# Hydrogen-based functional recycling of Nd-Fe-B sintered magnets: influence on GBDP microstructure evolution and possibilities to improve the resulting properties

Fraunhofer IWKS

TECHNISCHE UNIVERSITÄT DARMSTADT

MAX PLANCK INSTITUTE FOR SUSTAINABLE MATERIALS GMBH

Mario Schönfeldt[1,2], Jürgen Rossa[1], Konrad Opelt[1,2], Kilian Schäfer[2], Lukas Schäfer[2], Fernando Maccari[2], Matic Jovičević-Klug[3], Tim M. Schwarz[3], Chi-Chia Lin[1,2], Mahmudul Hasan[1], Jürgen Gassmann[1], Dierk Raabe[3], Oliver Gutfleisch[2]

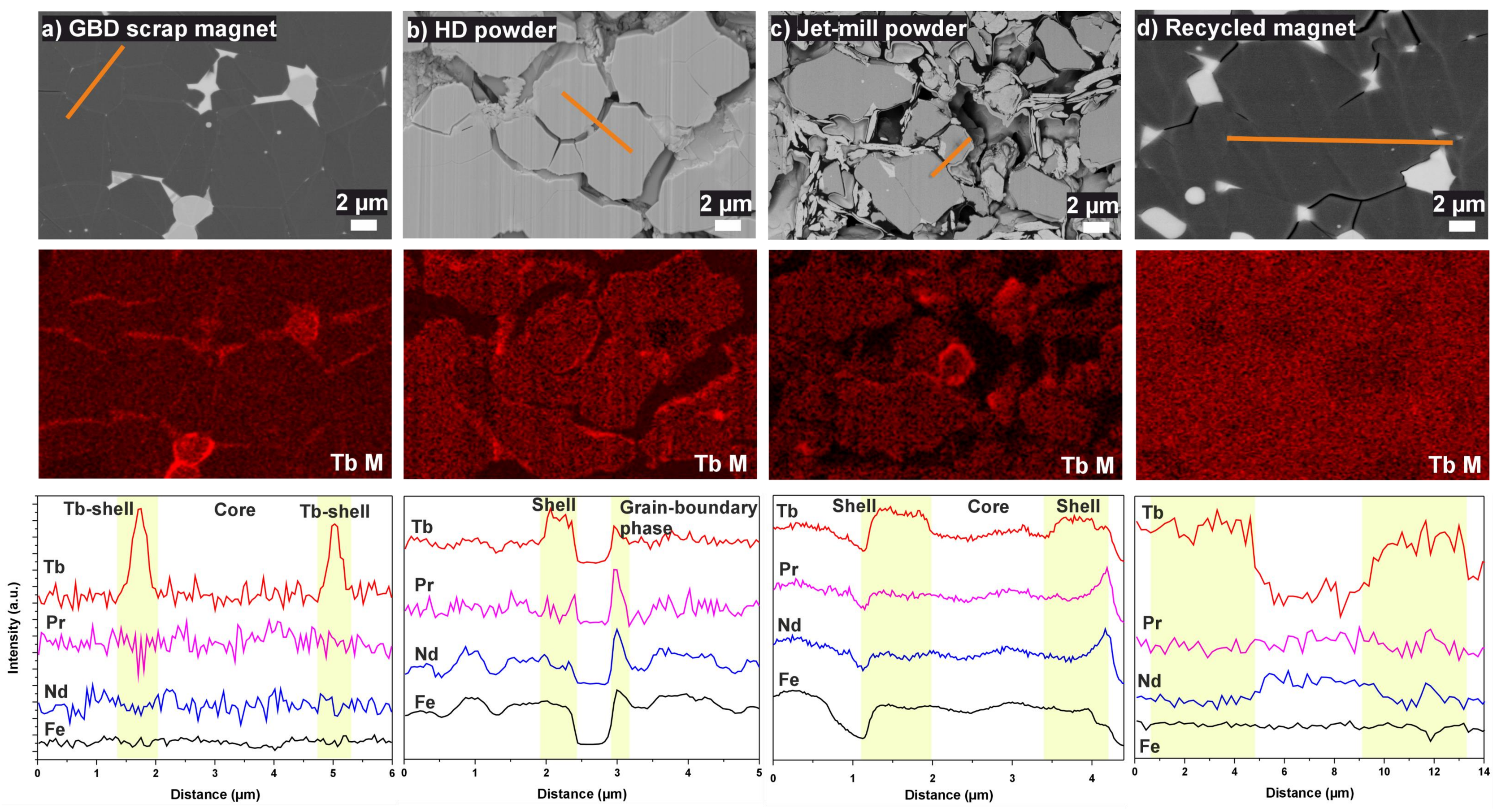
[1] Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, Aschaffenburger Str. 121, 63457 Hanau, Germany

[2] TU Darmstadt, Department of Materials and Geosciences, Functional Materials, Peter-Grünberg-Str. 16, 64287 Darmstadt, Germany

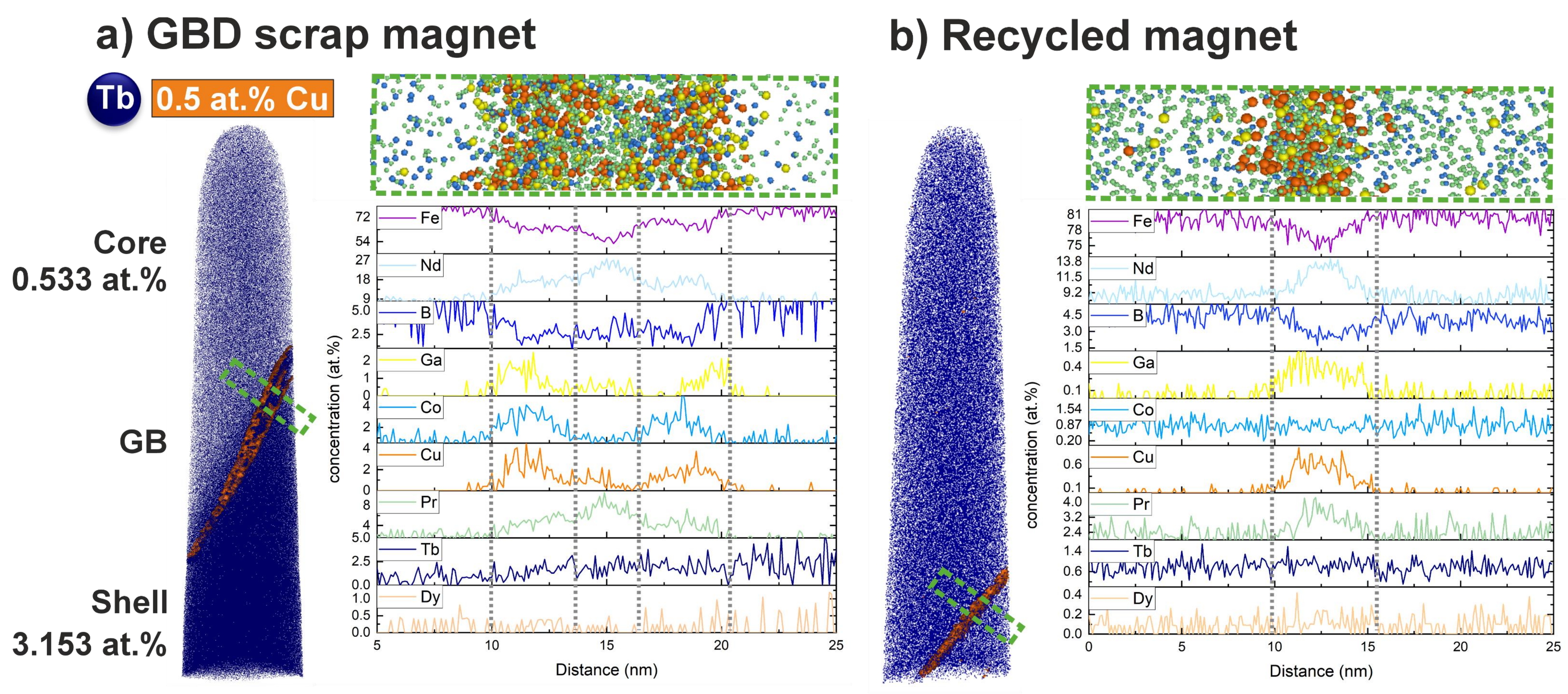
[3] Max-Planck-Institute for Sustainable Materials GmbH, Department of Microstructure Physics and Alloy Design, Max-Planck-Str. 1, 40237 Düsseldorf, Germany

## Recycling of resource-efficient GBDP magnets [1]

- Hydrogen decrepitation (HD) of over 100 commercial GBDP magnets (0.5 kg)
- Composition: $Nd_{23.0}Pr_{6.15}Tb_{1.76}Dy_{0.24}Fe_{bal}B_{0.93}Co_{0.89}Ga_{0.21}Al_{0.13}Cu_{0.08}$ (wt.%)
- Jet-milling to particle size $D_{50}$ of 5.4 µm, aligning, pressing, and sintering at 1100 °C for 4 h followed by annealing at 700 °C for 1 h and 500 °C for 1 h
- Investigations on the changes of the GBDP microstructure (core-shell) and magnetic properties
- GBDP with 1.5 wt.% pure Tb-foil at 900 °C for 9 h with subsequent low-temperature annealing to restore the magnetic properties




SEM-BSE images, EDS mappings, and EDS line scans through the functional recycling process. While at the GBD scrap magnet a narrow Tb-core-shell structure with 0.5 µm can be observed, the other samples show less clear core-shell formation but broader Tb enrichments at the outer regions of the grains.

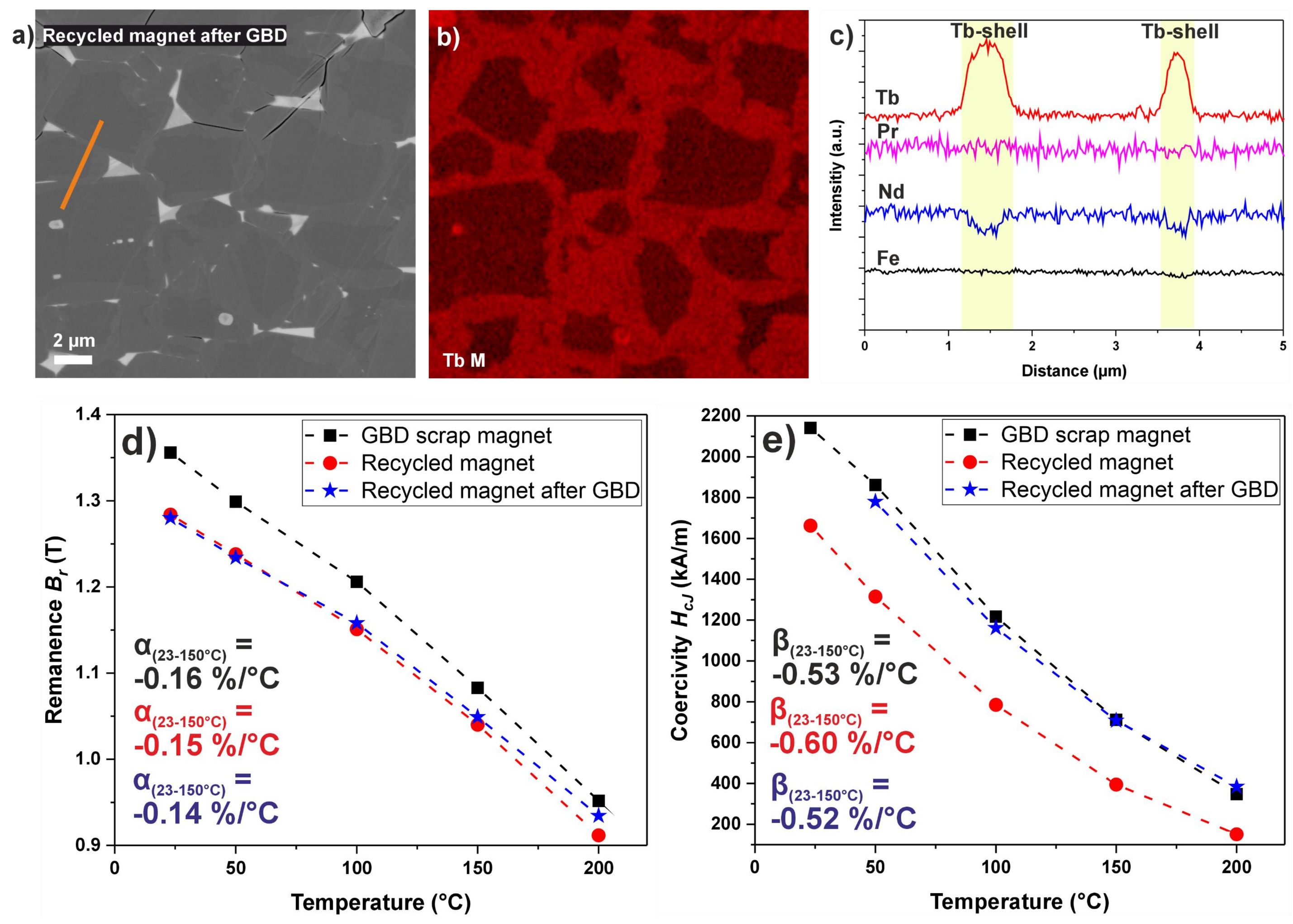



APT investigation of GBD scrap magnet (left) and recycled magnet (right) reveals beside a more homogenous distribution of Tb and disappearance of the core-shell microstructure also changes in the grain boundary elemental distribution through functional recycling.

## Contact

Mario Schönfeldt, M.Eng.
Magnetic Materials
Tel. +49 6023 32039-852
mario.schoenfeldt@iwks.fraunhofer.de

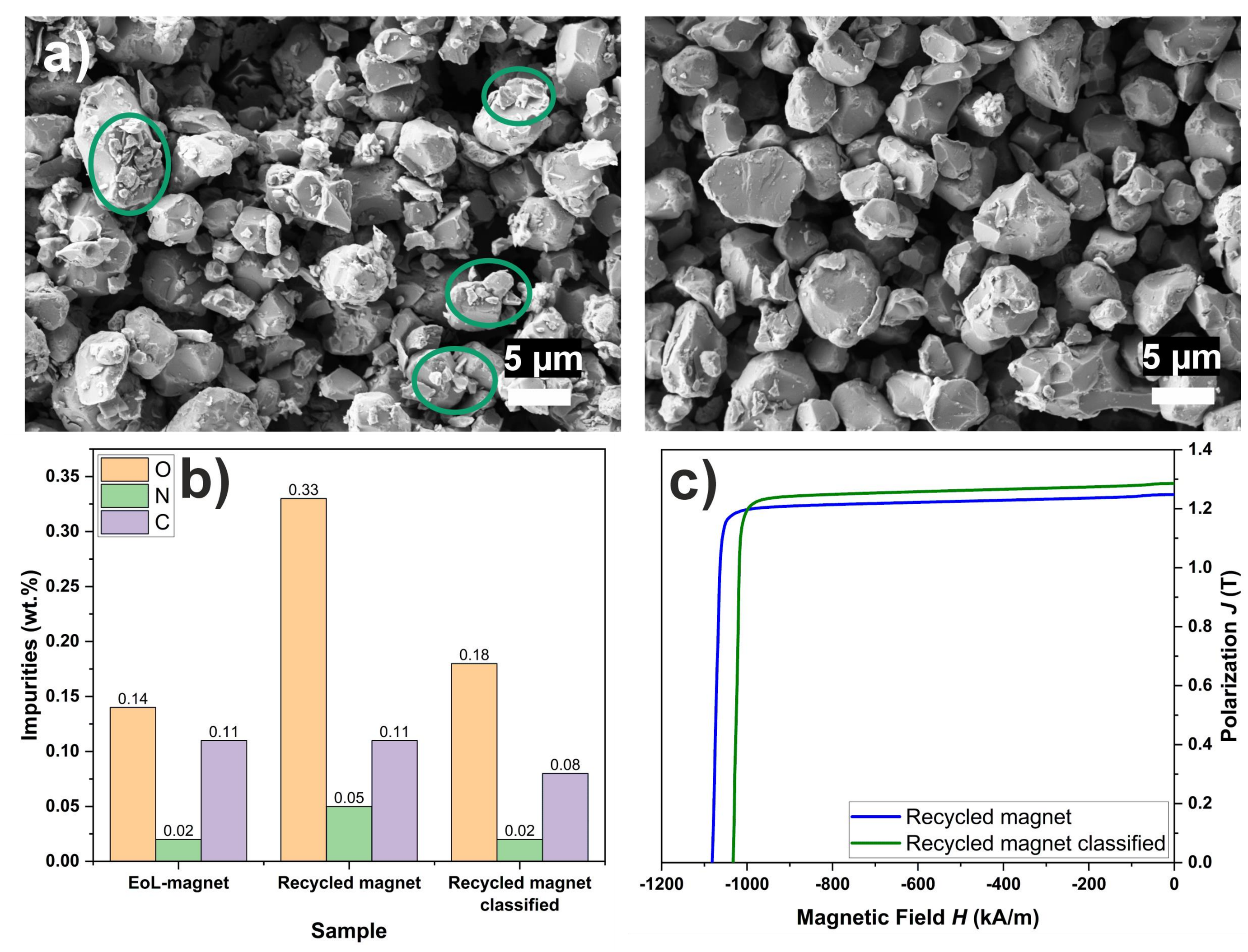
Fraunhofer IWKS
Aschaffenburger Str. 121
63457 Hanau, Germany
www.iwks.fraunhofer.de




A renewed GBDP process at a recycled magnet shows a new formation of Tb-shells, with thickness comparable to the scrap magnet. The coercivity of recycled magnets can be fully restored. The temperature coefficients exceed the original values which leads to an improved temperature stability of recycled magnets.

## Classifying of recycled powders [2]

- High oxidation affinity of fine (< 10 µm) Nd-Fe-B powder particles can lead to contaminations (e.g., absorption of $O_2$) during recycling
- Removal of particles < 1 µm should lower the content of impurities
- HD of 15 kg of EoL-magnets from wind turbines with subsequent milling and classifying at a spiral jet-mill




The classified powder shows a smaller number of finest particles (a). This leads to a reduction of the oxygen, nitrogen, and carbon content (b), and an improved $B_r$ and $(BH)_{max}$ value of the recycled magnets (c).

## Conclusion

- GBDP magnets can be recycled with similar rectangular demagnetization curves but reduced coercivity through microstructural changes
- A renewed GBDP or modified particle size distribution can improve and restore the magnetic properties

[1] M. Schönfeldt et al., Acta Materialia 283 (2025) 120532.
[2] M. Schönfeldt et al., Advanced Engineering Materials, to be published.

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