The role of the precipitation structure on the coercivity of Sm(Co,Fe,Cu,Zr)$_z$ magnets for HT applications

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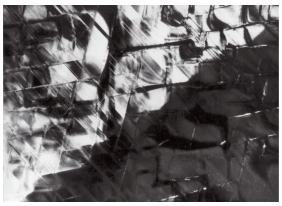
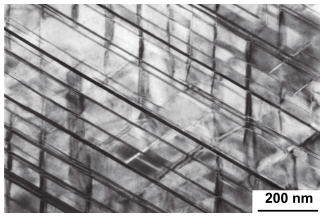
Sm(Co,Fe,Cu,Zr)$_z$ permanent magnets are the best choice for high temperature applications because of their large magnetocrystalline anisotropy and their high Curie temperature. A complex heat treatment which involves sintering, homogenizing, isothermal aging and annealing results in the formation of a cellular precipitation microstructure which provides pinning centers for magnetic domain walls.



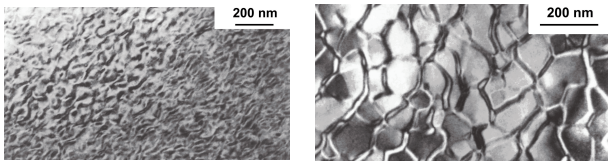
Lorentz microscopy:
Foucault Mode

The domain wall is pinned at the continous precipitation structure.

The microstructure consists of the $Sm_2(Co,Fe)_{17}$ cell matrix phase, the $Sm(Co,Cu)_{5-7}$ cell boundary phase and the Zr-rich lamella phase.

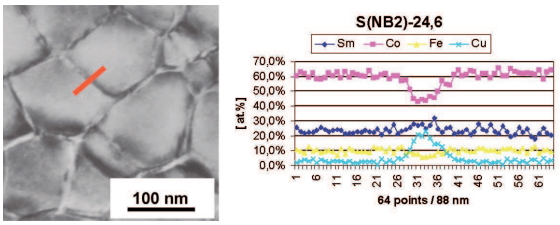


The cell size can be tailored by the profile of the heat treatment.

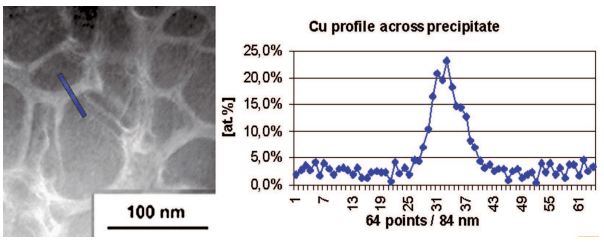


20 min Isothermal aging 120 min

Nanoanalytical investigations with a field emission gun FEI Tecnai 200 TEM reveal the elemental distribution across the precipitates. The cell boundaries are enriched in Cu and Sm whereas the cell matrix is enriched in Fe.

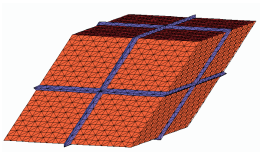


The Cu concentration determines the magnetic properties of the Sm(Co,Cu)$_5$ phase.



High Angle Annular Dark Field (HAADF) image and corresponding x-ray linescan of the Cu-concentration. Both methods together enable the determination of the width of the precipitate.

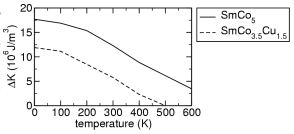
Micromagnetic modeling

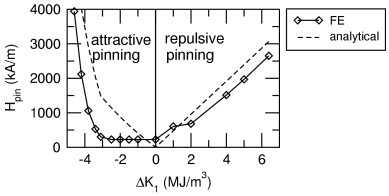


3D dynamic micromagnetic finite element model:

$Sm_2(Co,Fe)_{17}$ cells (red)
$Sm(Co,Cu)_{5-7}$ cell boundary phase (blue)

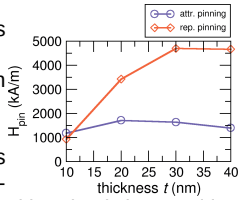
Temp. dependence of anisotropy difference between $Sm_2(Co,Fe)_{17}$ cells and intercellular phase
Tang et al., IEEE Trans. Magn. 37 (2001) 2515 and refs. therein





comparison with an analytical 1D model
Kronmüller, Goll, Physica B 319 (2002) 122
FE simulations: reduced pinning field due to influence of geometry

repulsive pinning: pinning field saturates for thick boundary phases
attractive pinning: bending of domain walls reduces the pinning field



The geometry of the rhombohedral cells plays a crucial role in the pinning mechanism. Together with the material composition (and the resulting magnetocrystalline anisotropy) it determines the pinning field and the coercivity of the magnet.

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