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6Dmag

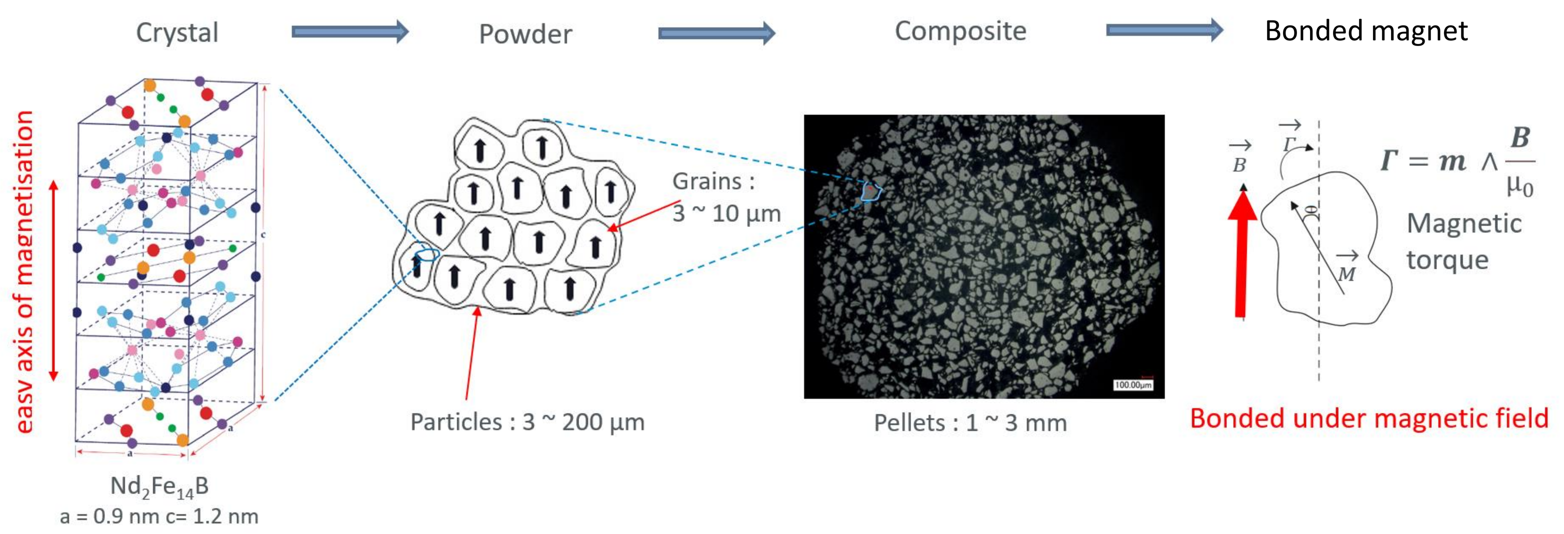
3D printing of anisotropic bonded rare-earth magnets

ICM'24 July 2024 BOLOGNA

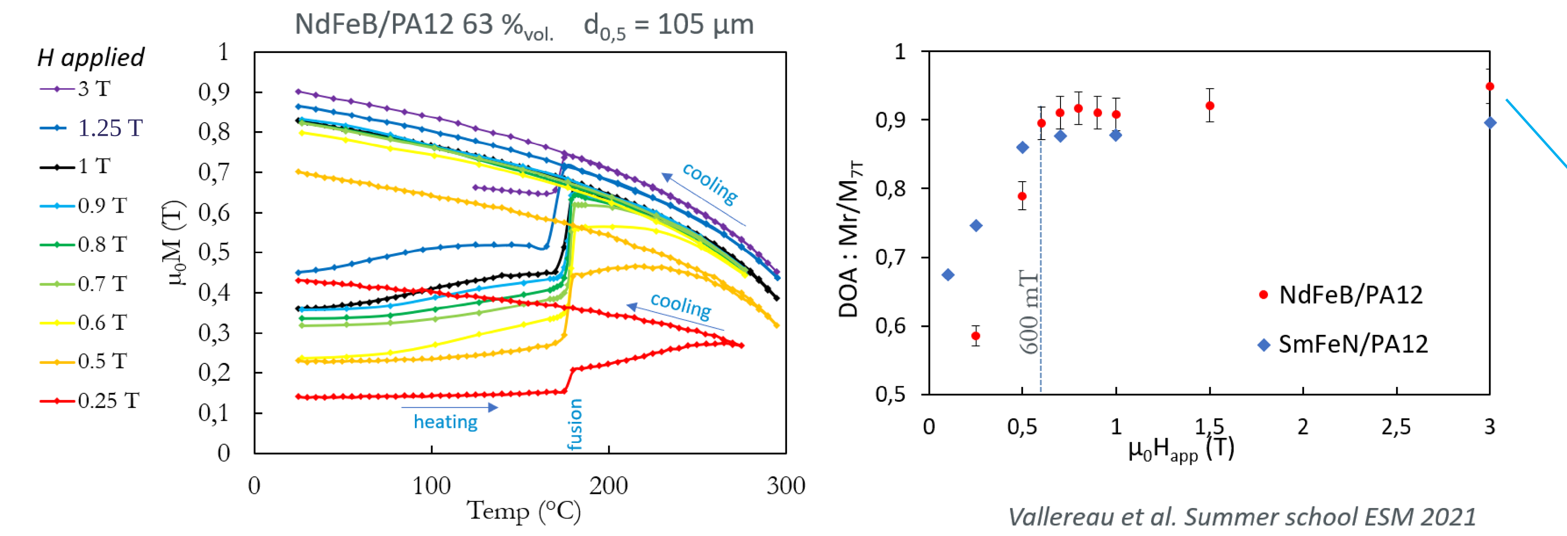
Abstract

- We present a novel way of producing cm-scale rare-earth based anisotropic bonded magnets through additive fabrication. The high-load compounds are based on industrial grade NdFeB and SmFeN powders (up to 63 vol%) in a PA12 nylon matrix. In our technology, the particles are axially prealigned by a magnetic field (500 mT) produced by an external permanent magnet flux source surrounding the extrusion nozzle. This pre-alignment happens immediately before the material's extrusion and subsequent deposition onto the printer hotbed. In the best cases the degree of alignment (DOA) of the deposited material can reach 83%, with remanence up to 0.56 T (as deposited).
- These state-of-the-art results are achieved thanks to several technological innovations, both to the compound composition, extrusion head, and deposition strategy. The high-load raw material was formulated into granulates/pellets instead of continuous filaments, for structural cohesion. Experiments were carried out on composites based on various types and sizes of particles, to determine the optimal parameters :
  - composition, magnetic field, alignment time, temperature range, extrusion pressure. The particles tested include powders obtained from recycled industrial sintered magnets.
- One main obstacle hindering particle alignment during deposition, and preventing finer resolution, is the mechanical spread resulting from contact with the nozzle. Extrusion-induced porosity and post-deposition magnetization are the next hurdles. Preliminary tests have also been carried out with fully magnetized particles.

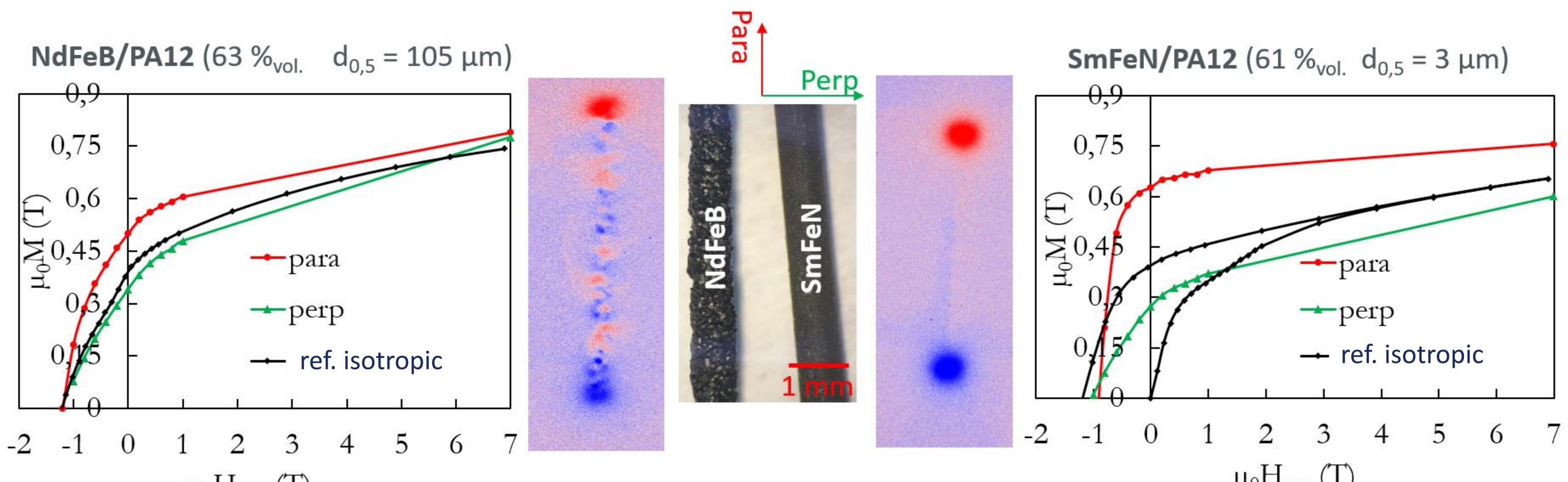
Permanent magnet anisotropy : various scales



Alignment of non-magnetised particles *vs.* field, temperature, time

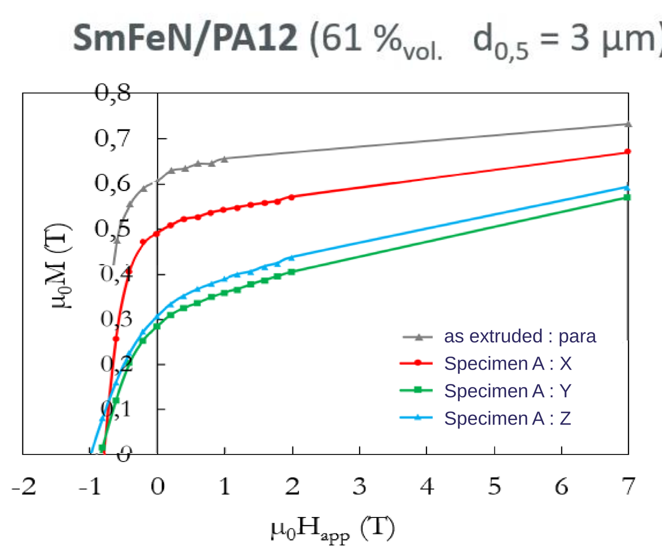


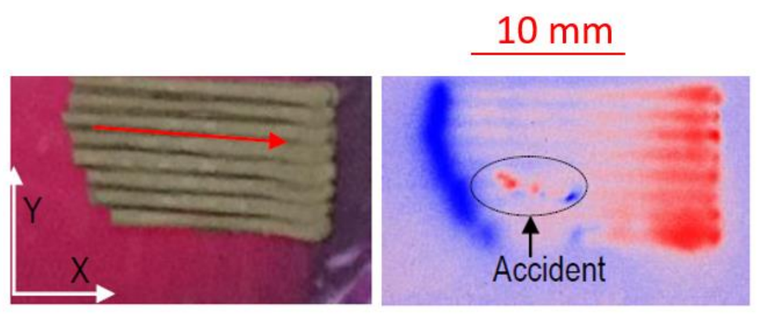
Extruded filaments: NdFeB & SmFeN



NdFeB	DOA	SmFeN
79 %	Aligned in VSM	86 %
65 %	Extruded @500 mT	83 %

SmFeN specimen aligned during deposition





Sample	M_r/M_{7T}
Filament	0,83
Specimen A	0,77

Conclusions of this thesis :

- printing high-load bonded magnets : > 63 $\%_{vol}$
- compact alignment field source : 515 mT @240°C
- novel extruder head : piston
- directionnal deposition strategy
- anisotropic bonded magnets :
  - SmFeN/PA12 : DOA (Mr/Ms) 77 %
  - NdFeB/PA12 : 65 %

Patent filed Sept. 2023 (n° FR2309186)
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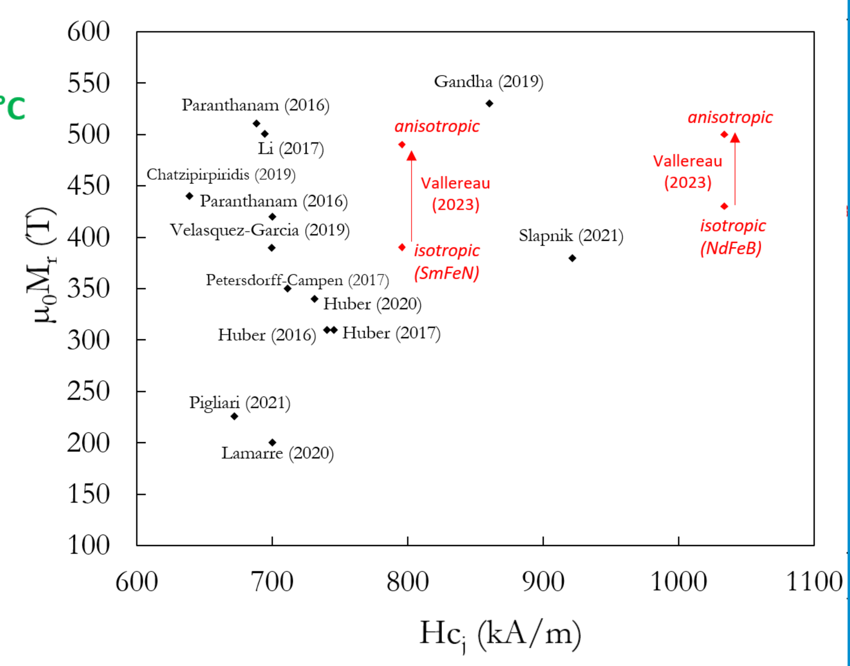
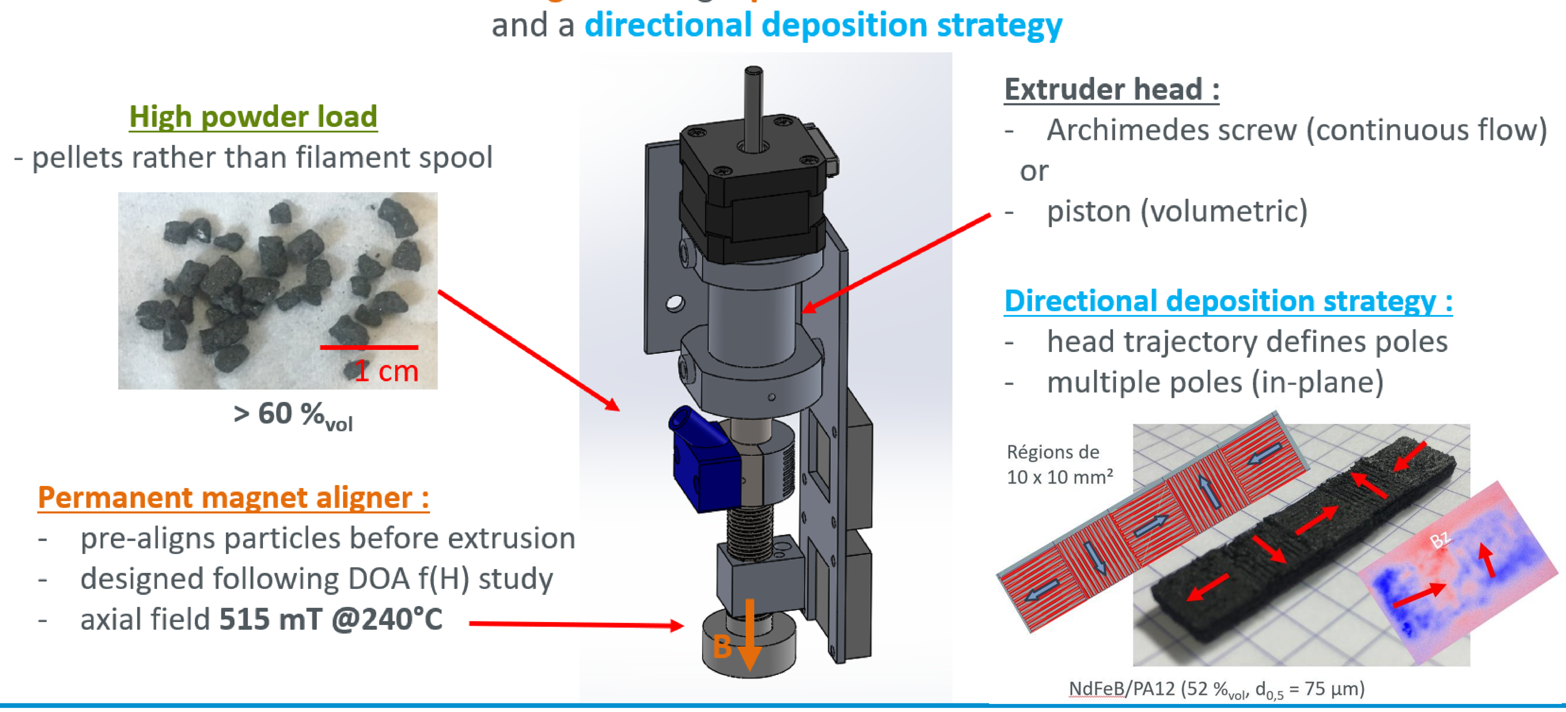
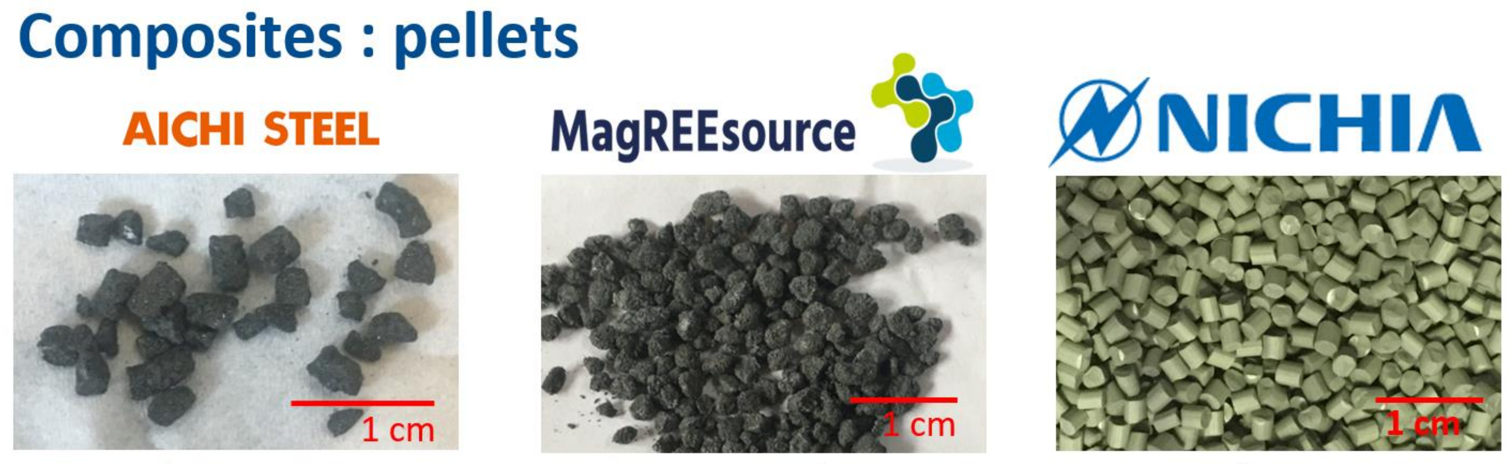


Goals of this thesis:

Print **highly loaded**, **anisotropic** bonded magnets
aligned using a **passive flux source**
and a **directional deposition strategy**



Composites : pellets



NdFeB/PA12 (63 $\%_{vol}$) NdFeB recycled/PA12 (67 $\%_{vol}$) SmFeN/PA12 (61 $\%_{vol}$)

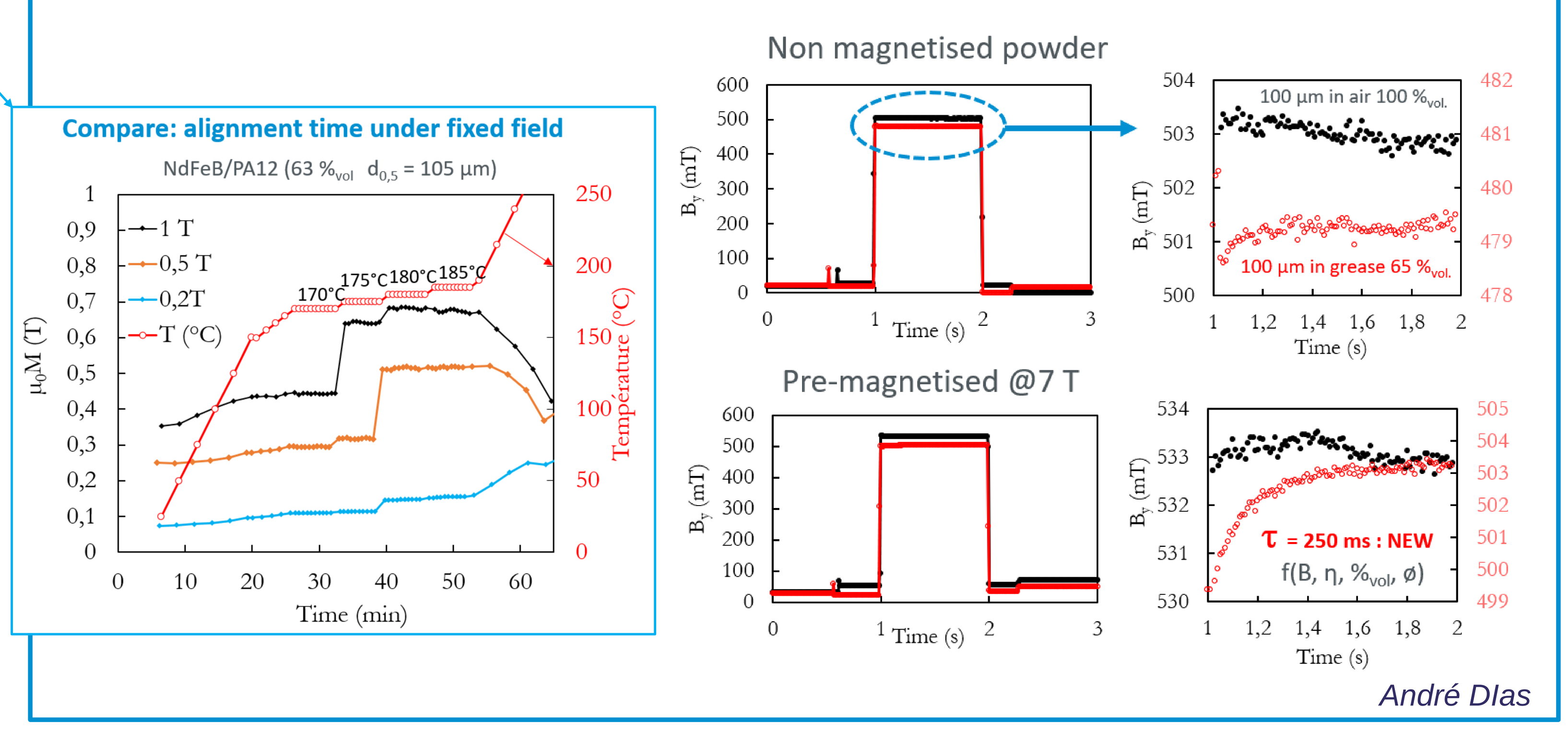
SETUP

Matrix : PA12 (Nylon) thermoplastic
T_{fusion} = 180°C
T_{print} > 220°C

Composite (/PA12)	$\%_{vol}$	$D_{0,5}$ (µm)	$\mu_0 M_r$ (T) isotropic
NdFeB	63	105	0,36
NdFeB	52	76	0,31
NdFeB recycled	67	56	0,20
SmFeN	61	3	0,37

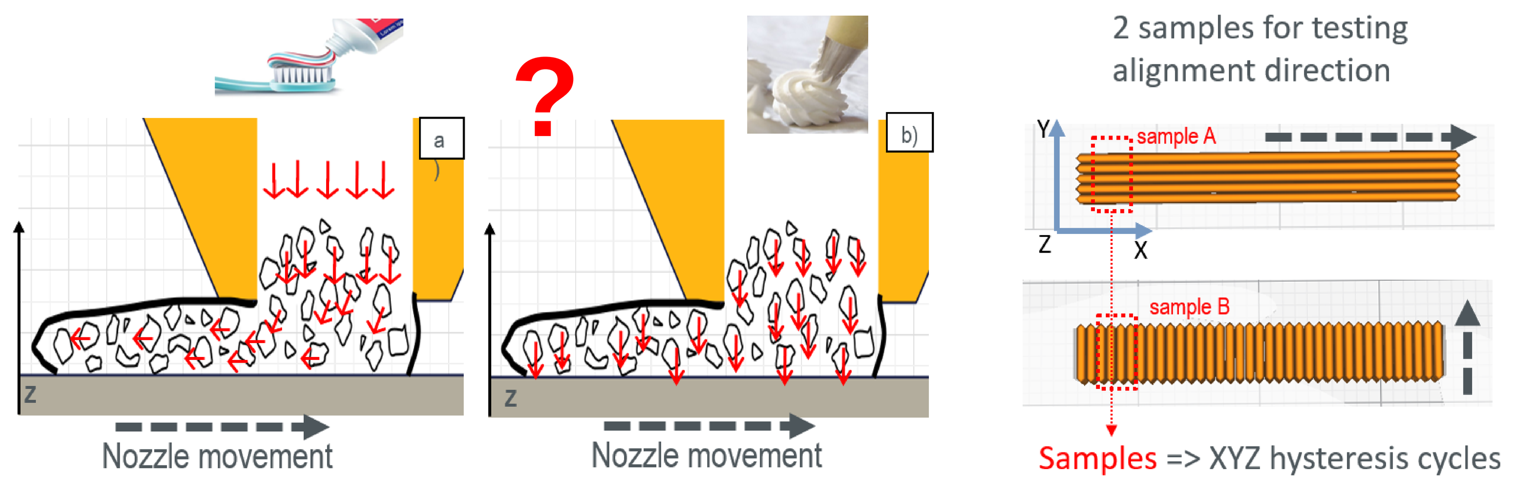
Particle alignment : real time measurements / pulsed field

Home made pulsed field coil + high-frequency miniature Hall probe



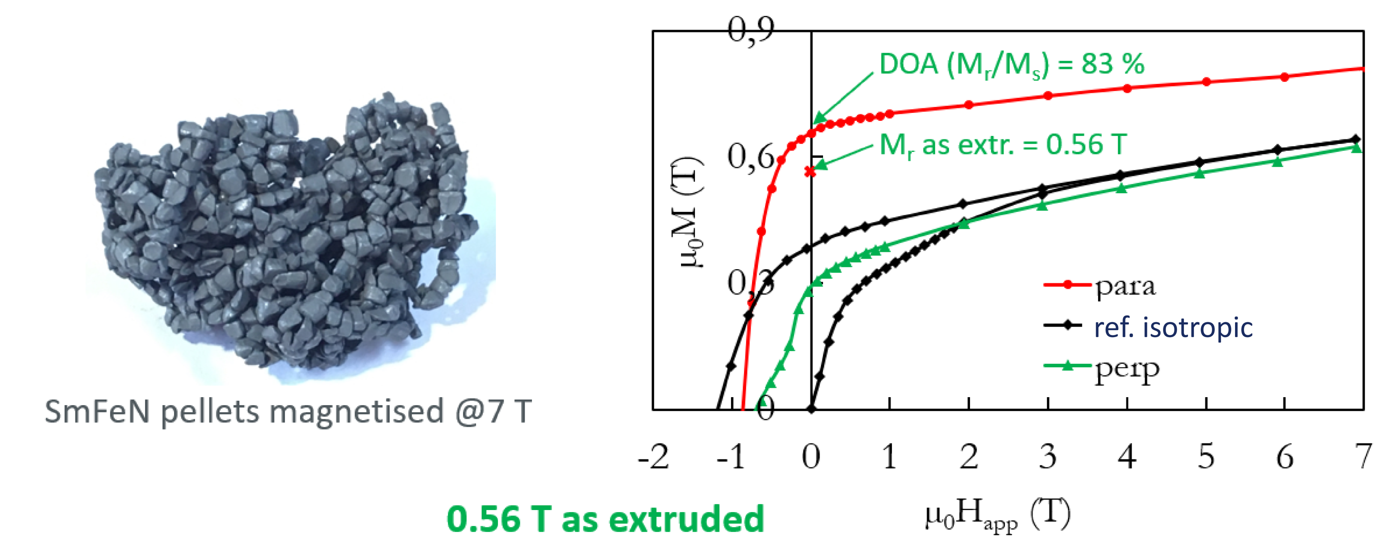
André Dias

How do particles realign upon deposition ?



Trajectory of extrusion head defines direction of anisotropy
Change of direction => multiple poles (in plane)

Filament extruded from pre-magnetised SmFeN



0.56 T as extruded
=> ... and after deposition ?

Acknowledgements

I.Néel/SERAS: E Roy, G Perroux, J Lacipière, M. Heigeas, G Kapoujyan, P Taboga
Pôles **ThEMA**, **Ingéniérie Expérimentale** : D Dufeu, L Del Rey,
CNRS/INP/G2Elab: J. Ferrari, L. Gimeno
CNRS/CEA/SPINTEC: I. Joumard
MagREEsource : A. Dias, H. Pascal, F. Mandil, E. Petit
Setup Performance : L. Goujard

Project & PhD were funded by Institut Carnot / Energies du Futur