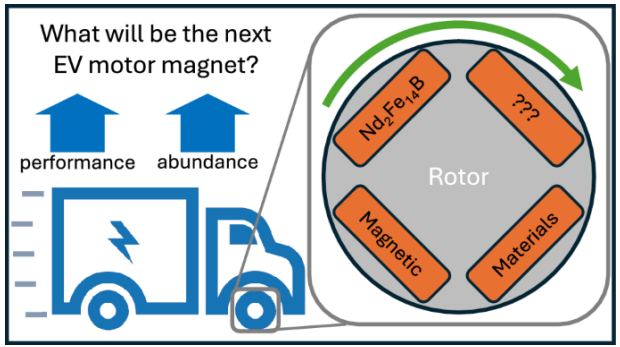


Rom, Smaha, O'Donnell, Dugu, Bauers, *MRS Bulletin,* 2024,
doi: 10.1557/s43577-024-00743-4

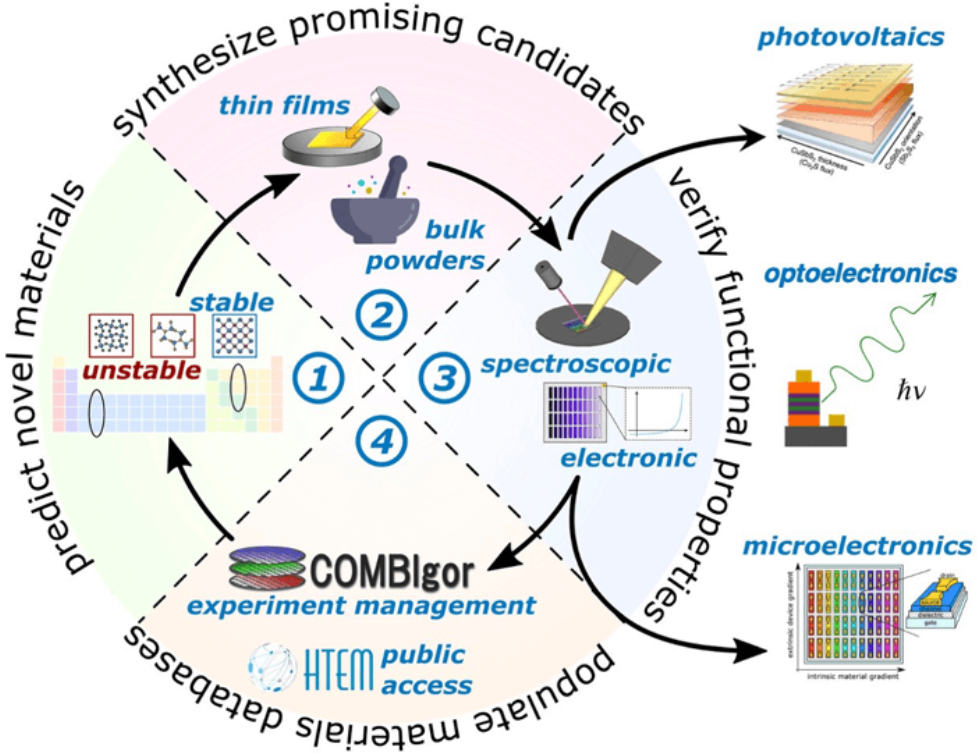
Emerging magnetic materials for electric vehicle drive motors

Chris Rom (he/him), Rebecca W. Smaha, Shaun O'Donnell, Sita Dugu, Sage R. Bauers

Materials Discovery Team

National Renewable Energy Laboratory

Materials Discovery at NREL



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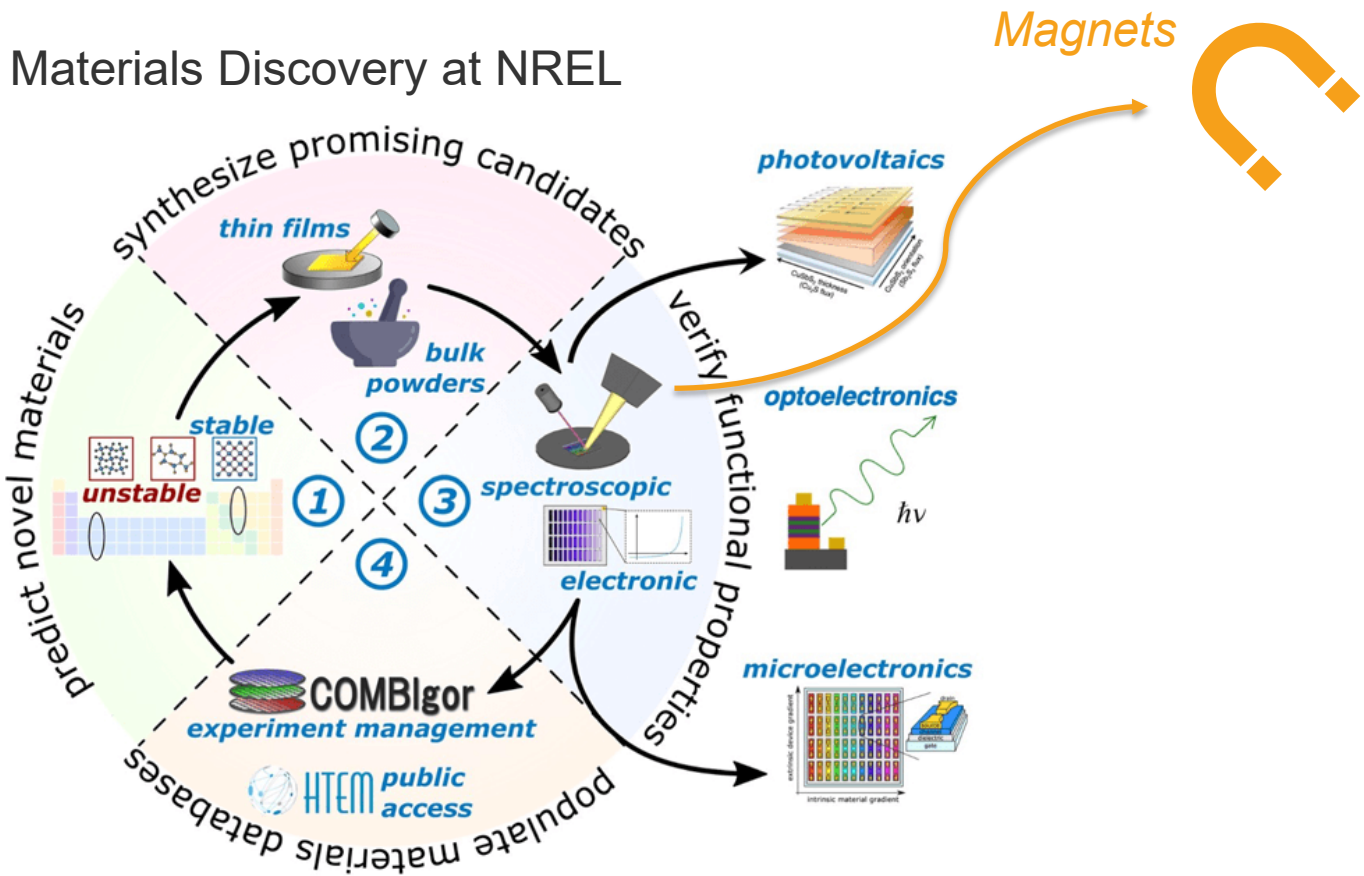

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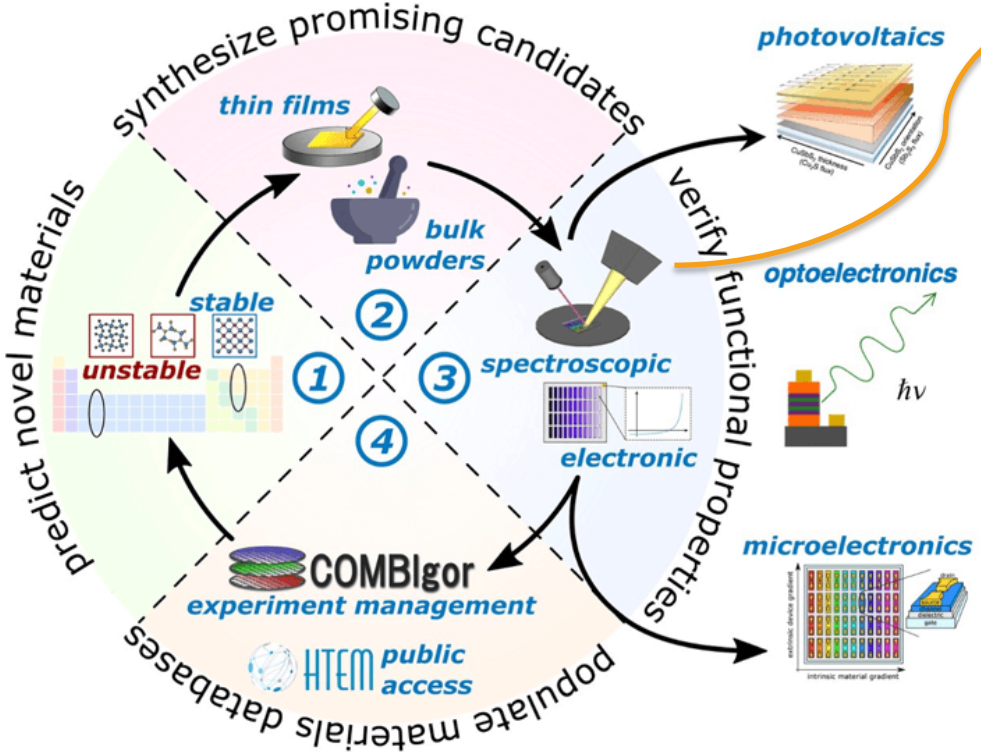
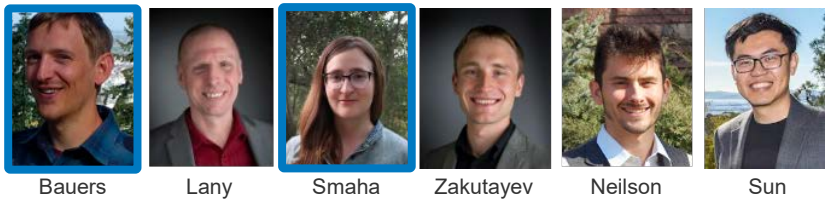


PIs



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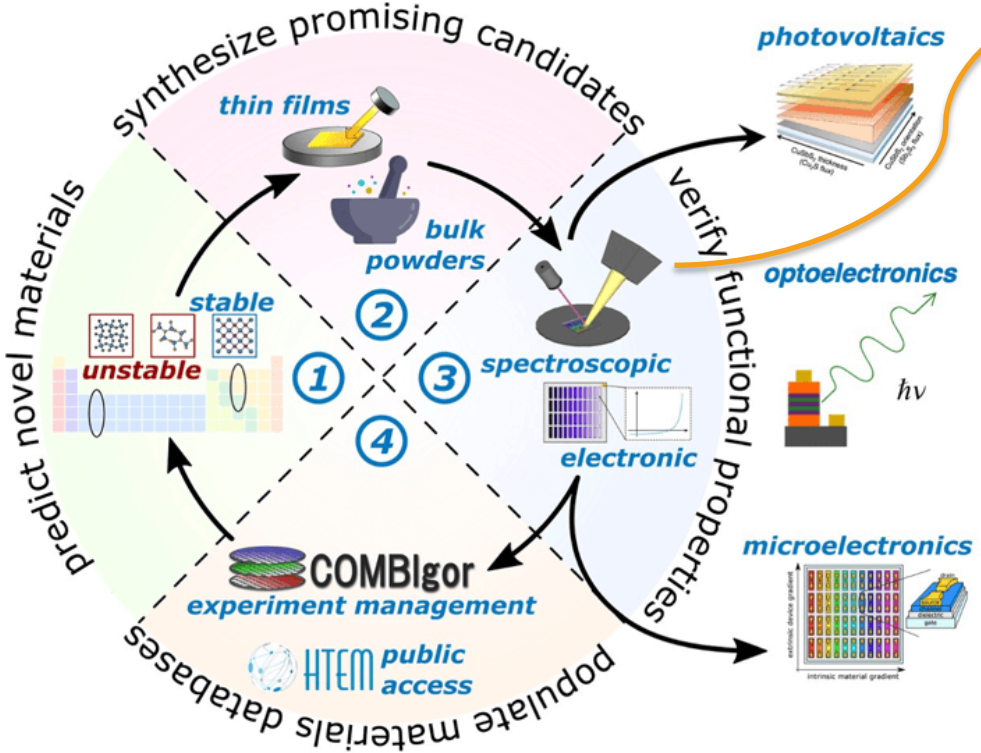
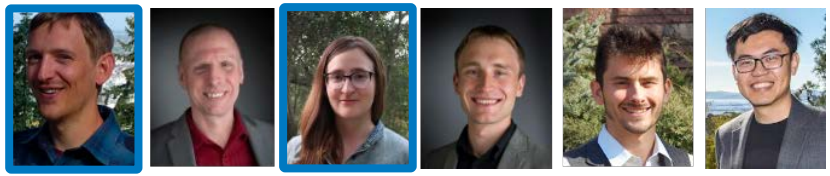


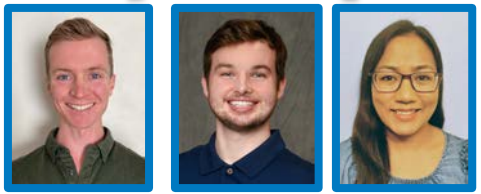
Magnets

PIs



Review co-authors

Postdocs



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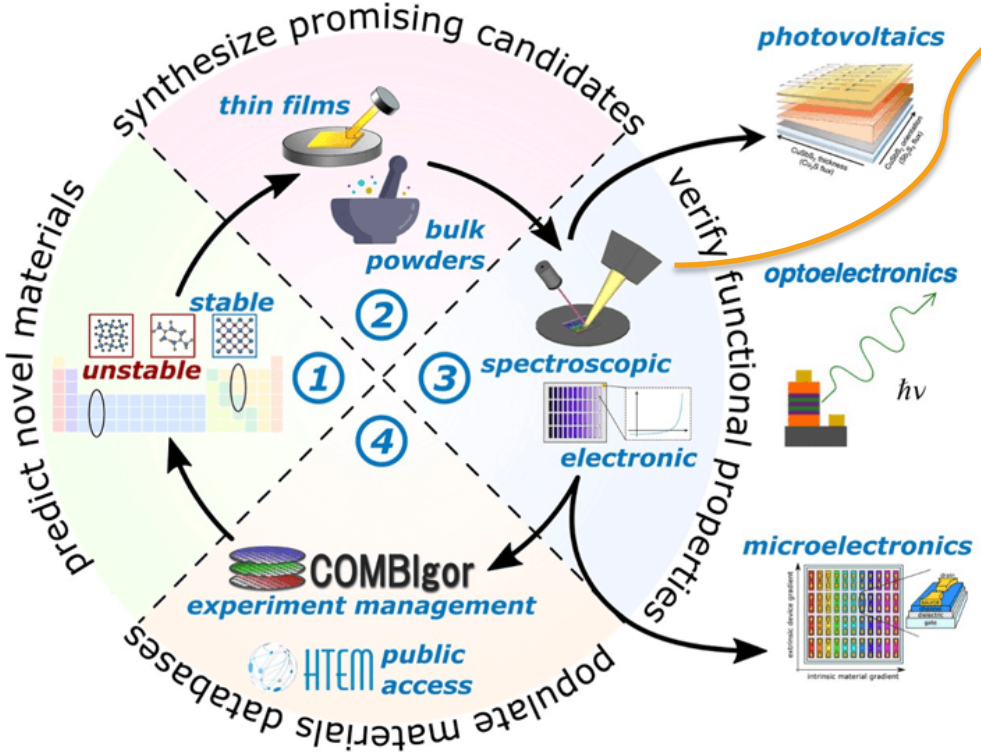
Materials Discovery at NREL



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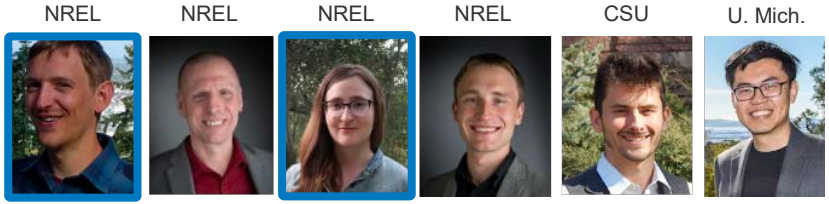

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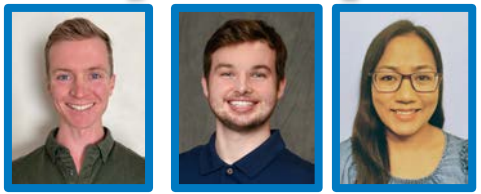

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Materials chemistry perspective

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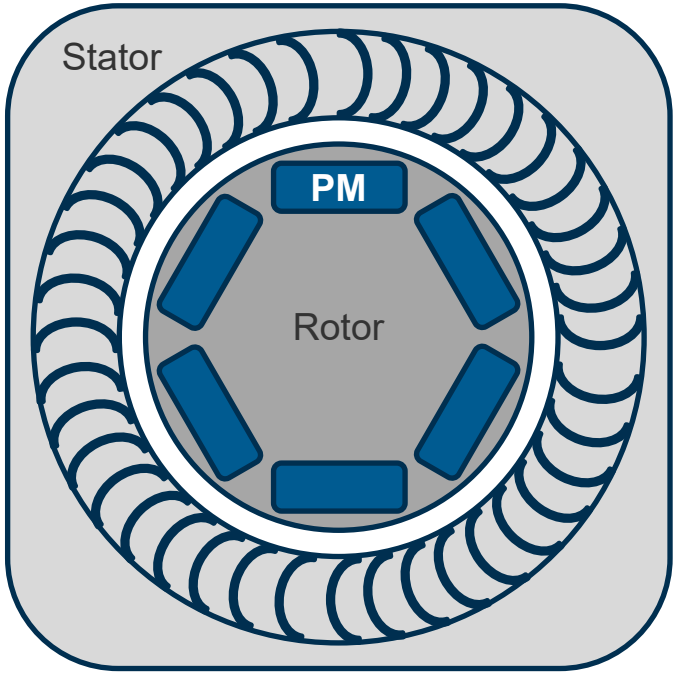
Each EV needs ~2 kg of permanent magnets



Rom, Smaha, O'Donnell, Dugu, Bauers, *MRS Bulletin,* 2024, doi: 10.1557/s43577-024-00743-4

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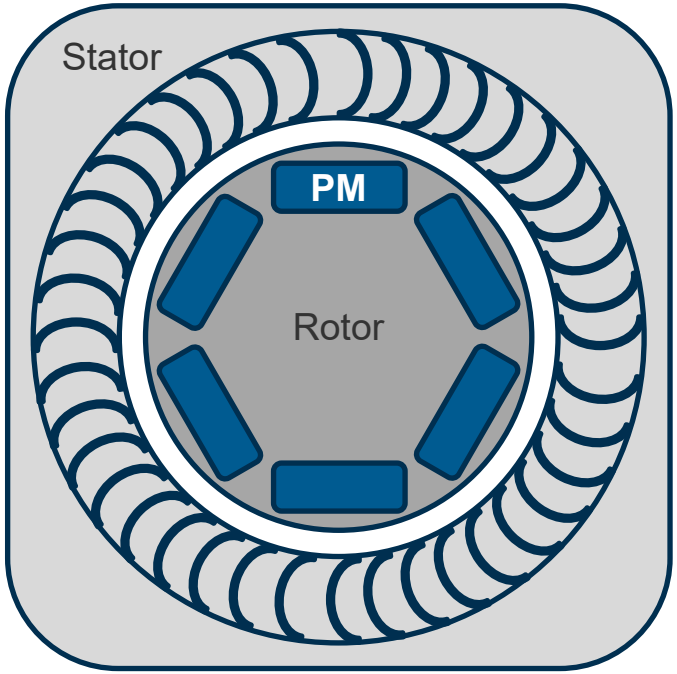
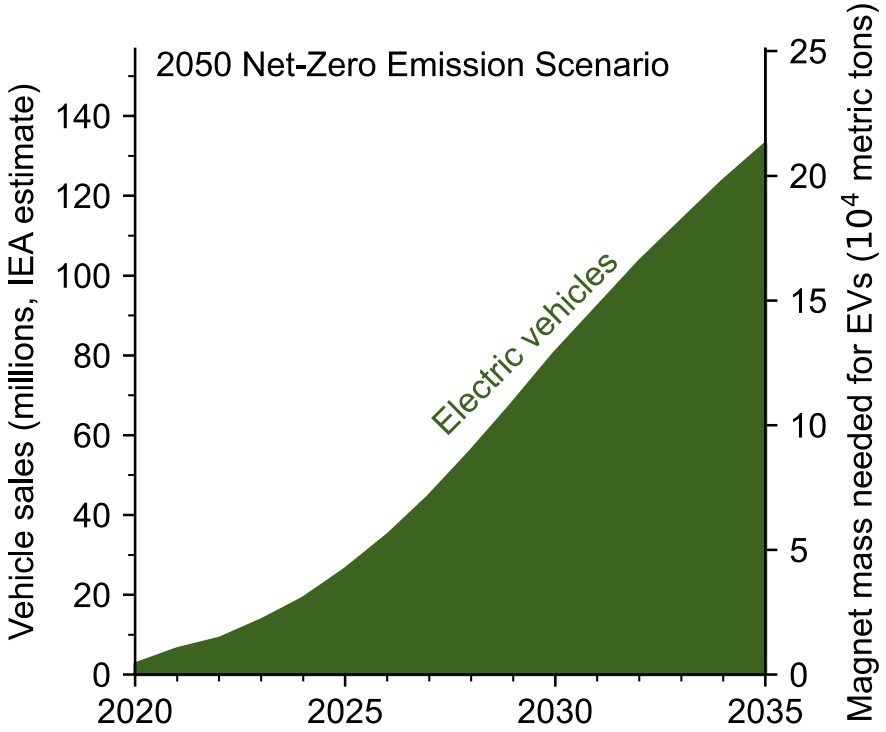
Each EV needs ~2 kg of permanent magnets → massive demand





US Department of Energy (DOE), *Critical Materials Assessment* (DOE, Washington, DC, 2023)

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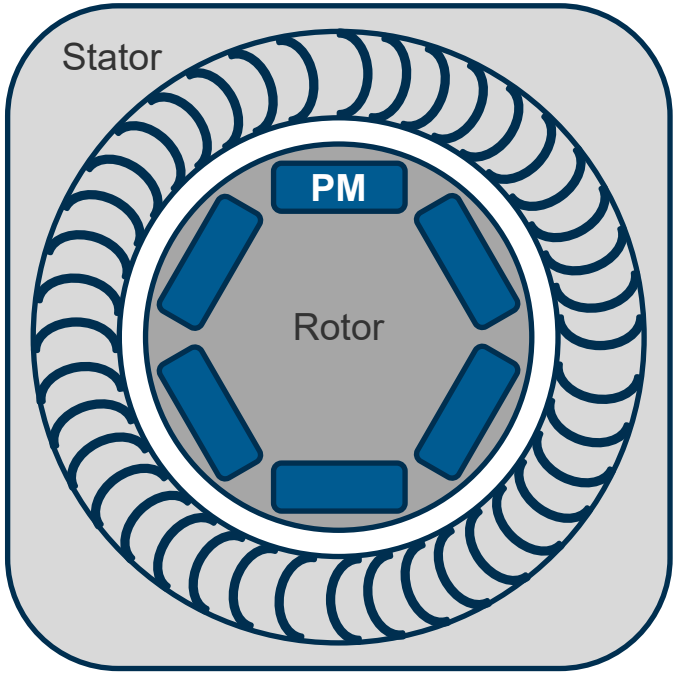

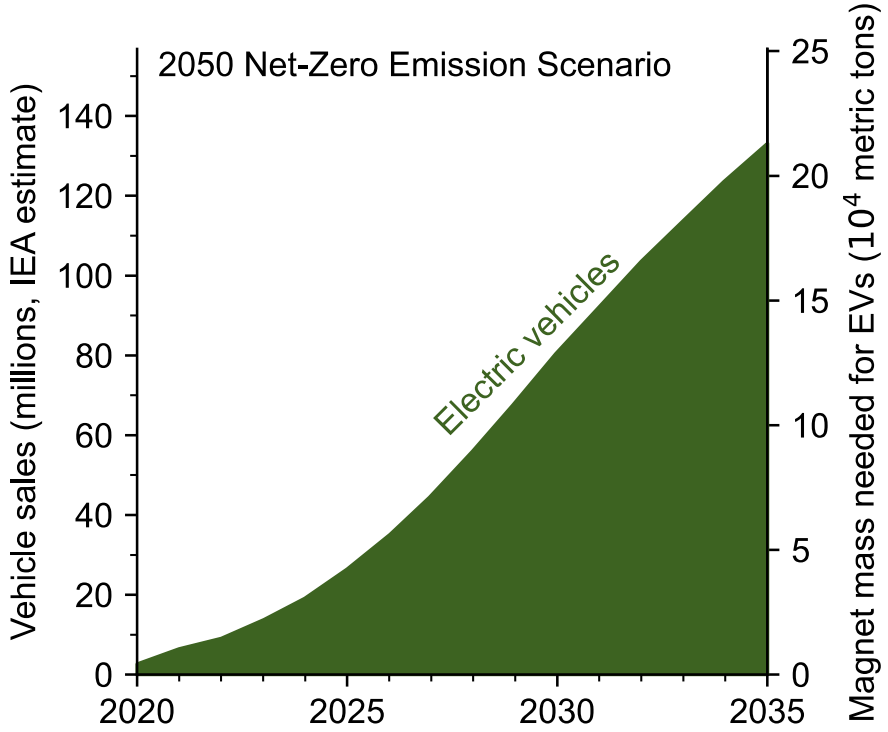

US Department of Energy (DOE), *Critical Materials Assessment* (DOE, Washington, DC, 2023)

What magnets will drive future EVs?

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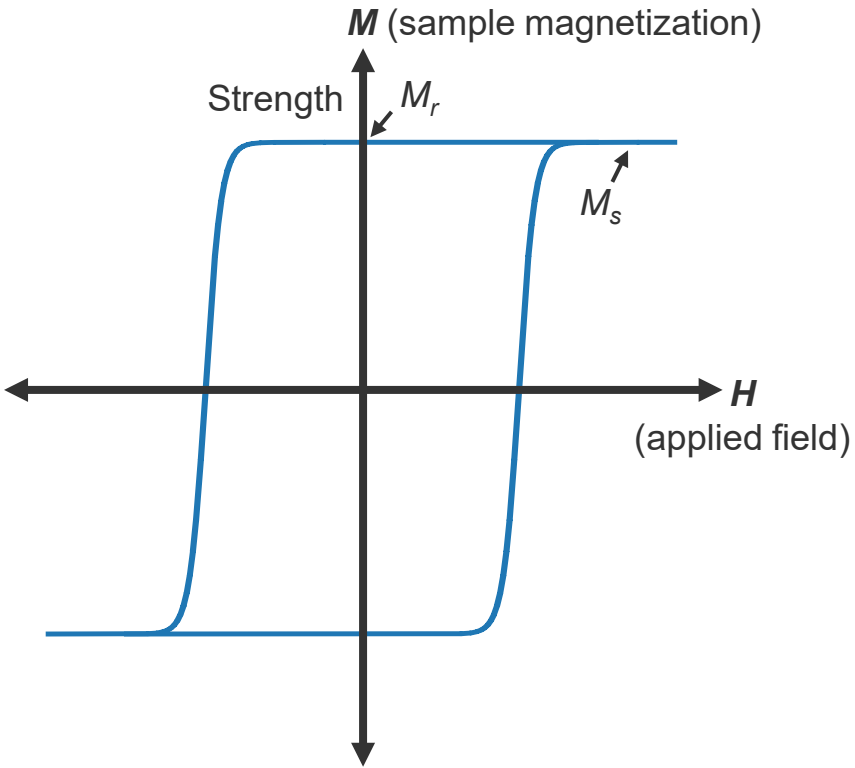
Magnets need high magnetization



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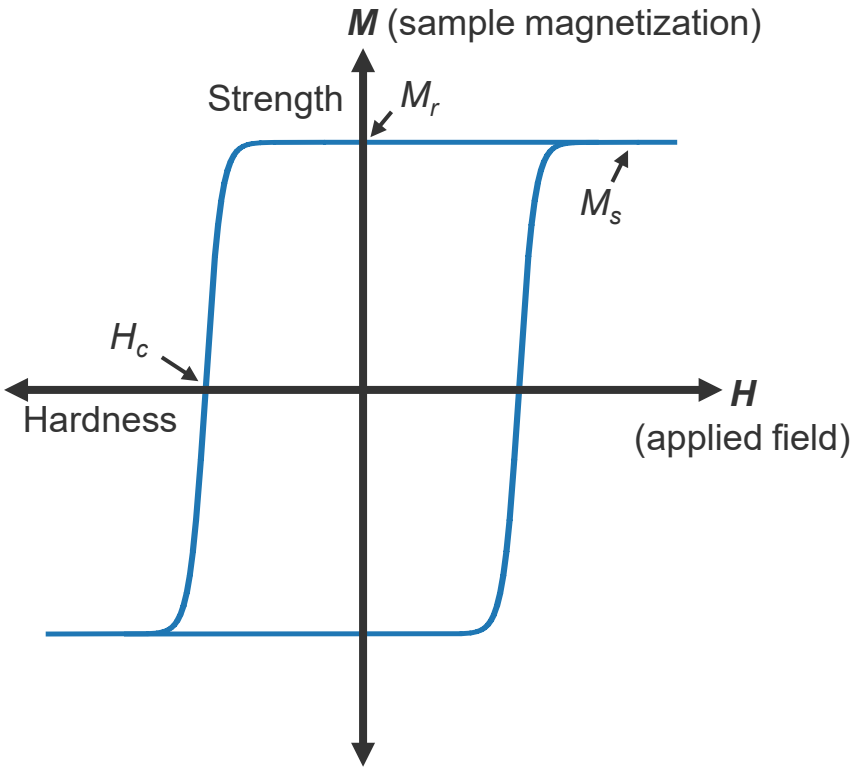
Magnets need high magnetization, coercivity



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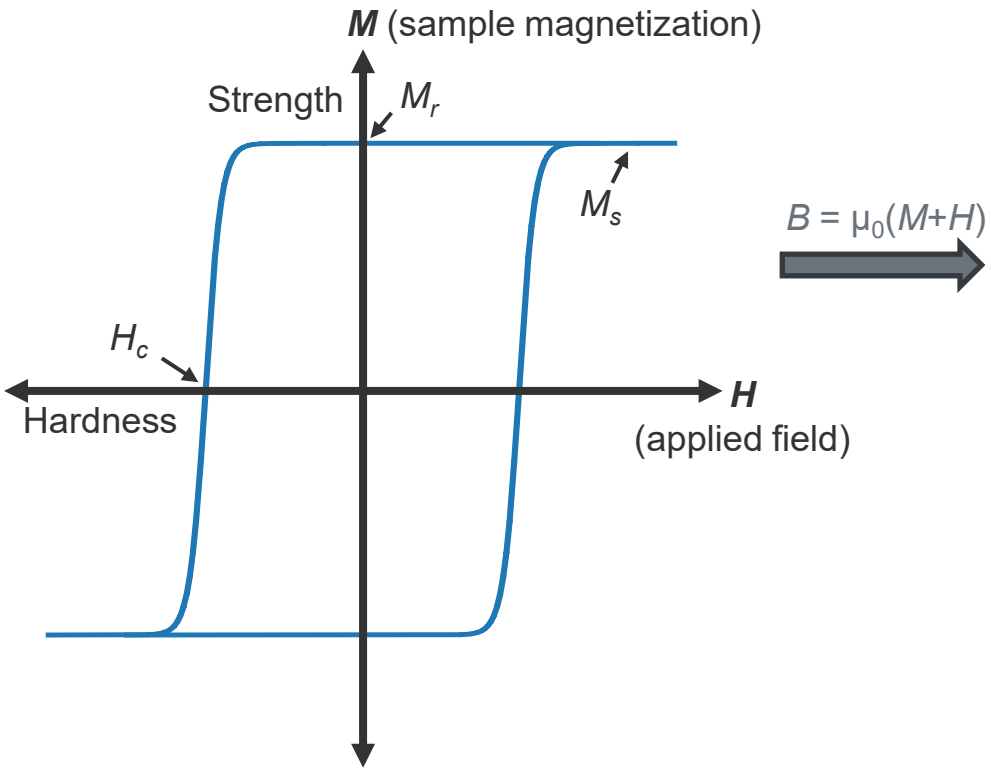

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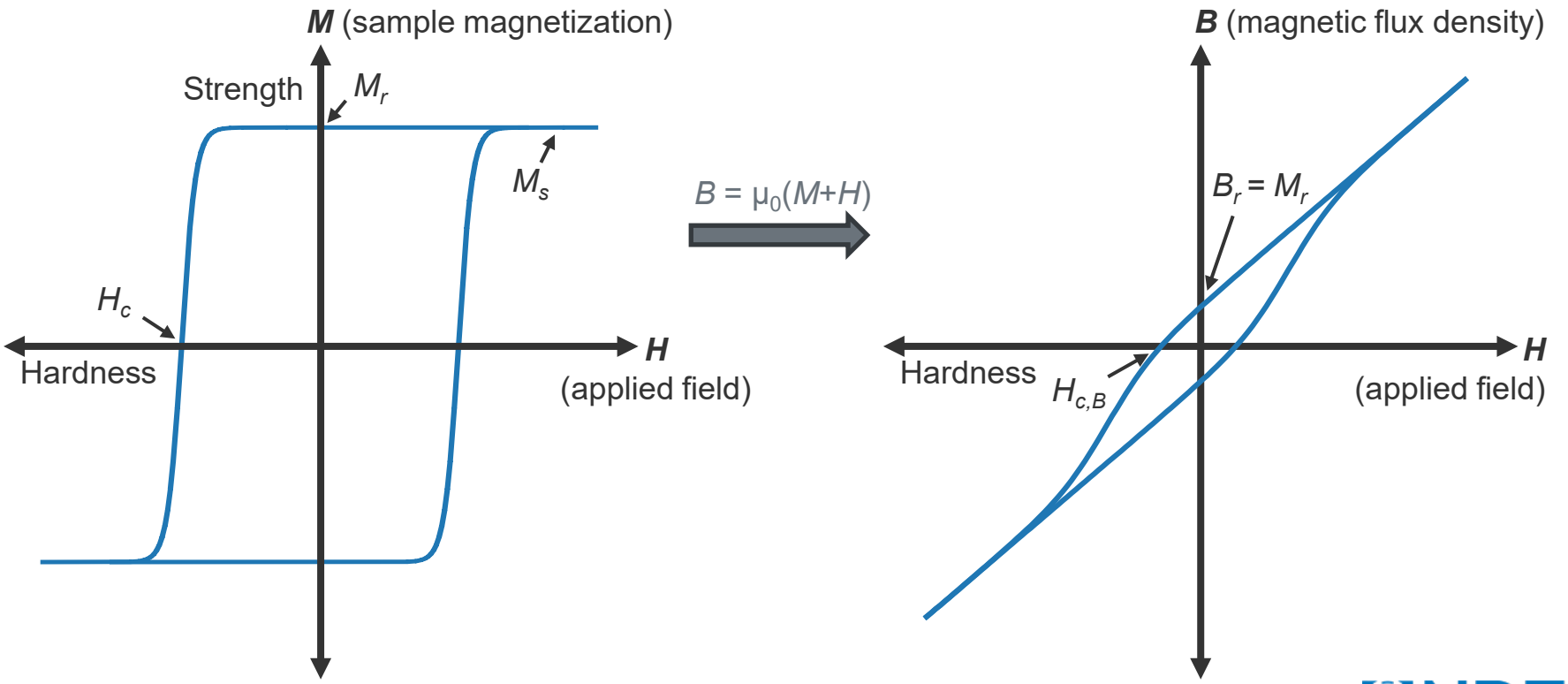

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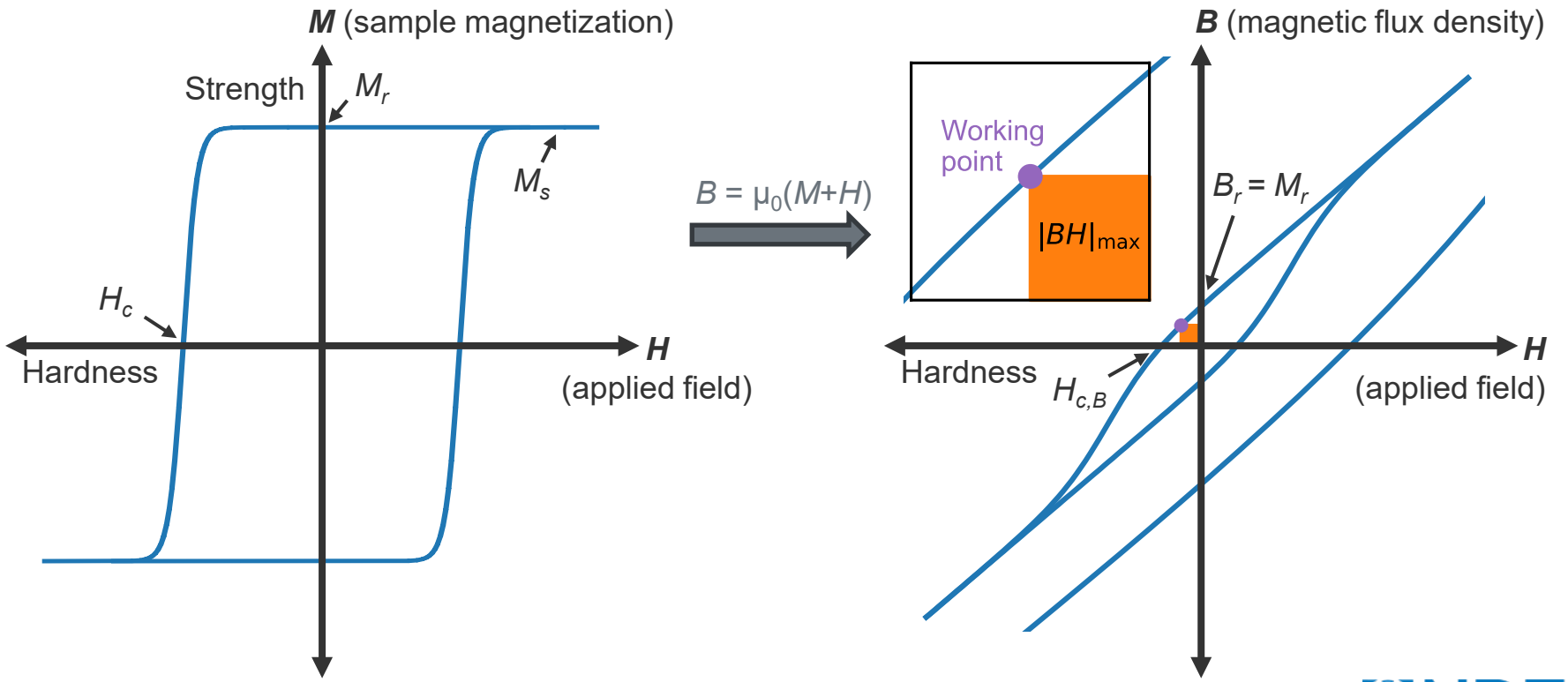

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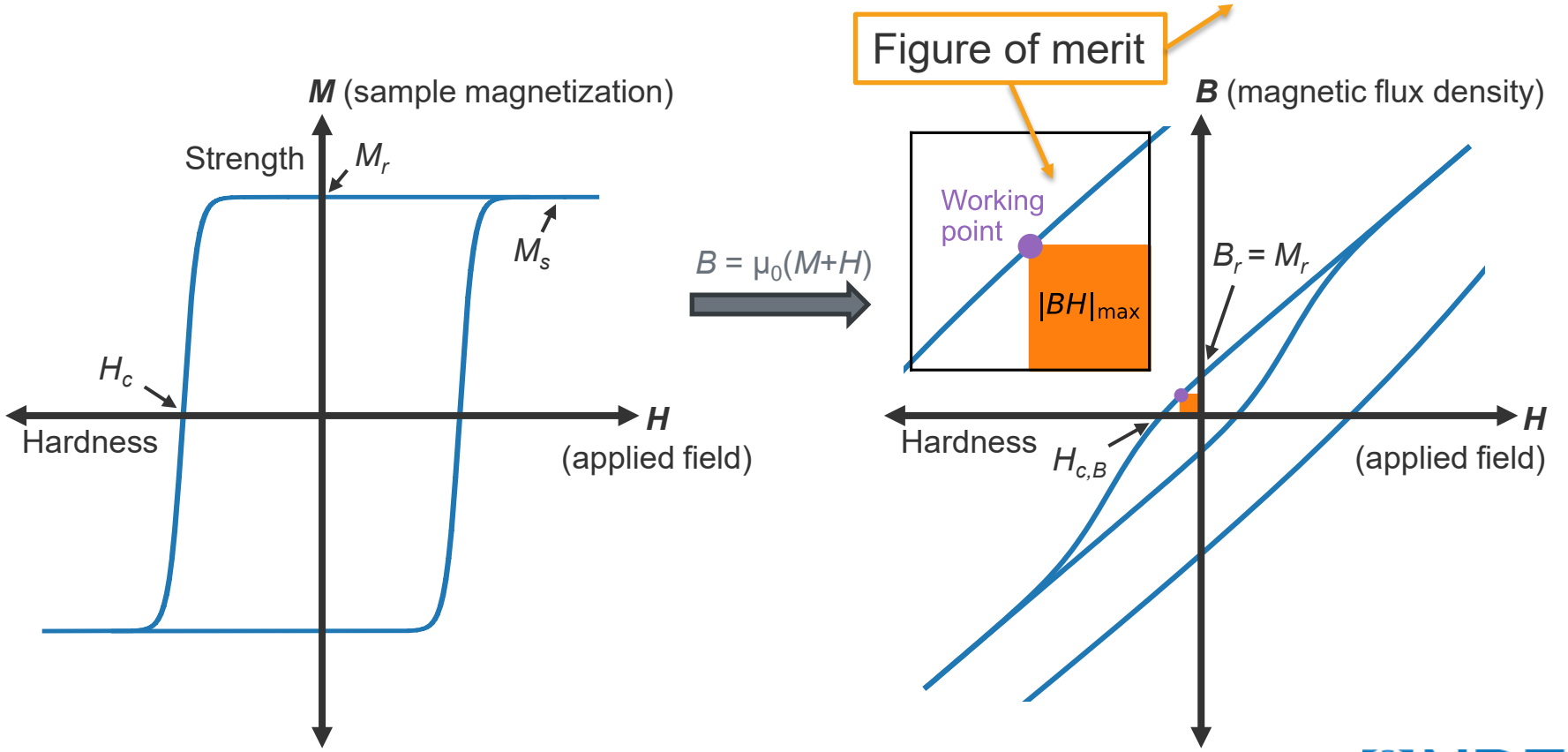

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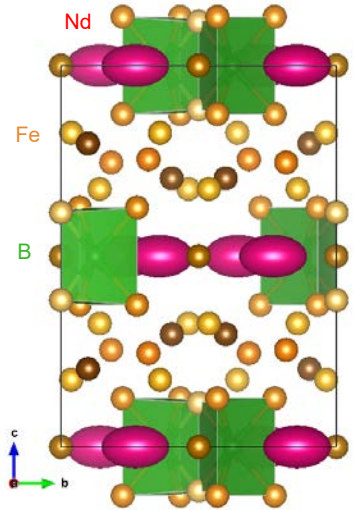
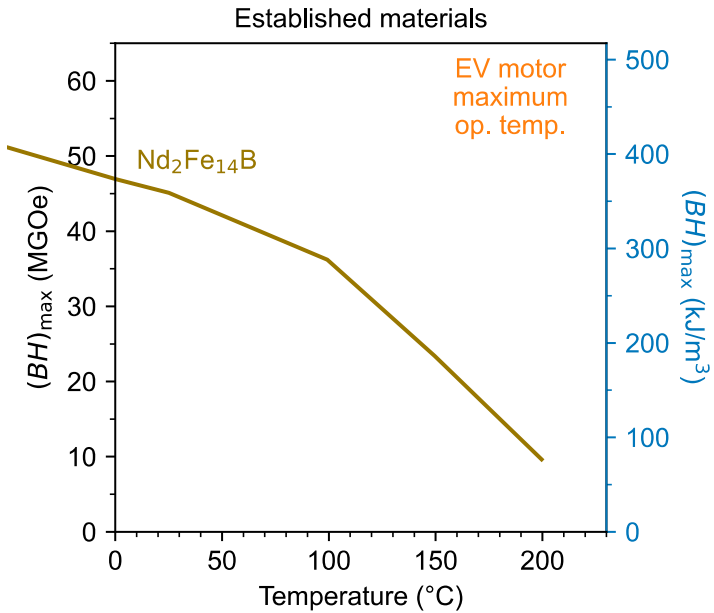
$Nd_2Fe_{14}B$ is the leading magnet for EVs





Adapted from: Cui, Kramer, Zhou, Liu, Gabay, Hadjipanayis, Balasubramanian, Sellmyer, *Acta Mater.* **158**, 118 (2018)

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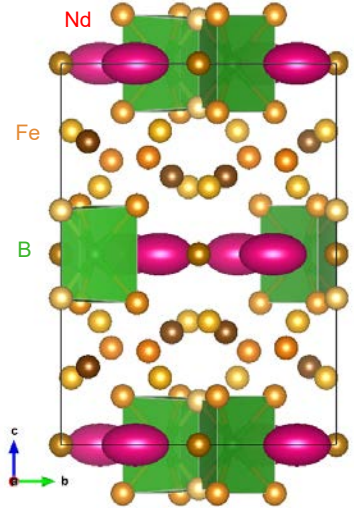

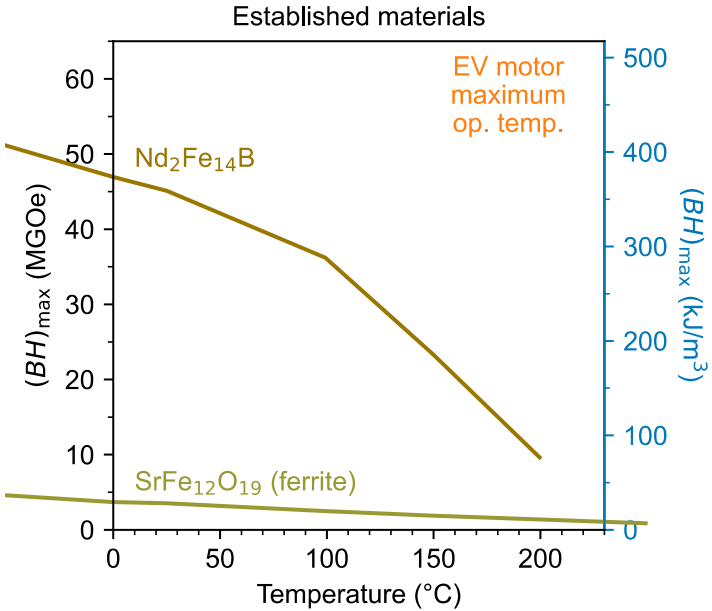

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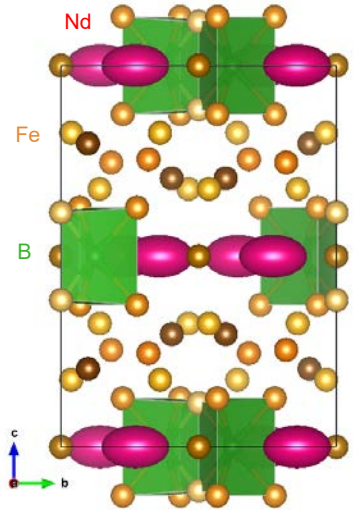

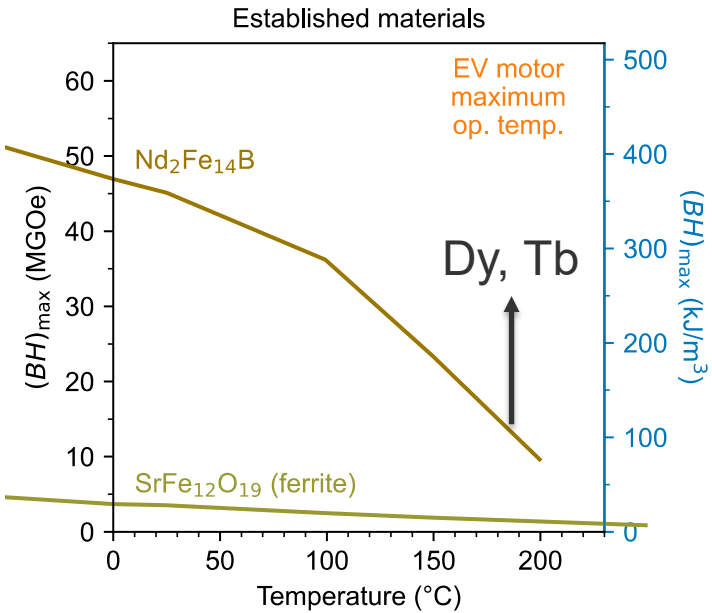

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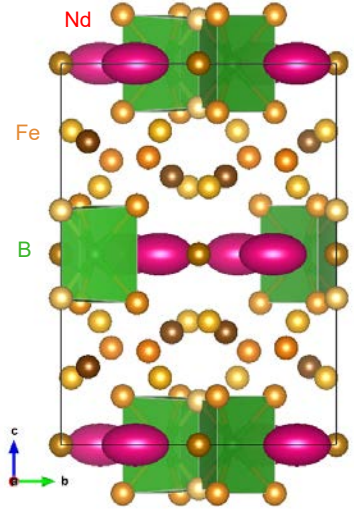
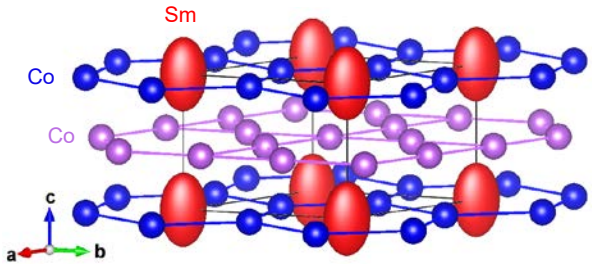
$Nd_2Fe_{14}B$ is the leading magnet for EVs, Sm-Co are pricier alternatives



$SmCo_5$



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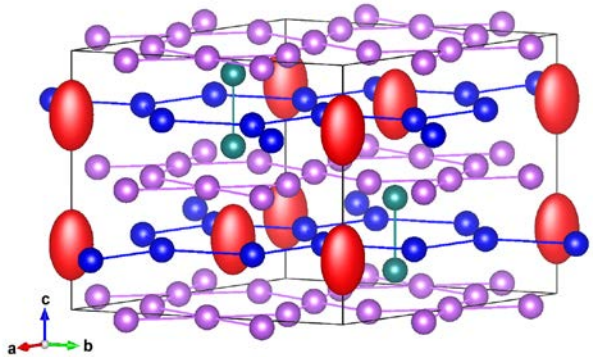

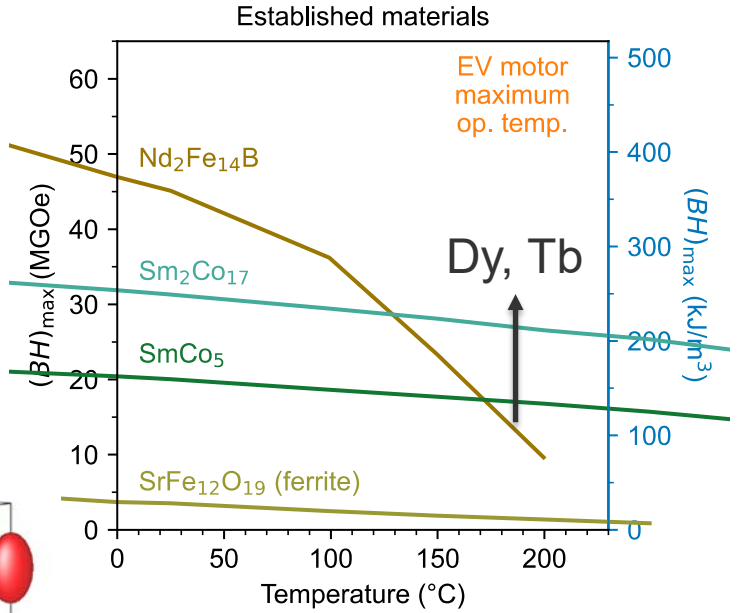

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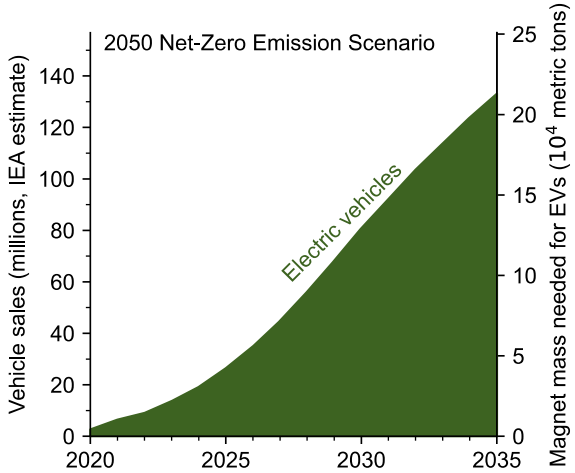
Established PM materials rely on critical materials



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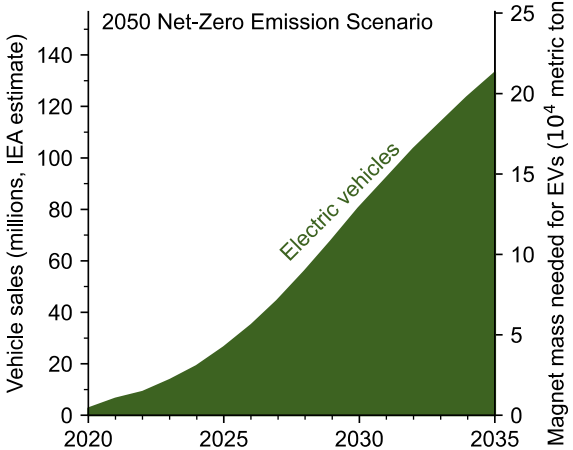

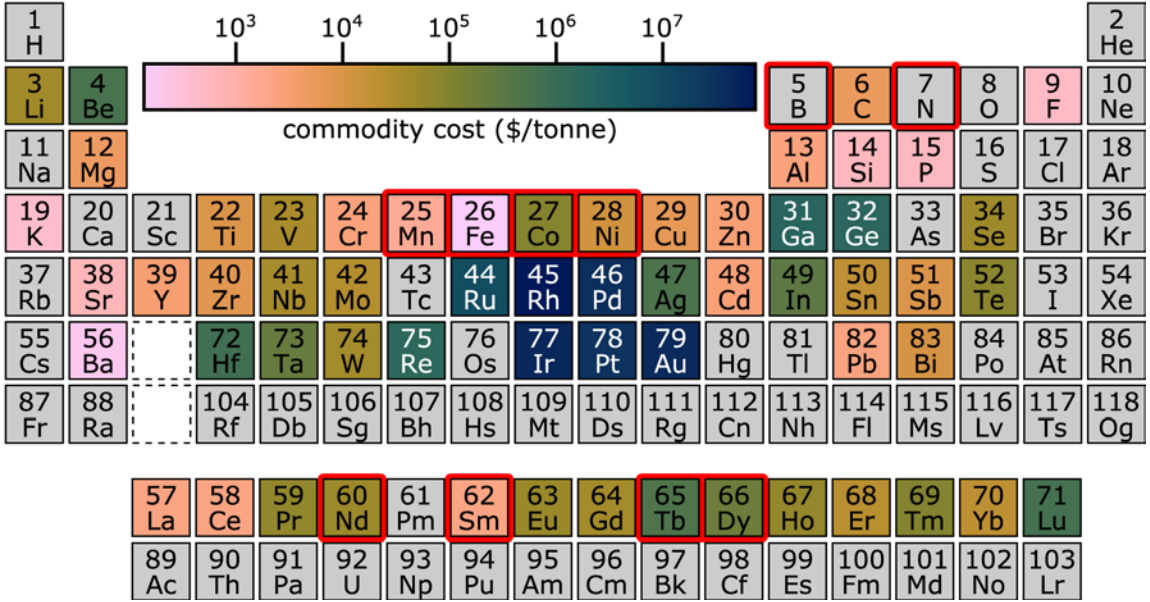

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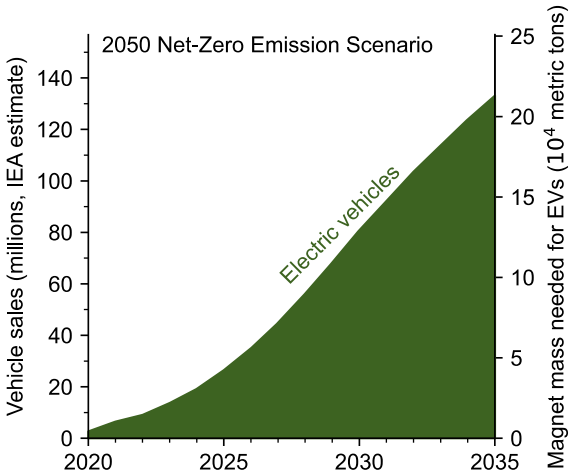

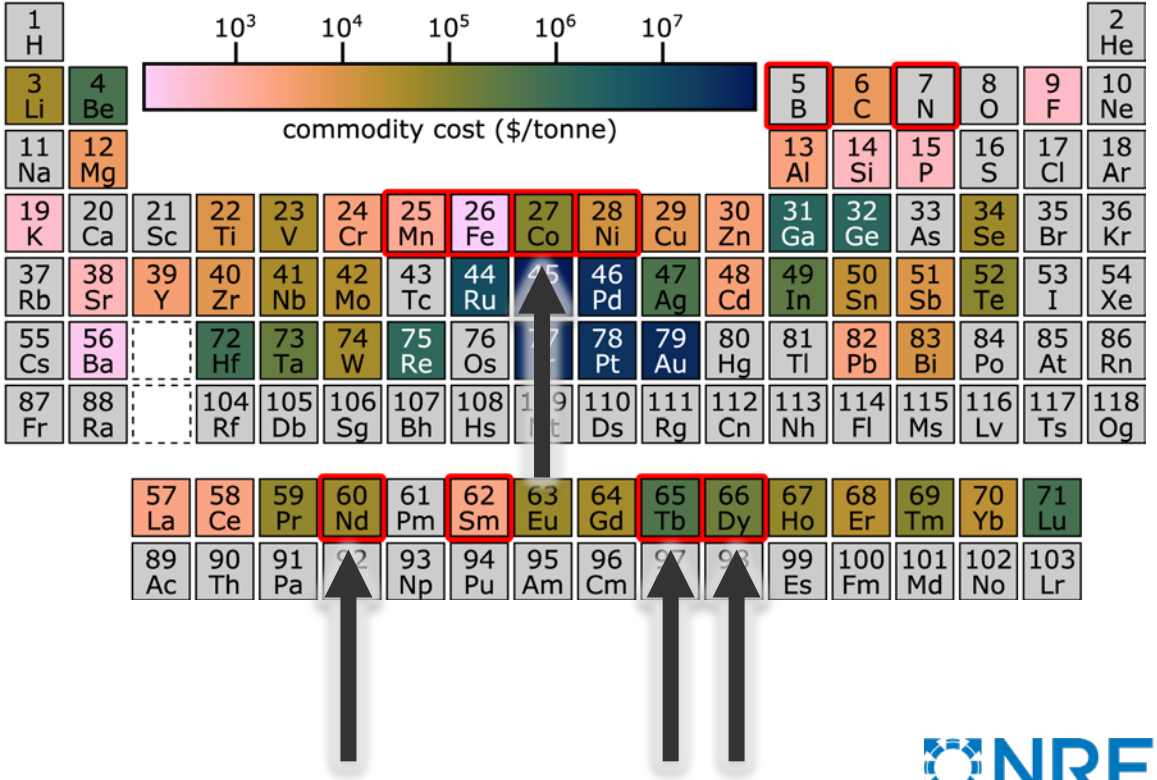

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Emerging PM materials rely on non-critical materials

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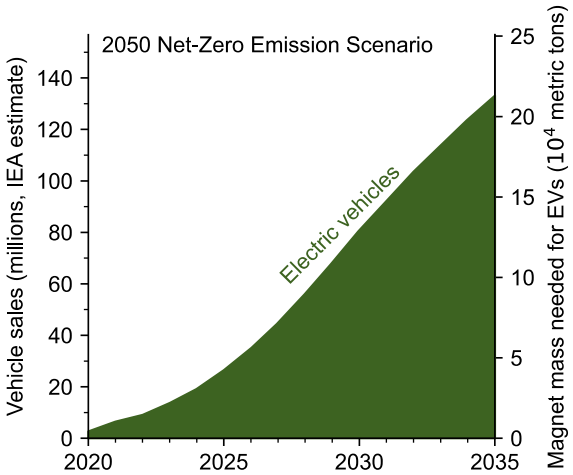

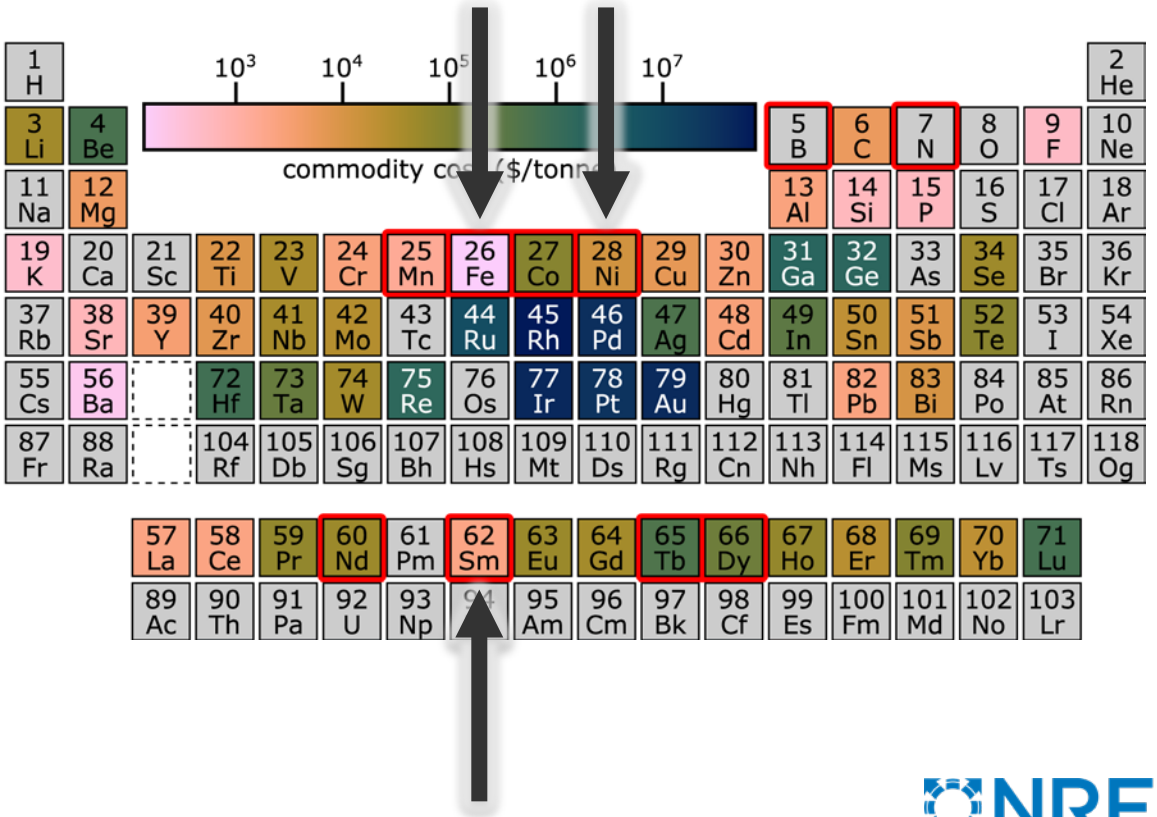

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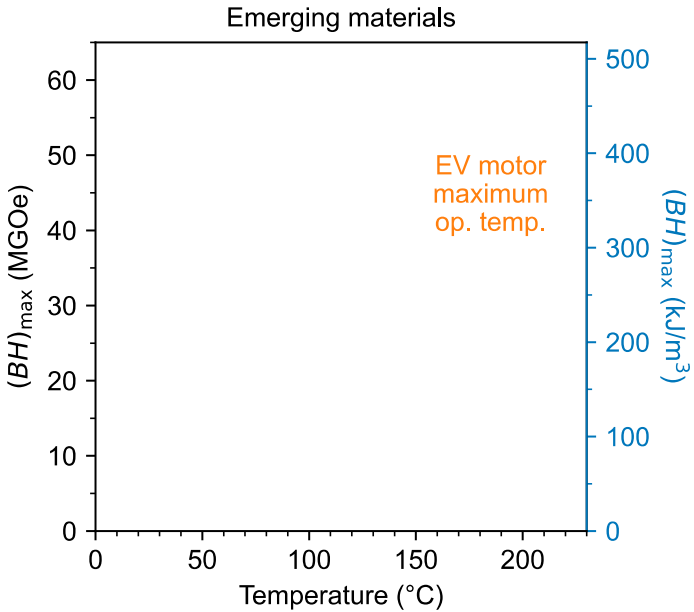

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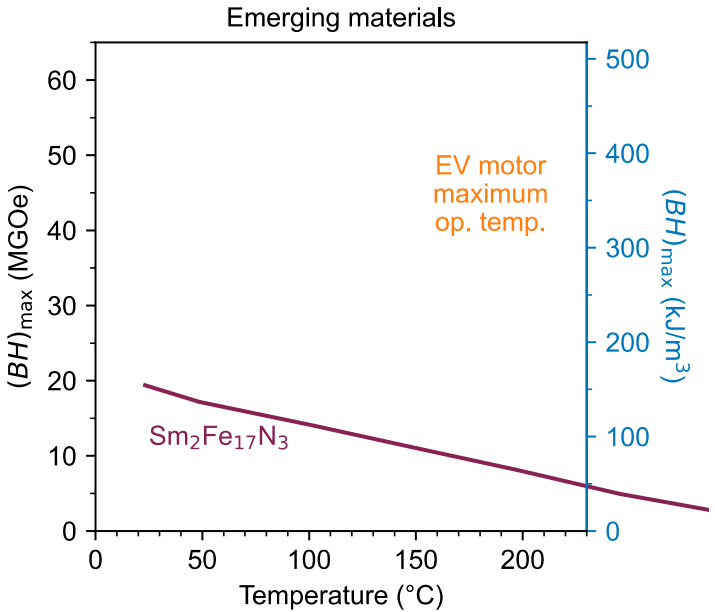
$Sm_2Fe_{17}N_3$ relies on non-critical Sm and Fe



Kuchi, D. Schlagel, T.A. Seymour-Cozzini, J.V. Zaikina, I.Z. Hlova, *J. Alloys Compd.* **980**, 173532 (2024)

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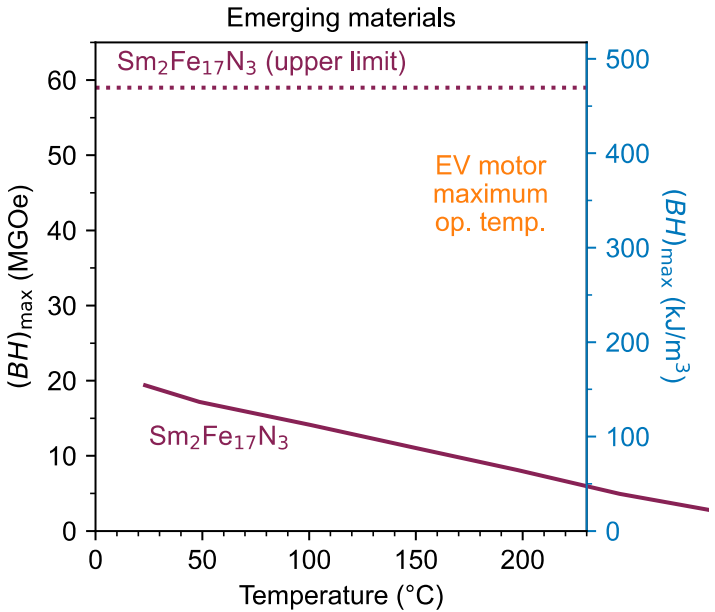

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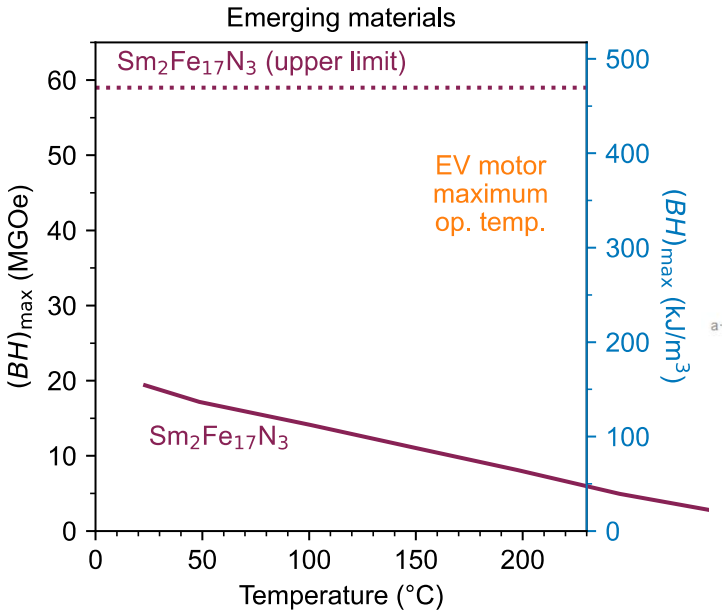

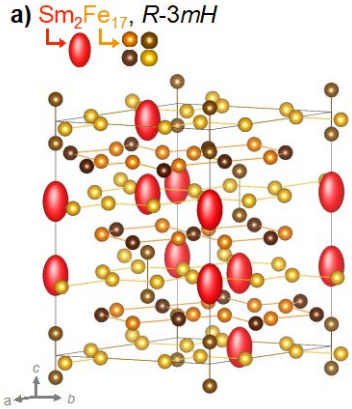

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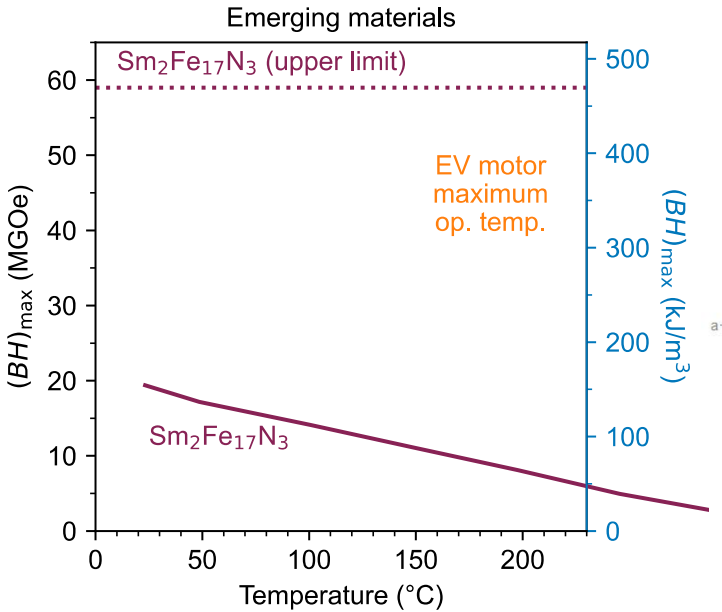

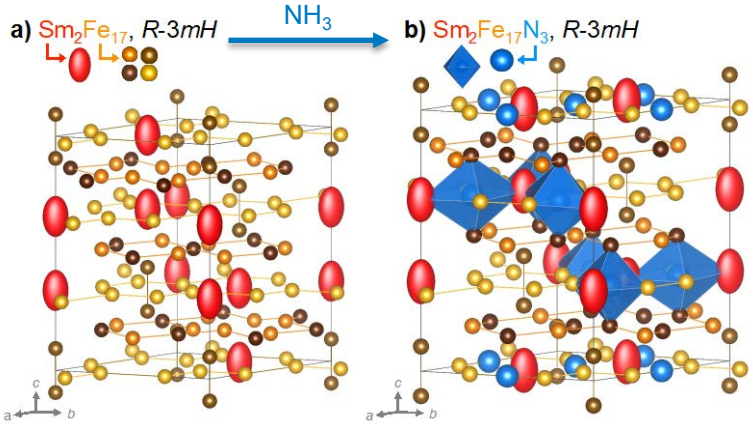

Kuchi, D. Schlagel, T.A. Seymour-Cozzini, J.V. Zaikina, I.Z. Hlova, *J. Alloys Compd.* **980**, 173532 (2024)

Rom, Smaha, O'Donnell, Dugu, Bauers, *MRS Bulletin,* 2024, doi: 10.1557/s43577-024-00743-4

NREL Transforming ENERGY

$Sm_2Fe_{17}N_3$ relies on non-critical Sm and Fe

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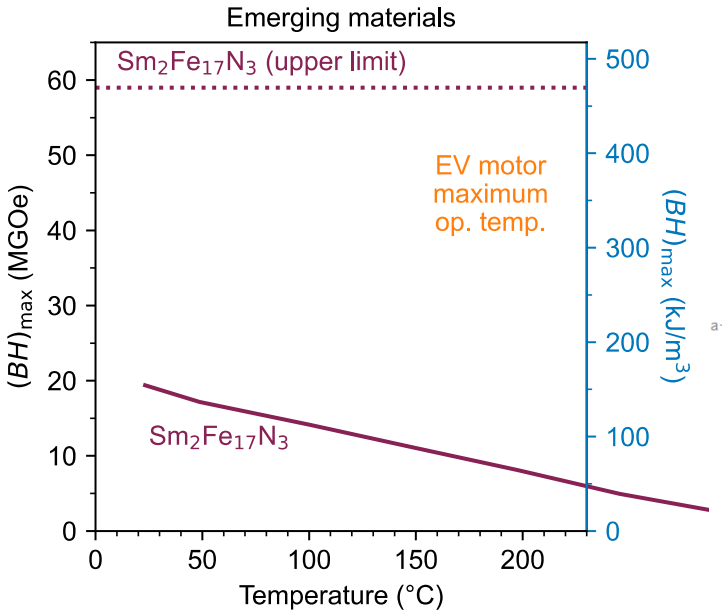

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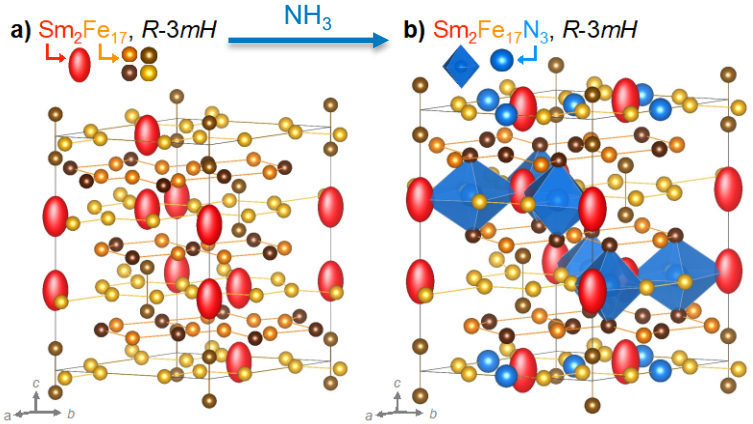

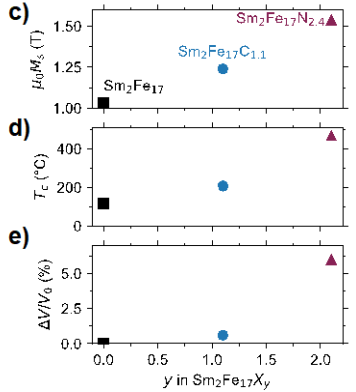

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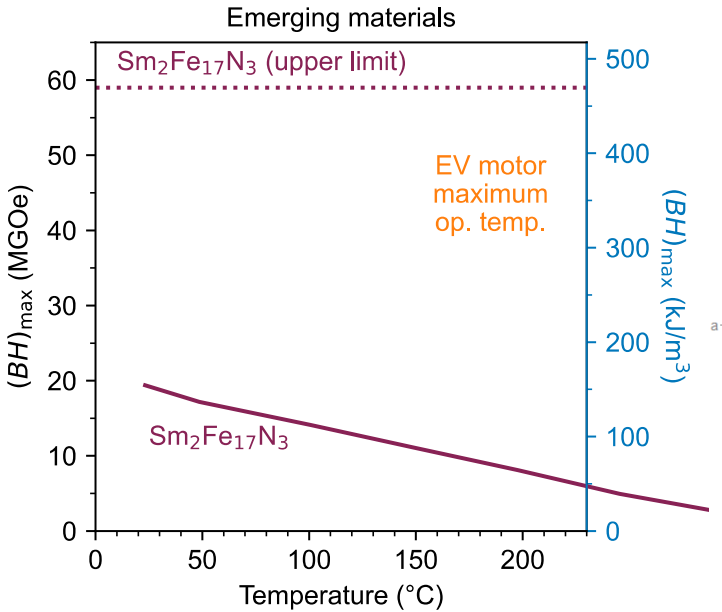

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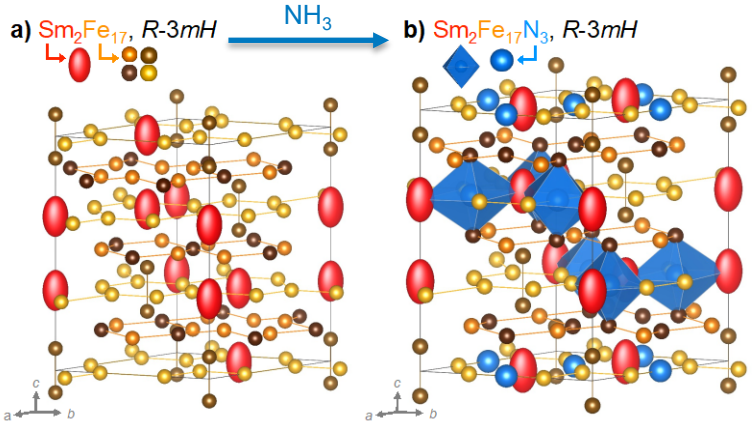

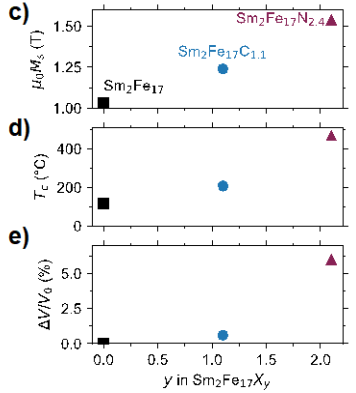

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N expands lattice, strengthens magnet

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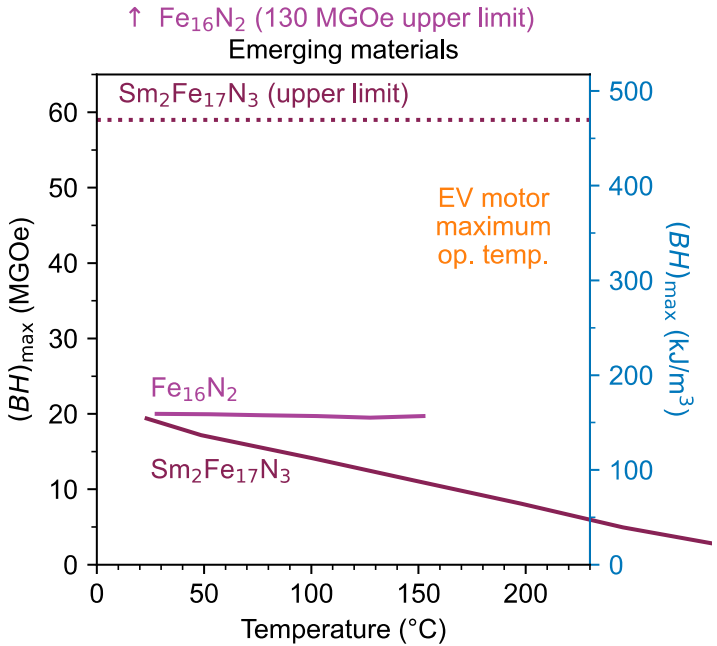

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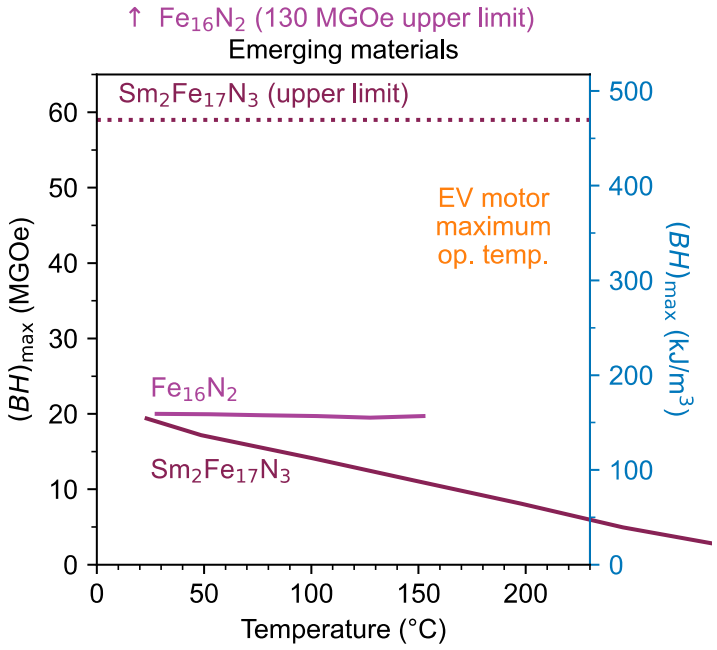

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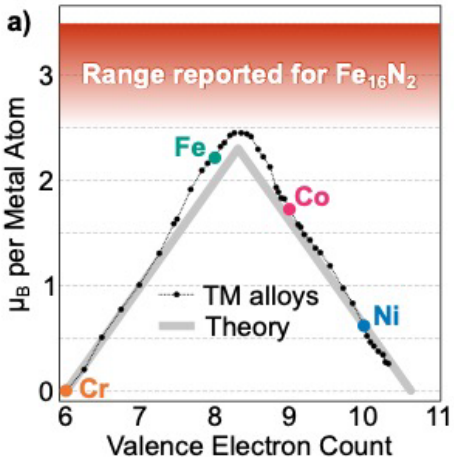

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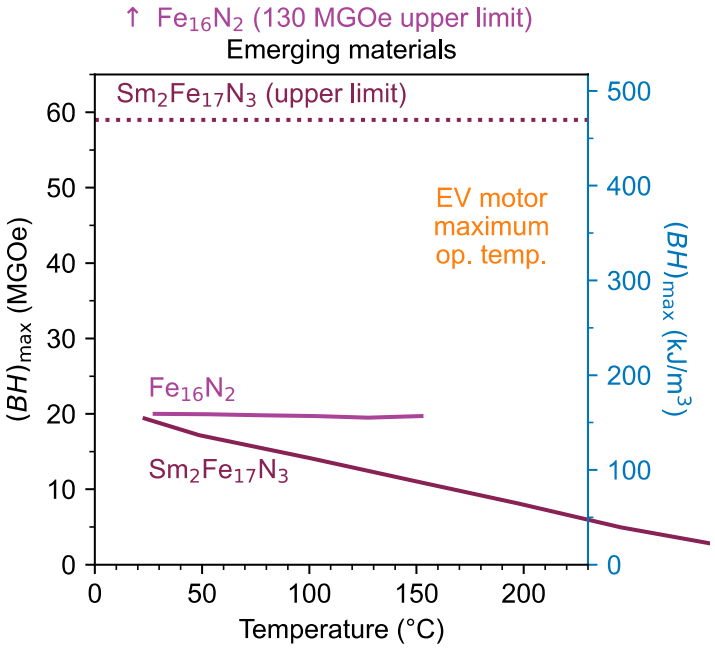

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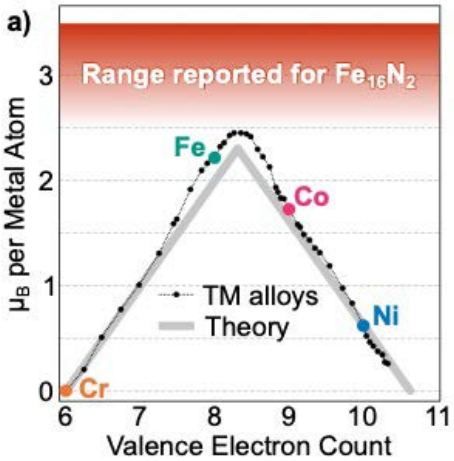

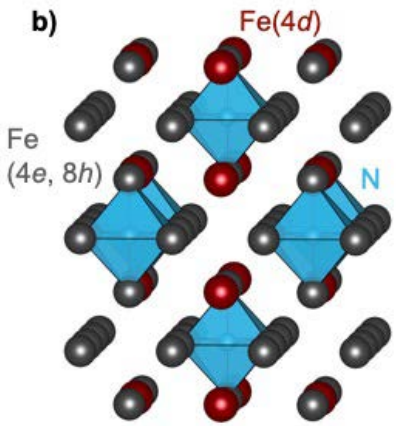

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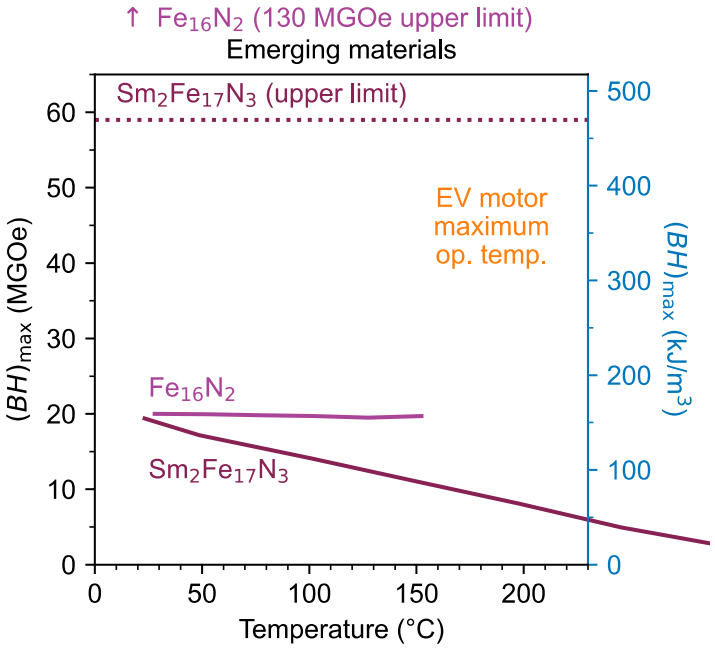

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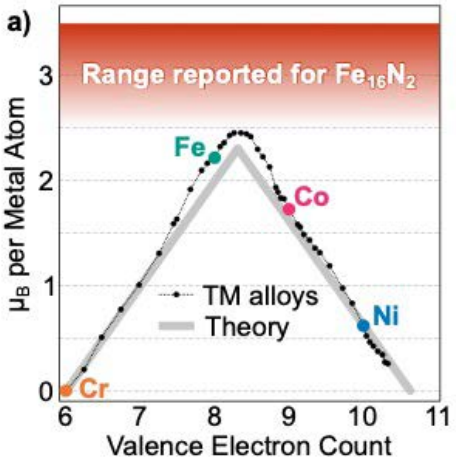

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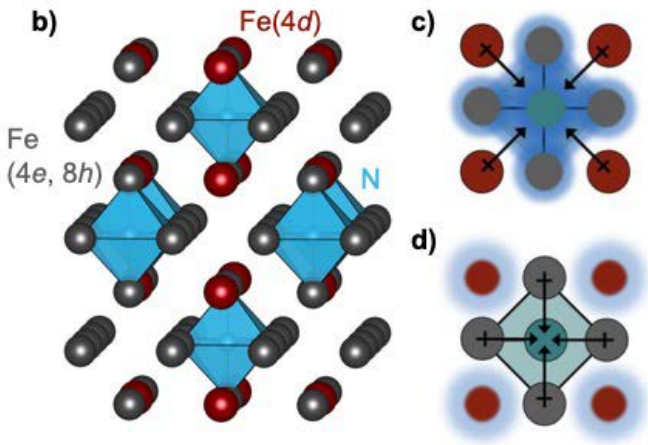

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- Hiraka, et al., *Phys. Rev. B* **90**, 134427 (2014).
- Hang, Matsuda, Held, Mkhoyan, Wang, *Phys. Rev. B* **102**, 104402 (2020).

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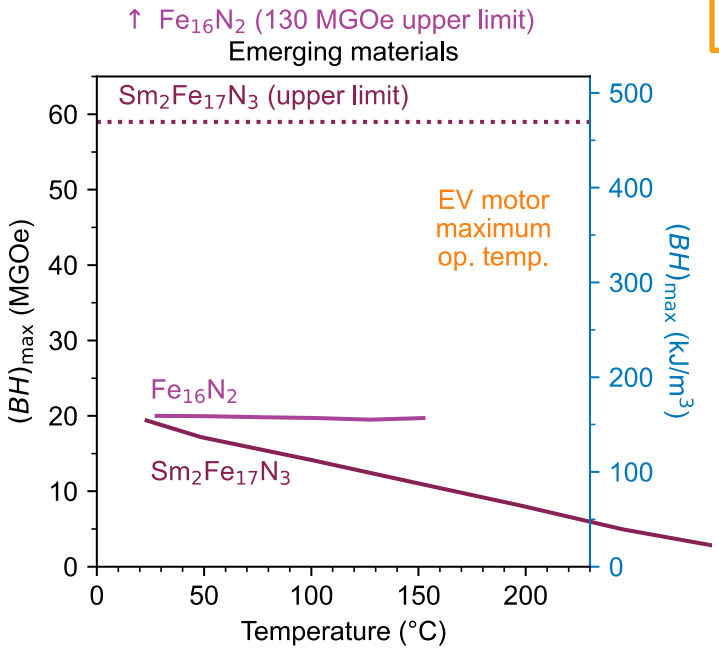

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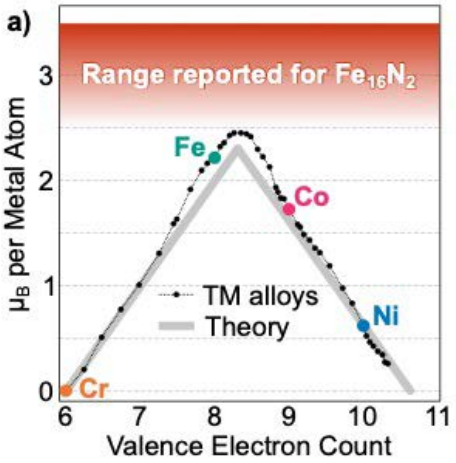
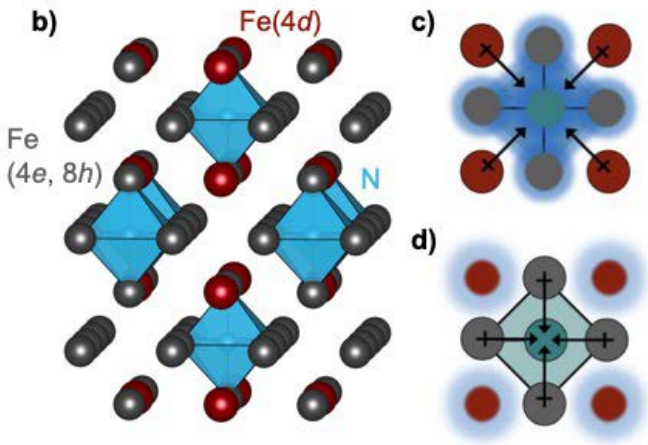
N changes charge distribution, strengthens magnet





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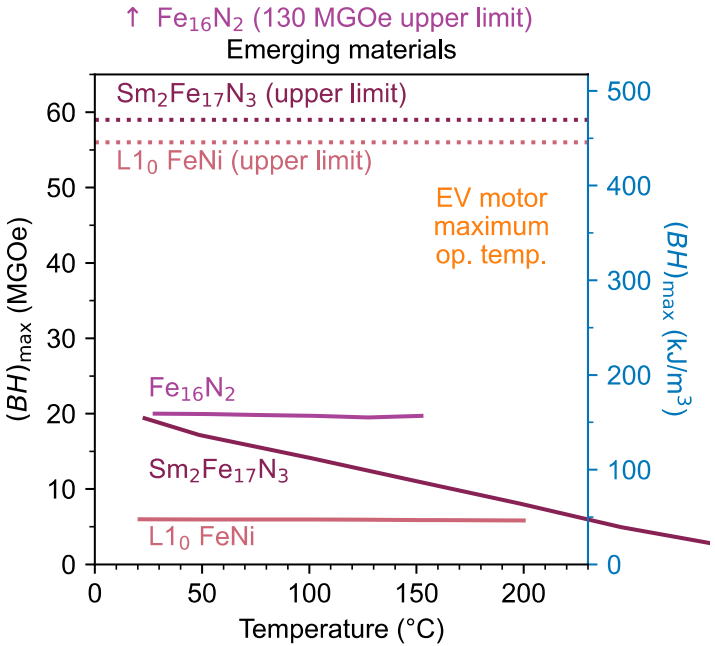
$L1_0$ FeNi has high H_c if ordered



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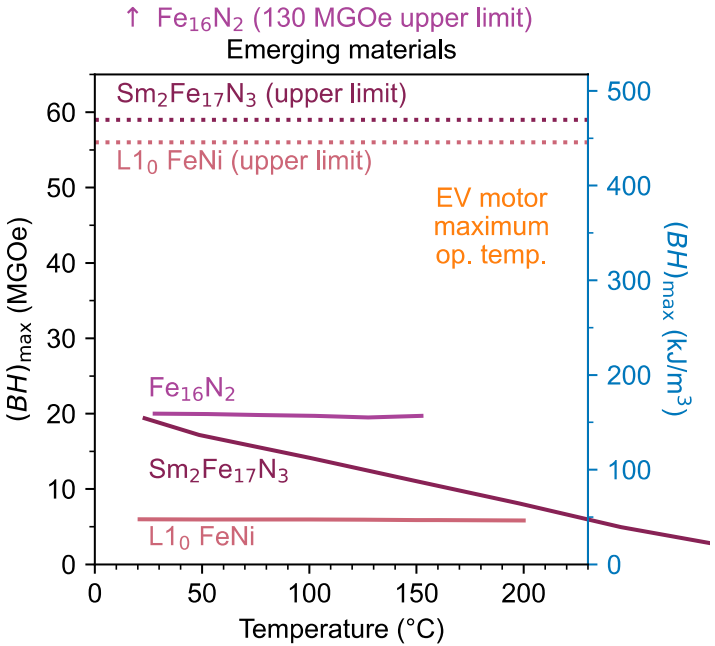

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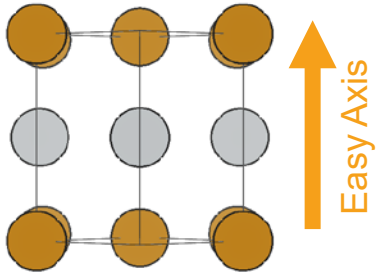
$S = 1.0$
$P4/mmm$



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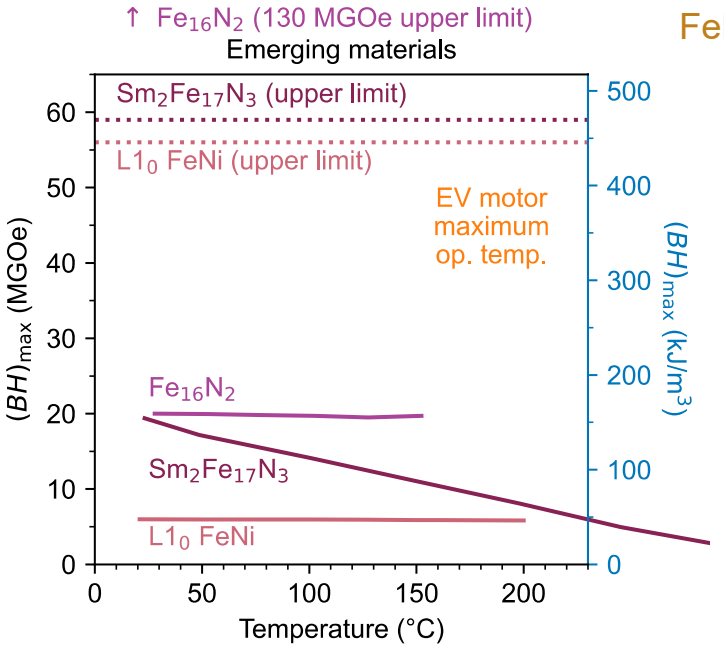

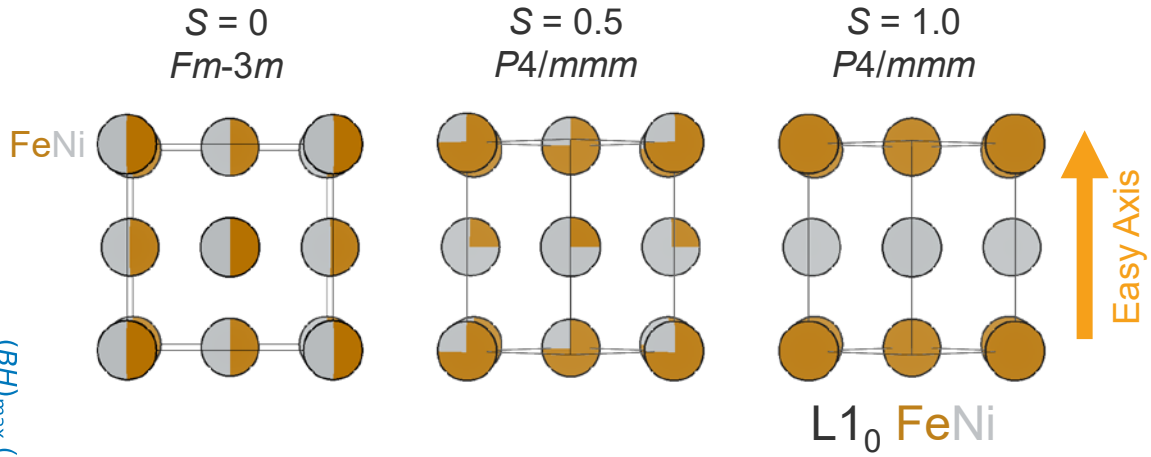

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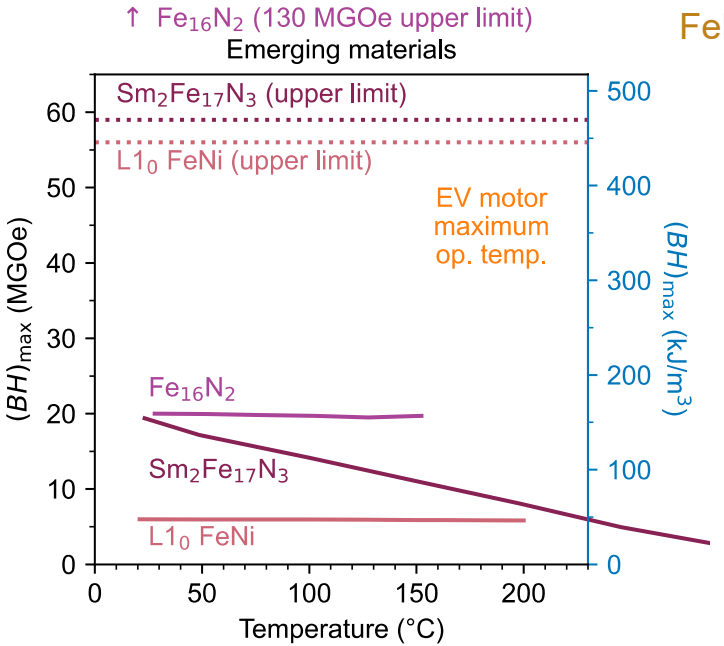

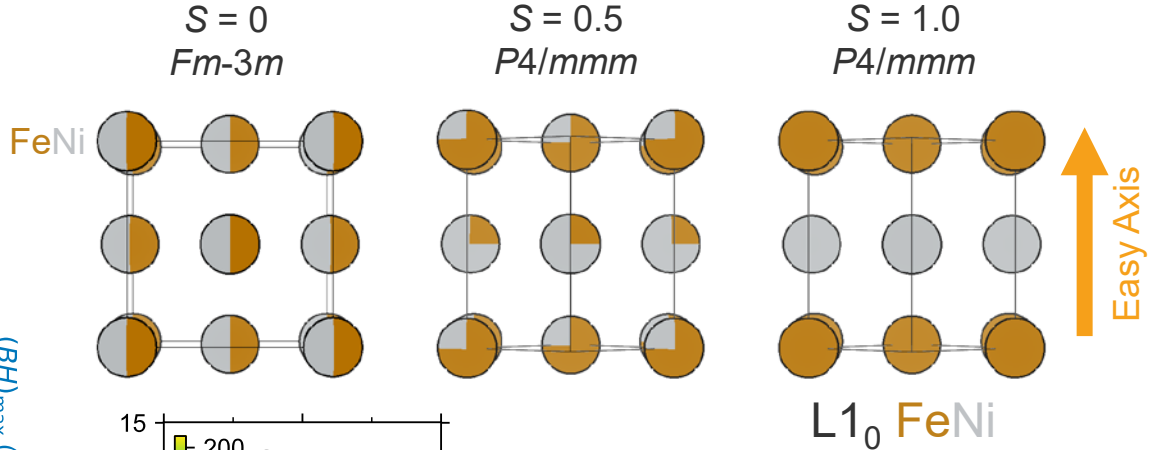

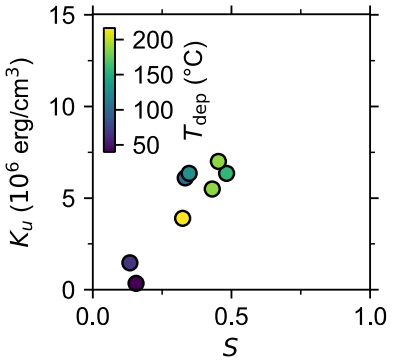

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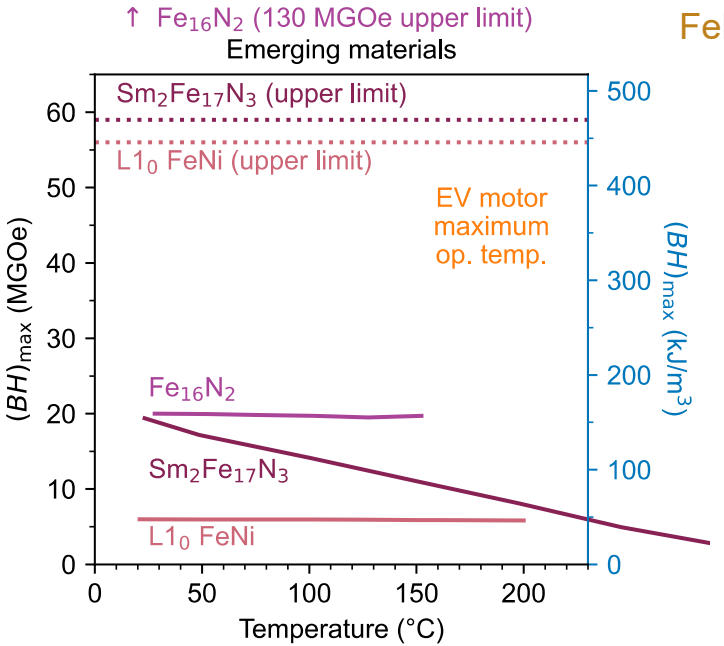

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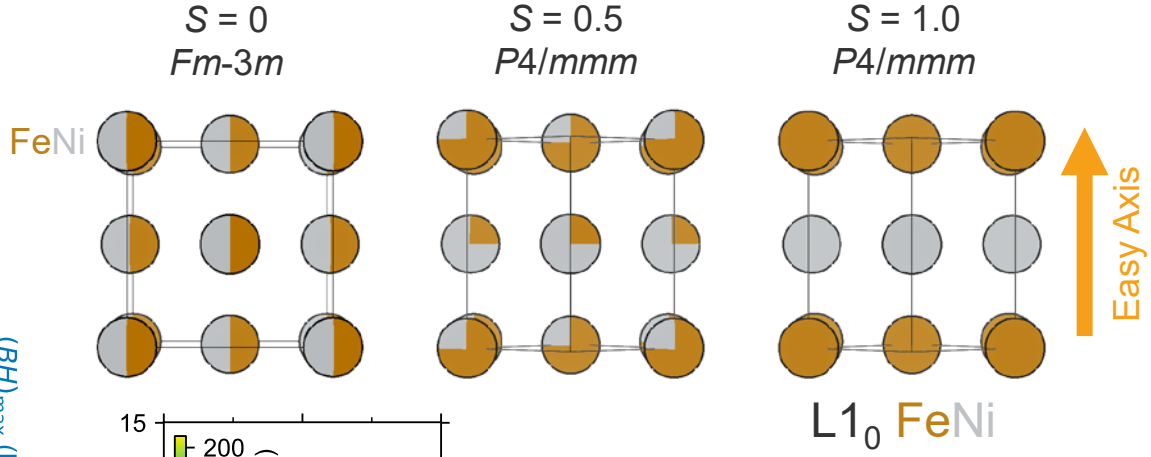

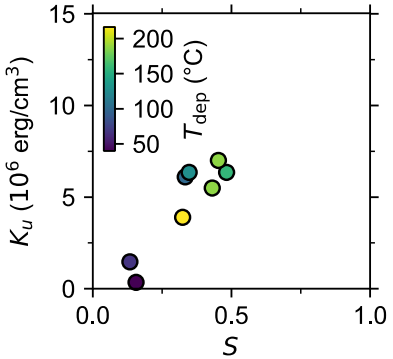

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More ordering needed

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NREL Transforming ENERGY

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$T_{decomp.}$ ~ 600 °C

Christodoulou, Takeshita, *J. Alloys Compd.* **198**(1–2), 1 (1993).

$Fe_{16}N_2$

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Lewis, Mubarok, Poirier, Bordeaux, Manchanda, Kashyap, Skomski, Goldstein, Pinkerton, Mishra, Kubic Jr., Barmak, *J. Phys. Condens. Matter* **26**, 064213 (2014).

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Needed: Low temperature processing methods

NREL Transforming ENERGY

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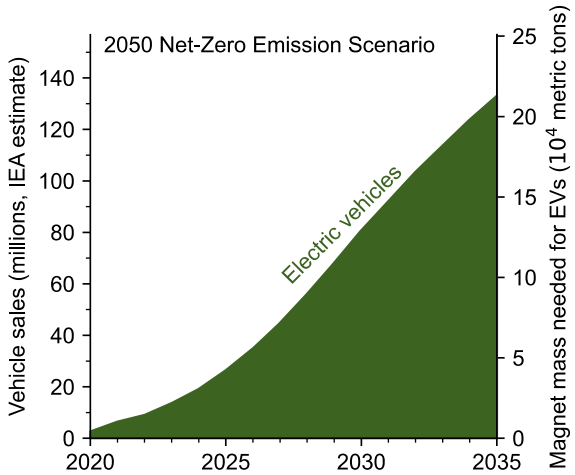

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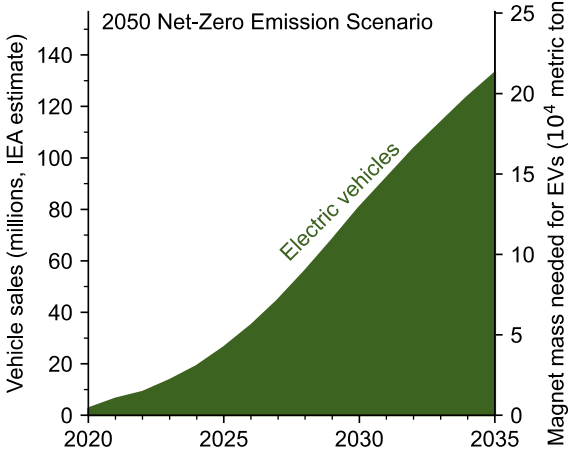

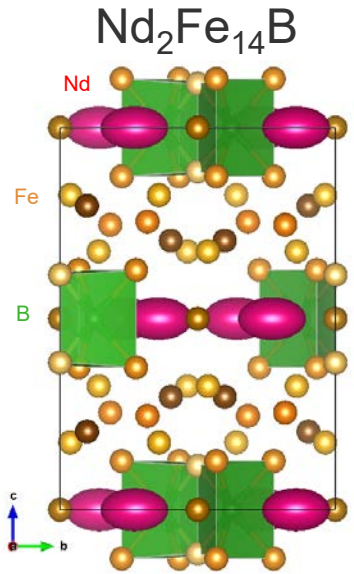

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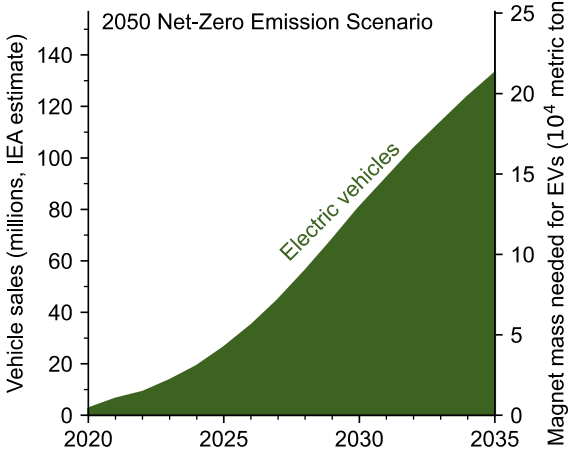
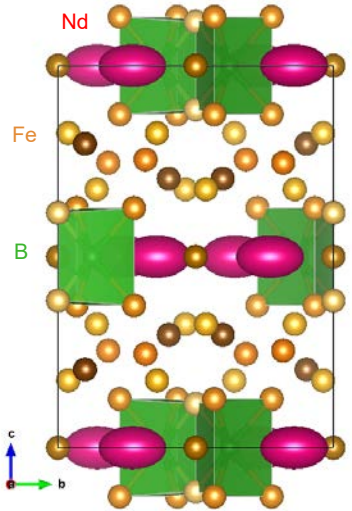


$Nd_2Fe_{14}B$



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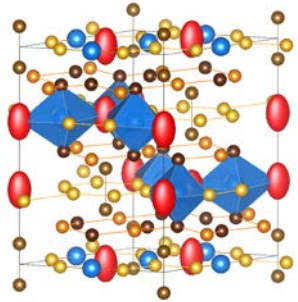

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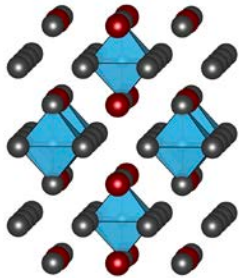

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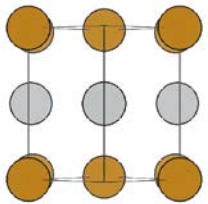

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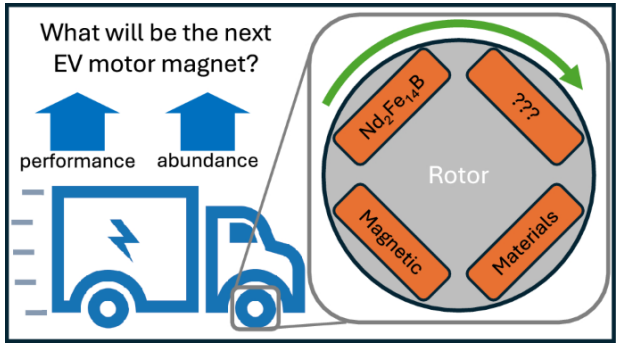

Rom, Smaha, O'Donnell, Dugu, Bauers, *MRS Bulletin,* 2024, doi: 10.1557/s43577-024-00743-4

Thank you!

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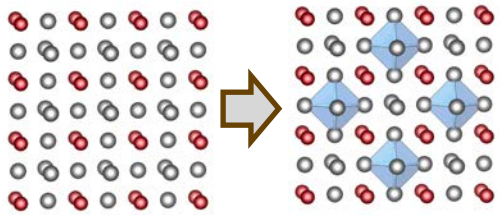
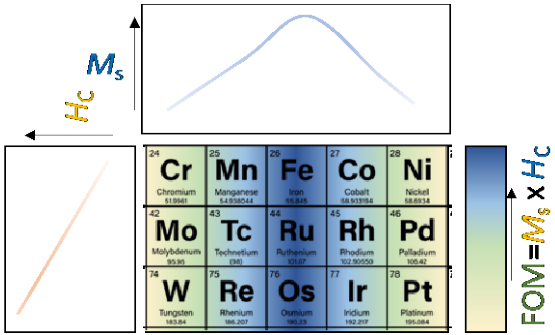
Backup slides

Design principles

a) 0D motifs



b) Combining 3*d* and 4*d*/5*d* metals



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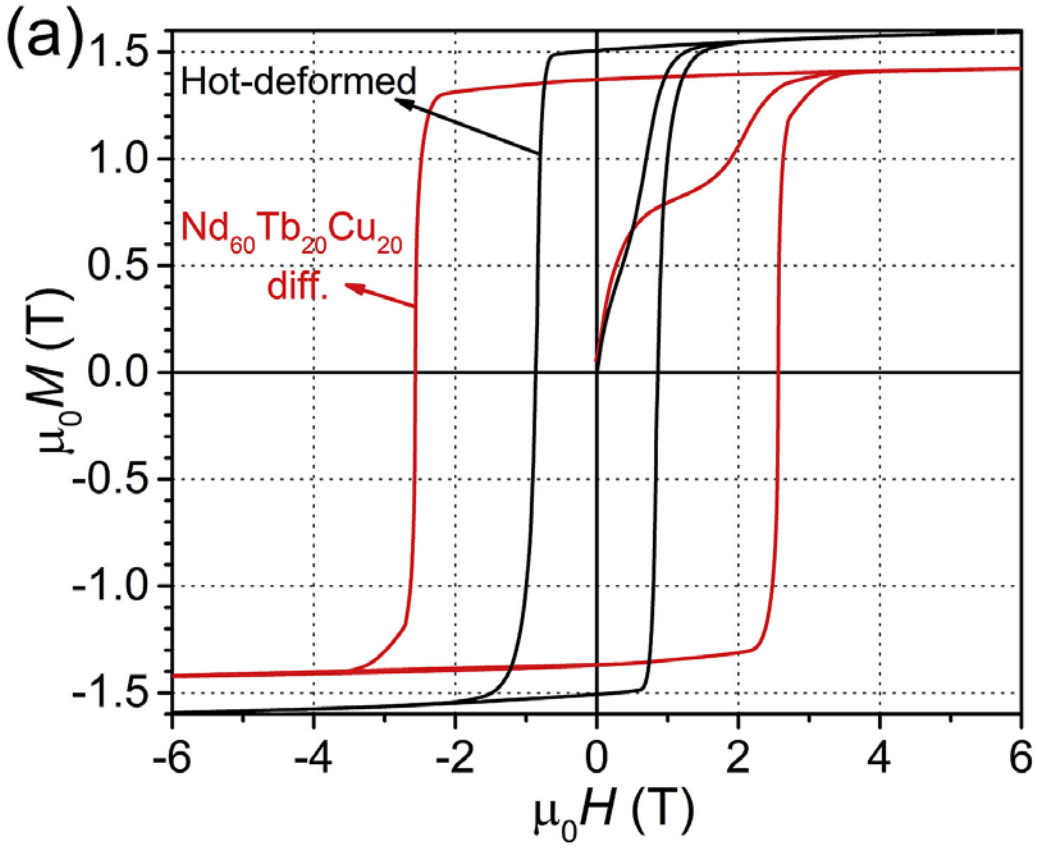

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