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PII: S0925-8388(17)33075-X

DOI: 10.1016/j.jallcom.2017.09.046

Reference: JALCOM 43102

To appear in: *Journal of Alloys and Compounds*

Received Date: 16 April 2017

Revised Date: 4 September 2017

Accepted Date: 5 September 2017

Please cite this article as: M.A.R. Önal, C. Jönsson, W. Zhou, T. Van Gerven, M. Guo, A. Walton, B. Blanpain, Comparative oxidation behavior of Nd-Fe-B magnets for potential recycling methods: Effect of hydrogenation pre-treatment and magnet composition, *Journal of Alloys and Compounds* (2017), doi: 10.1016/j.jallcom.2017.09.046.

Comparative Oxidation Behavior of Nd-Fe-B Magnets for Potential Recycling Methods: Effect of Hydrogenation Pre-treatment and Magnet Composition

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Abstract

Recycling of Nd-Fe-B magnets is one of the few solutions to alleviate the supply risks of certain rare earth elements (REE) such as Nd and Dy. One of the most promising solutions with regards to extraction of end-of-life (EOL) magnets is to apply hydrogen decrepitation and to physically separate the Nd-Fe-B as a demagnetized hydrogenated powder. Such a powder can be directly recycled into new sintered magnets, or indirectly recycled by a conventional oxidation roasting and acid leaching flowsheet. The oxidation stability of powders, the microstructure after oxidation and the role of compositional variations can be of importance for the success of such subsequent direct or indirect recycling routes. In this study, magnets with varying compositions were subjected to different hydrogen treatments (e.g. hydrogenation, partial or full degassing and vacuum or conventional disproportionation) and subsequently studied for their comparative oxidation behavior and microstructural changes. While initial magnet composition was found to have little or no effect on oxidation behavior, the treatment type was found to have a direct impact on both the particle size distribution and the oxidation mechanism. The general oxidation rate was found to be the equally highest for hydrogenated and partially degassed samples followed by fully degassed and then disproportionated samples. After complete oxidation, complex REE-Fe-O compounds were formed more extensively in hydrogenated and fully degassed NdFeB samples than in the disproportionated samples.

Keywords: Recycling, Nd-Fe-B magnet, hydrogenation, decrepitation, disproportionation, oxidation.

1. Introduction

Nd-Fe-B magnets are the strongest magnets available, and they play an important role in the miniaturization of electronics, and in the transition to green energy systems [1]. Nd-Fe-B magnets are composed of around 30 % rare earth elements (REEs) (mainly Nd), around 70 % transition metals (mainly Fe) and ~1 % B [2]. Alterations to the composition may occur depending on the operational temperature and environment, availability and price of the constituents, and on the manufacturer. As for Dy, which is added for increased coercivity at elevated temperatures, the content can vary from close to 0 wt. % (hard disk drives, HDDs) to as high as 8.5 wt. % (electric car motors) [3]. Other REEs (Pr, Tb, Gd, Eu) or other elements such as Al, Co, Ga, Nb, Si and Zr can