion and Thermal Stability of Internally Oxidized Fe-Y Alloys

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Oxide dispersion strengthened (ODS) alloys are desirable for high temperature applications, as dispersed oxide particles within the metal matrix act as barriers to dislocation motion and grain growth at elevated temperatures. Traditional processing routes for ODS alloys are powder metallurgy based, utilizing mechanical alloying by high energy ball milling to mix metal and oxide powders, necessitating compaction techniques such as hot isostatic pressing or hot extrusion to create a dense final product. Recent studies have investigated production of dispersion strengthened alloys without powder metallurgy by introducing a dispersed ceramic phase to a bulk alloy via a physical application process, such as spraying [1], followed by severe plastic deformation to refine grain size. This study proposes an ODS synthesis method of introducing oxides via selective internal oxidation, followed by equal channel angular pressing (ECAP) to refine grain size.

In this work, Fe-1.5 wt% Y alloys were studied. The as-cast microstructure consisted of an α-Fe matrix and $Fe_{17}Y_2$ intermetallic, as shown in Figure 1a. Oxides were introduced into the bulk alloy when the material underwent selective internal oxidation, during which the $Fe_{17}Y_2$ intermetallic phase oxidized to Y_2O_3 particles and pure Fe, leaving the α-Fe matrix unaltered [2].

Internal oxidation was followed by ECAP in order to refine the matrix Fe grain size while also dispersing the Y_2O_3 particles. During ECAP, as illustrated in Figure 1b, strain is introduced as the ingot is pressed through a die at an angle, which for this study was 90°. Because the dimensions of the cross section are the same before and after deformation, the piece can undergo multiple consecutive passes, each introducing additional plastic deformation to the sample. The processing variables studied in this work were the number of ECAP passes and the temperature at which ECAP was performed. In this study, ECAP was performed at room temperature (25°C) and an elevated temperature (350°C), for four ECAP passes and for eight ECAP passes.

After ECAP, Fe grains in the matrix were imaged using electron channeling contrast via backscattered electron detection in a FEI Quanta 600 FEG-SEM. Post-ECAP grain size of the Fe matrix was measured using the ASTM E112 linear intercept method [3], finding that increased number of ECAP passes had no significant impact on grain size. A series of thermal stability anneals at 250°C, 400°C, and 1000°C were performed, and Vickers microhardness measurements taken before and after annealing found that the high-temperature ECAP samples maintained similar hardness after 400°C, while room temperature ECAP samples exhibited loss of thermal stability based on an observed significant drop in hardness after 400°C anneals.

An automated high-throughput dispersion analysis program was developed to quantify particle dispersion using the quadrat method [4]. Applying the dispersion program to the ECAP samples, it was found that the room temperature ECAP samples had more dispersed particles than high temperature ECAP, but number of passes did not have a significant effect on particle dispersion.

Additional insight on microstructural modification by this new processing route is obtained by orientation mapping via electron backscatter diffraction (EBSD) and ASTAR automated crystal orientation mapping (ACOM) in TEM. Insight regarding microstructural texture evolution as a function of processing conditions will be critical to further improve oxide dispersion and thermal stability of the alloy [5].

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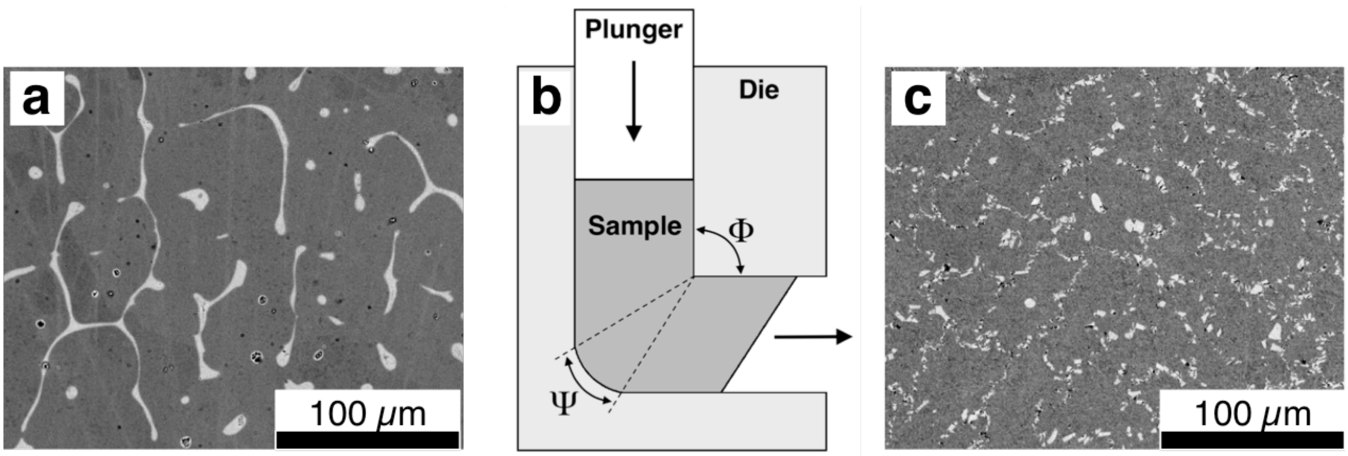

Figure 1. Schematic of the ECAP process (b), and backscatter SEM micrographs of the unoxidized core with dark Fe matrix with bright $Fe_{17}Y_2$ intermetallic before ECAP (a) and after four ECAP passes (c).

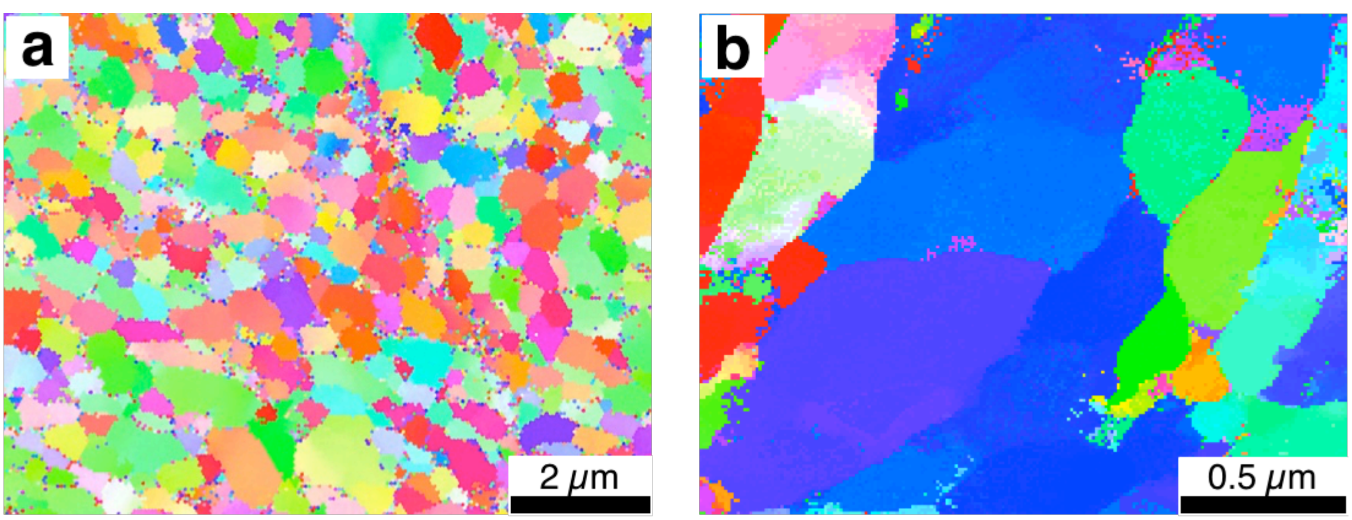

Figure 2. EBSD map of Fe matrix after eight ECAP passes at 350°C (a), and ACOM map of Fe matrix after eight ECAP passes at 25°C (b).

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