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Effect of aging on the temperature dependence of Fe_{0.5}SiNbB nanocrystalline alloys

Rania Saoudi¹, Laurent Morel¹, Marie Ange Raulet¹

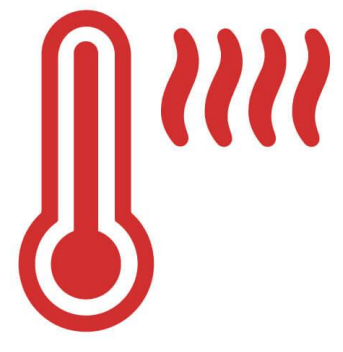
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Introduction

Due to their attractive magnetic properties, nanocrystalline materials are used in many applications nowadays. However, the operating conditions in these systems expose the magnetic components to high temperatures. Not only their magnetic properties varies at high temperatures, but also exposing these materials to high temperatures for long periods of time, changes their magnetic properties.

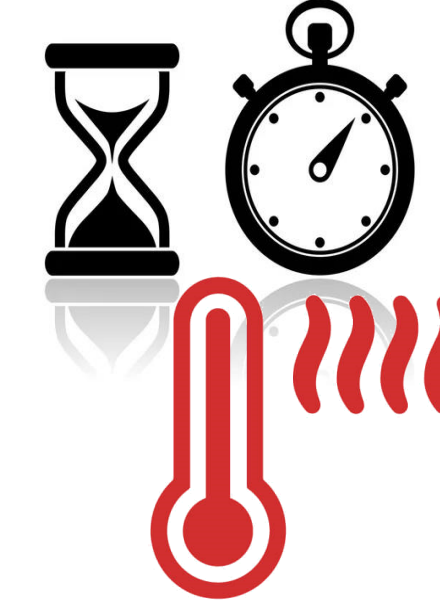
Objectives

1



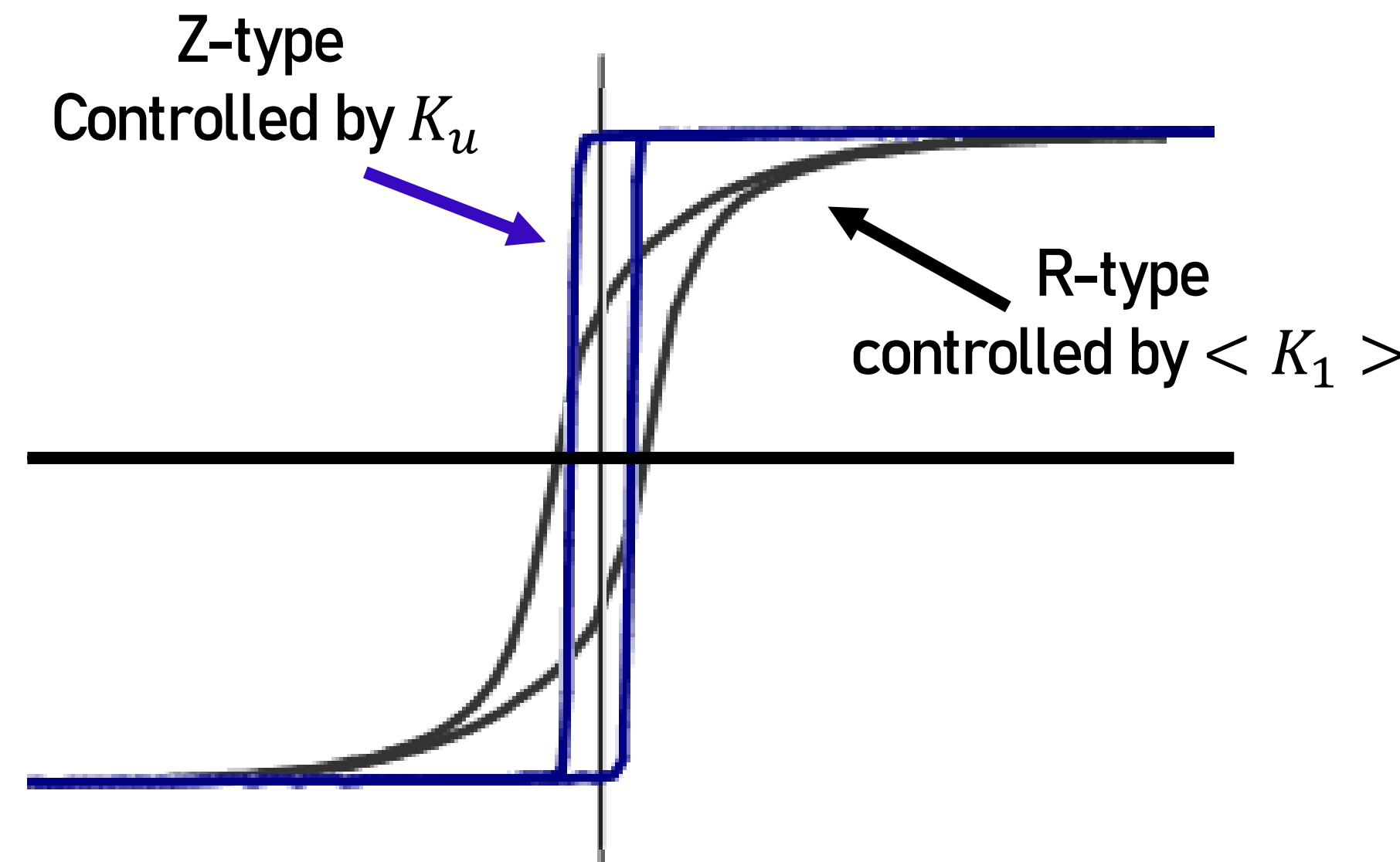
Magnetic behavior at different measuring temperatures of two nanocrystalline nuances

2



Aging impact on the temperature dependence behavior in Z-type nanocrystalline materials

Materials & conditions



Fe_{73.5}Cu₁Nb₃Si_{15.5}B₇ nanocrystalline alloys

Measuring temperatures : -55 to 125 °C
Quasi-static characterizations

A Z-type sample is exposed to 200 °C in its demagnetized state.

Results & Discussion

Origin of soft magnetic properties [1]

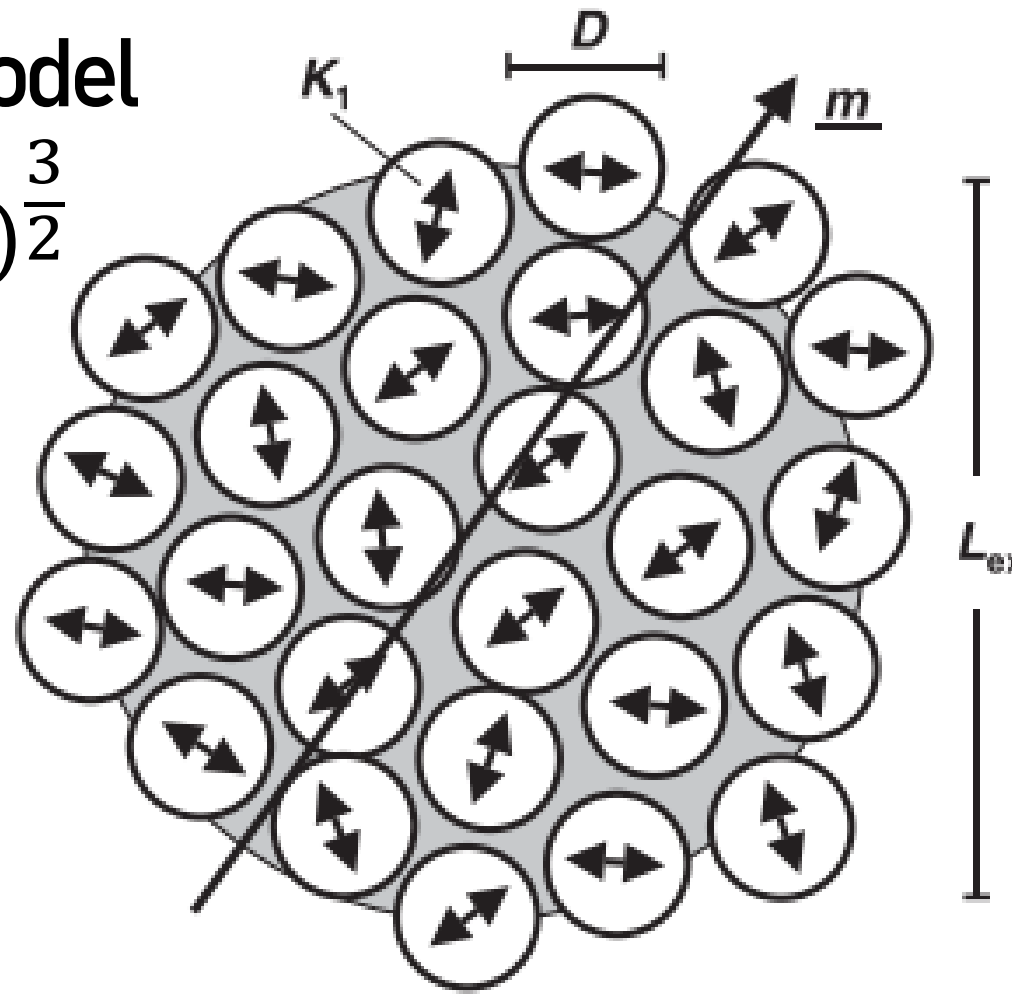
Local magnetocrystalline anisotropies are randomly averaged out thanks to grain sizes D smaller than the ferromagnetic exchange length.

the random anisotropy model

$$\langle K_1 \rangle = K_1 / (D / L_{ex})^3$$

The exchange length

$$L_{ex} = \sqrt{\frac{A}{\langle K_1 \rangle}}$$



A exchange stiffness
 K_1 magnetocrystalline anisotropy constant

1. Behavior at high temperatures [2]

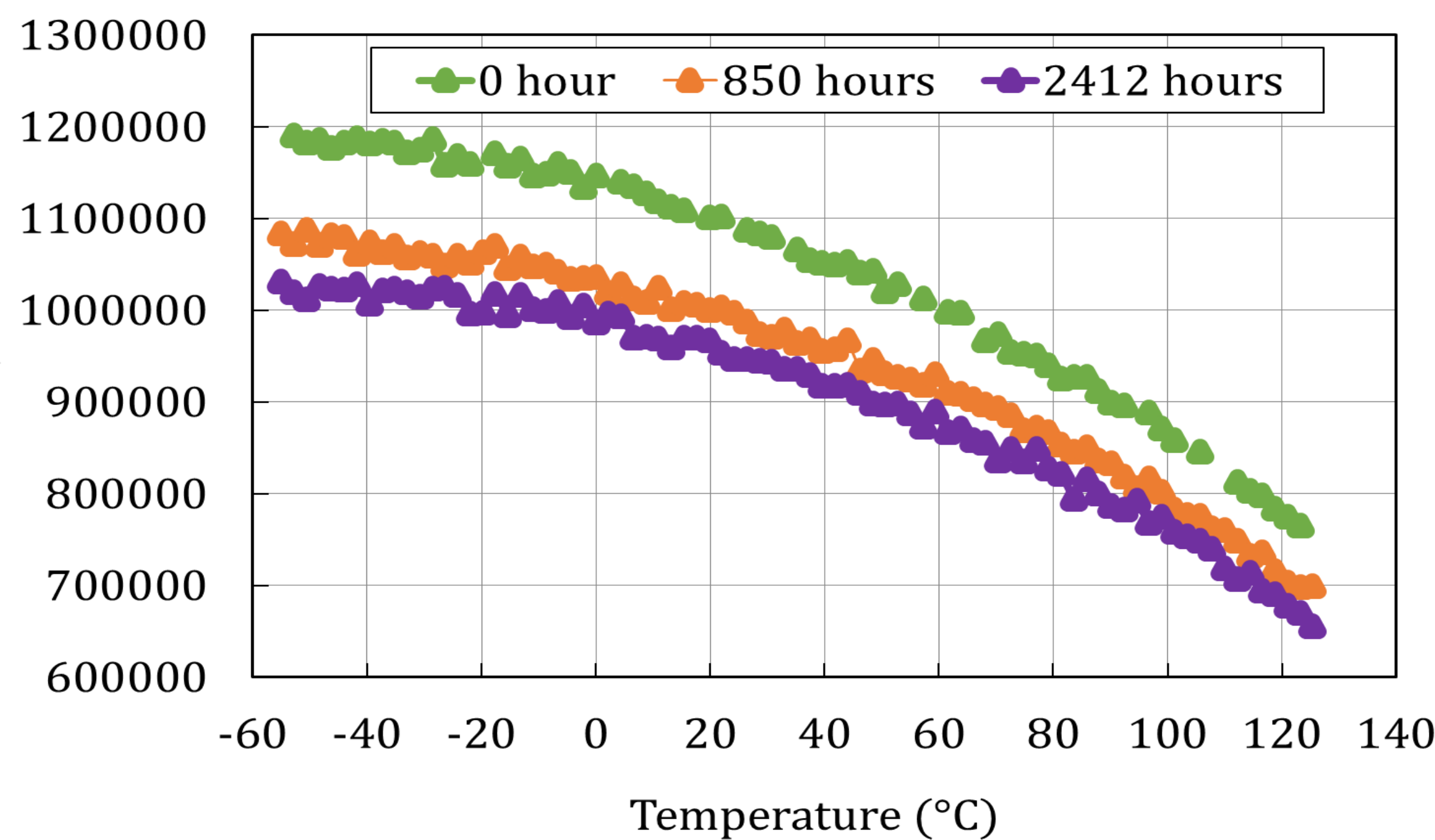
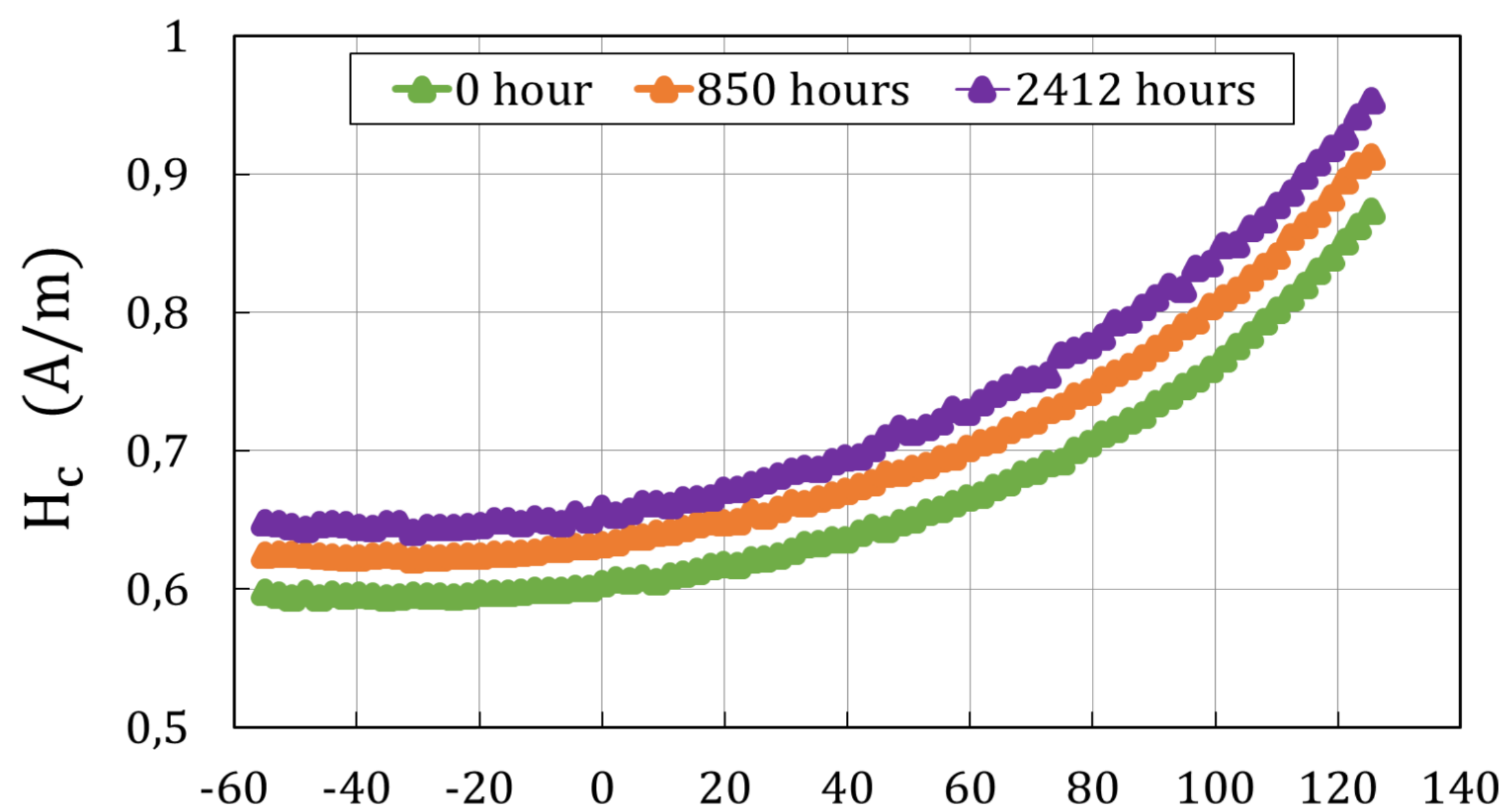
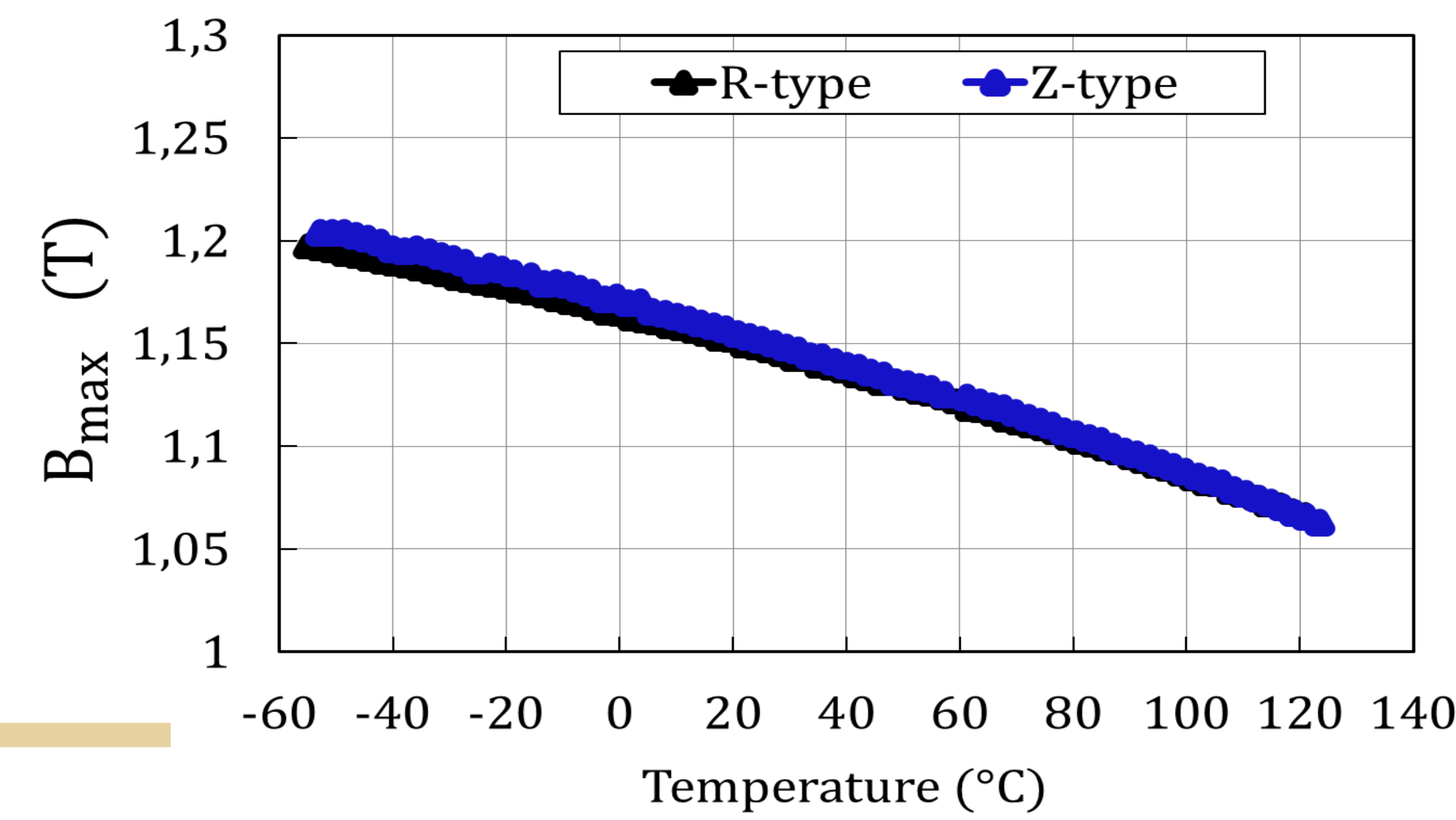
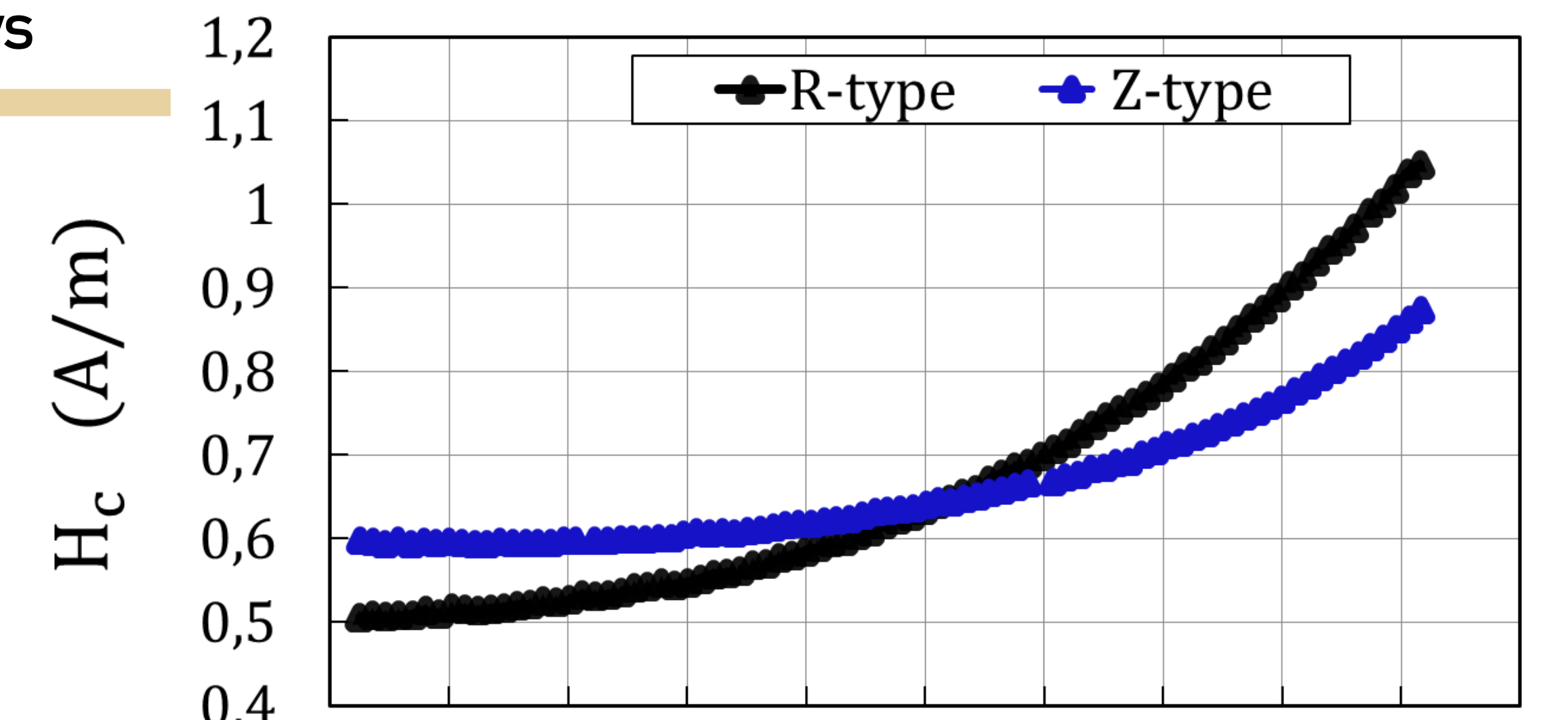
By increasing measurement temperature and approaching T_c^{am} and the exchange length is reduced.

=> Random anisotropy increases

=> Soft magnetic properties degraded : coercive force increases, saturation induction and permeability decreases...

Comparison

- Kinetics of degradation are slower in Z-type since K_u was dominating
- In R-type $\langle K_1 \rangle$ was already dominating and increases faster.



2. Aging impact in Z-type nanocrystalline

Coercive force H_c has increased as function of aging time, whereas maximal permeability μ_{max} has dropped.

Aging in Z-type nanocrystalline materials was related [3] to a formation of locally field induced anisotropy along the spontaneous magnetization vectors within domains walls.

Grain size would not change as XRD measurements showed in [4] => Same kinetic before and after aging at 200 °C.

Conclusions

Soft magnetic properties in nanocrystalline are instable as a function of measuring temperature, this is due to the reduction in the intergranular exchange coupling length.

Temperature stability depends on annealing conditions. The Z-type nanocrystalline materials are more stable as function of temperature where the degree of freedom of random anisotropy formation is reduced by inducing a uniform anisotropy during field annealing.

Aging in nanocrystalline materials is not due to microstructural changes. It is rather related to a disturbance of the uniform anisotropic energy.

[1] Herzer G. IEEE Trans Magn (1989) 25, 3327-3329.
[2] Herzer G. Acta Materialia (2013) 61, 718-734.

[3] Saoudi R et al. Journal of Magn and Magn Materials (2022) 563, 169986.
[4] Lekdim A et al. Journal of Magn and Magn Materials (2017) 428, 260-268.