

📅 Tue. Jul 29, 2025 4:35 PM - 6:00 PM JST | Tue. Jul 29, 2025 7:35 AM - 9:00 AM UTC 🏠 Green zone, Conference rooms 101 and 102(1F)

[P2] Raw Materials & Recycling

Session Chair: Mr. Johann Fischbacher (University for Continuing Education Krems, Austria), Dr. Yusuke Hirayama (AIST, Japan)

[P2-25] Investigation of Oxidation Behaviour and Passivation Rates for Recycled Hydrogen Processed NdFeB Powder

*Safiyah Hussain¹, Shahrouz Nayeboossadri¹, Viktoria Kozak¹, Oliver Brooks¹, Vicky Mann¹, Allan Walton¹ (1. University of Birmingham (UK))

Keywords : Oxidation、 Recycling、 Powder Passivation

Due to their exemplary magnetic properties and versatility, neodymium-iron-boron magnets ($\text{Nd}_2\text{Fe}_{14}\text{B}$) are the most widely employed rare-earth (RE) magnets, utilised in technological applications such as electric vehicles and wind turbines.

RE elements are high on the UK Critical Minerals list and EU critical materials list for supply risk due to instability within the rare earth element global supply chain, and demand for RE materials is projected to continue increasing in the coming years. Consequently, there is a growing focus on establishment of alternative neodymium supply routes. The pressure on the supply chain, partly due to the key role magnetic technologies play in the sustainable energy transition, can be alleviated through the recycling of NdFeB End-of-Life (EoL) magnets. A possible solution is the recycling of Nd from large reserves of spent NdFeB magnets, reducing the demand for virgin material, and providing a more sustainable future supply.

A recycling method patented at the University of Birmingham named Hydrogen Processing of Magnetic Scrap (HPMS), uses hydrogen to extract demagnetised NdFeB powder from bulk EoL magnets contained within sources such as hard disk drives and automotive scrap. This hydrogenated powder is purified through sieving and jet milling, resulting in particles of $\leq 5\mu\text{m}$, before reprocessing through re-sintering.

The fine hydrogenated powder produced by HPMS is highly pyrophoric and susceptible to oxidation during subsequent processing. The oxidation behaviour and stability of the powder has implications on the viability of the downstream processing, as oxide contamination to the powder can result in porosity and a reduction in coercivity in the final magnets. After production some pyrophoric powder may remain in the equipment, this requires passivation to safely clean the systems ready for processing of subsequent batches. Additionally if material is to be used in the long loop process routes this requires oxidation to change the state of the iron.

This work investigates the oxidation behaviour of recycled magnetic material produced from the HPMS process. Powders from multiple scrap sources were analysed from multiple stages in the HPMS process: hydrogen processed, $150\mu\text{m}$ sieved, $90\mu\text{m}$ sieved,

jet milled coarse fraction and jet milled fine fraction. Powders were characterised prior to oxidation using ICP-OES and O/N analysis, to assess oxide and RE concentration from processing as well as the effect of powder impurities. The oxidation rates were determined using thermogravimetric analysis for each of these powder fractions when exposed to air after inert HPMS processing. Contamination within the powder is studied at multiple HPMS stages in correlation with the powder particle size and powder handling. Residual gas analysis was conducted to determine degassing behaviour of the powder material under high temperature conditions.

Thermogravimetric analysis of powder from each processing stage found oxidation in increasingly finer fractions to be slower, despite the smaller powder particle sizes up to the jet milled coarse fraction. This was found to correlate to increased powder handling as the powder moves from hydrogen processed to jet milled. However, the jet milled fine powder fraction was found to oxidise significantly quicker than any other powder stage, due to a concentration of residual oxide impurities from the EoL magnets, and RE elements. The sensitivity of the RE-rich and oxide-rich fines is corroborated by the results of 2 g burn tests conducted on each powder stage, with jet milled fines being the only powder that exhibited self-ignition. Additionally, pre-oxidation characterisation in powder direct from processing stages found oxygen wt% to be inversely proportional to powder size. This work demonstrates the necessity for passivation and controlled oxidation when handling fine jet milled powder compared to coarse. Further, it highlights a need for oxidation research in the processing, storage, safety, and scaling up of the process.