Technology Offer

Rare-earth free magnetic material suitable for permanent magnet production
Ref.-No.: 1303-6197-LC

Driven by the favourable operational effectiveness of neodymium iron boron (NdFeB) magnets, there has been a considerably rising demand for neodymium in permanent magnet manufacturing. According to Spherical Insights & Consulting the global neodymium magnet market size was valued at 2.3 Billion US$ in 2022 and is expected to reach 3.83 Billion US$ by 2032. As the market for rare earth materials is heavily influenced by Chinese supplies, which causes supply and price uncertainties, end users outside of China are urgently seeking rare-earth free alternatives for important permanent magnet applications like micro electronics and electrical motors.

Technology
Prof. Claudia Felser and co-workers at the Max-Planck-Institute for Chemical Physics of Solids developed a concept to create optimized rare-earth metal and platinum free permanent magnets.

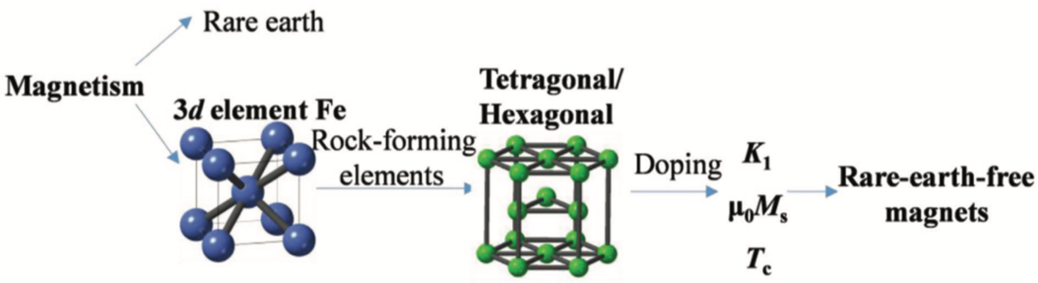

Fig. 1: Design of rare-earth-free permanent magnets. Iron provides the basic magnetism: compounds consisting of iron and common rock-forming elements with an uniaxial crystal structure provide anisotopic crystal field; intrinsic magnetic properties are modified by further doping; extrinsic properties like grain size are controlled by engineering issues to make real magnets.

It was found that Fe_2P-based compounds co-doped with Co and Si show promising properties for the utilization as permanent magnets. This can be achieved through doping Fe_2P at the Fe site, preferably with Co, in order to increase its Curie temperature (T_C), and through doping at the P site, preferably with Si, in order to simultaneously maximize its anisotropy constant (K_1). In particular, $(Fe_{0.92}Co_{0.08})_2(P_{0.78}Si_{0.22})$ single crystals suit contemporary market demands in terms of energy density, $(BH)_{MAX}$ (= $\frac{1}{4}\mu_0 M_s^2$) ≈ 180 kJ m^{-3}, and thermal stability, T_C > 500K. The stoichiometry above was found experimentally for maximizing the room temperature magneto-crystalline anisotropy (K_1 = 1.09 MJ m^{-3}) through the variation of said dopants. Thus, Co and Si co-doped Fe_2P fills the gap between the expensive rare-earth magnets and cheap but poor-performance ferrite magnets. Among all the gap magnets, Fe_2P exhibits the largest theoretical $(BH)_{MAX}$, which is almost double those of MnBi and MnAl and four times that of ferrite.

Single Crystal Composition	$\mu_0 Ms$ [T] (300 K)	K_1 [MJ m^{-3}] (300 K)	B_a [T] (300 K)	T_C [K]	κ (300 K)	$(BH)_{MAX}$ [kJ m^{-3}] in theory	θ_p [K] (c axis)
$(Fe0.91\ Co0.09)_2$ $(P0.89\ Si0.11)$	0,84	0,77	2,3	414	1,16	141	479
$(Fe0.92\ Co0.08)_2$ $(P0.78\ Si0.22)$	**0,96**	**1,09**	**2,8**	**506**	**1,2**	**183**	**522**
$(Fe0.91\ Co0.09)_2$ $(P0.74\ Si0.26)$	1,01	0,93	2,3	560	1,07	204	562

Max-Planck-Innovation GmbH
Arnulfstr. 58
80335 München
www.max-planck-innovation.de

For use as a magnet the compounds of the present invention can be sintered as raw material or bonded with an appropriate binder material. In collaboration with the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS corresponding technical processes for the production of nano or micro structured permanent magnets based on the novel materials are currently developed.

Advantages

- rare-earth element and platinum free, only cheap and available raw materials used
- suitable for applications at room temperature and above
- enhanced durability caused by Si suppressed first-order magnetoelastic coupli

Applications

- Electric motors for robots, cars etc and electric generators for wind turbines
- Micro electronics

Patent Information

Priority patent application EP4050624 filed 24.02.2021,
WO2022179979A1 filed 21.02.2022 nationalized in EP, US, CN, JP, KR

Literature

He, Y., Adler, P., Mu, Q., Borrmann, H., Schnelle, W., Fecher, G. H., Felser, C., Schneider, S., Rellinghaus, B., Soldatov, I., Schaefer, R.: "Intrinsic Magnetic Properties of a Highly Anisotropic Rare-Earth-Free Fe_2P-Based Magnet"; Advanced Functional Materials 2022, 32(4), 2107513

Contact

Dr Lars Cuypers

Senior Patent- & License Manager
Chemist

Phone: +49 (0)89 / 29 09 19 - 21
eMail: cuypers@max-planck-innovation.de

Max-Planck-Innovation GmbH
Arnulfstr. 58
80335 München
www.max-planck-innovation.de