The Influence of Short Time Heat Treatment on the Microstructure and Magnetic Behavior of the $SmCo_5$/α -Fe Nanocomposite Obtained by Mechanical Milling

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Abstract: Short time annealing of $Nd_2Fe_{14}B$/α–Fe nanocomposites, at temperatures in the vicinity of the recrystalization temperature of the hard magnetic phase, produced well crystallized samples, with Fe crystallites under 20 nm and a strong hard/soft exchange coupling [1]. Therefore, in order to check whether this is true for other exchange coupled nanocomposites, the effect of short time annealing on the structure, microstructure and magnetic behaviour of mechanically milled (MM) $SmCo_5$+20 wt% α–Fe nanocomposites was investigated. The samples were produced by milling $SmCo_5$+20 wt% α–Fe powder for 6 h, with the calculated total shock energy around 39 KJ/g. The resulting powder was then annealed for upwards of 30 min at 500, 550 and 600 °C and for 1.5 min at 700, 750, 780, 800 and 820 °C (followed by rapid cooling in water). The structure and microstructure of the annealed powders was studied trough X-ray diffraction. The average crystallite sizes of the soft magnetic phase were calculated using the Scherrer method and were found to be within the 10-20 nm range. The soft phase crystallites were sufficiently small to ensure a good interphase exchange coupling. The magnetic properties of the nanocomposites were studied from demagnetization curves and dM/dH vs. H plots, in applied fields up to ±10 T. A maximum coercive field of 0.83 T was obtained, with a remanent magnetization value of around 100 Am^2/Kg, and a maximum energy product of 130 KJ/m^3. Short time annealing was found to produce nanocomposites with a good degree of magnetic interphase exchange coupling. The structure, microstructure, and magnetic properties were analyzed taking into account the different annealing routes. Both long and short time annealing routes were shown to be effective in producing well coupled hard/soft magnetic nanocomposites.

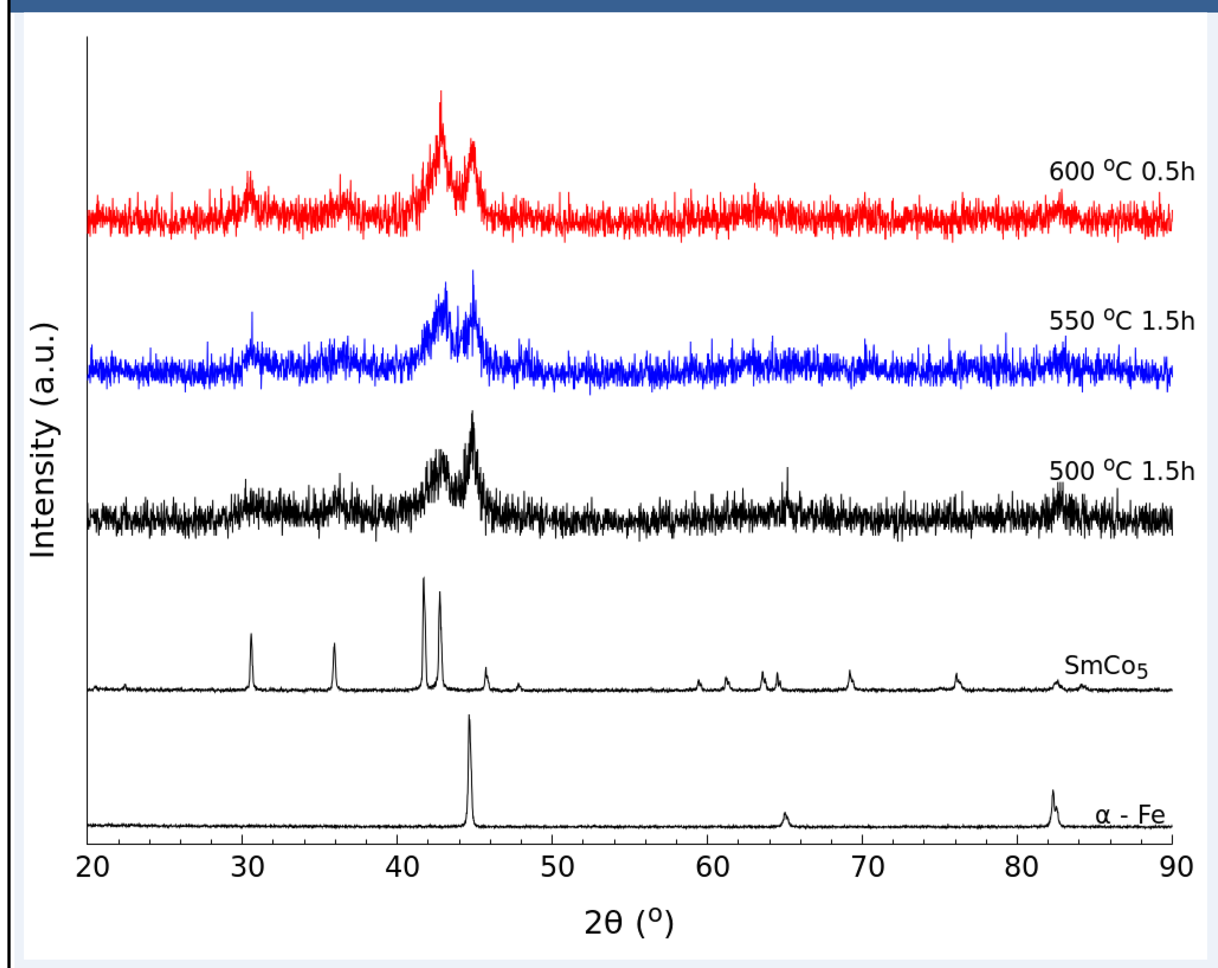
Experimental:

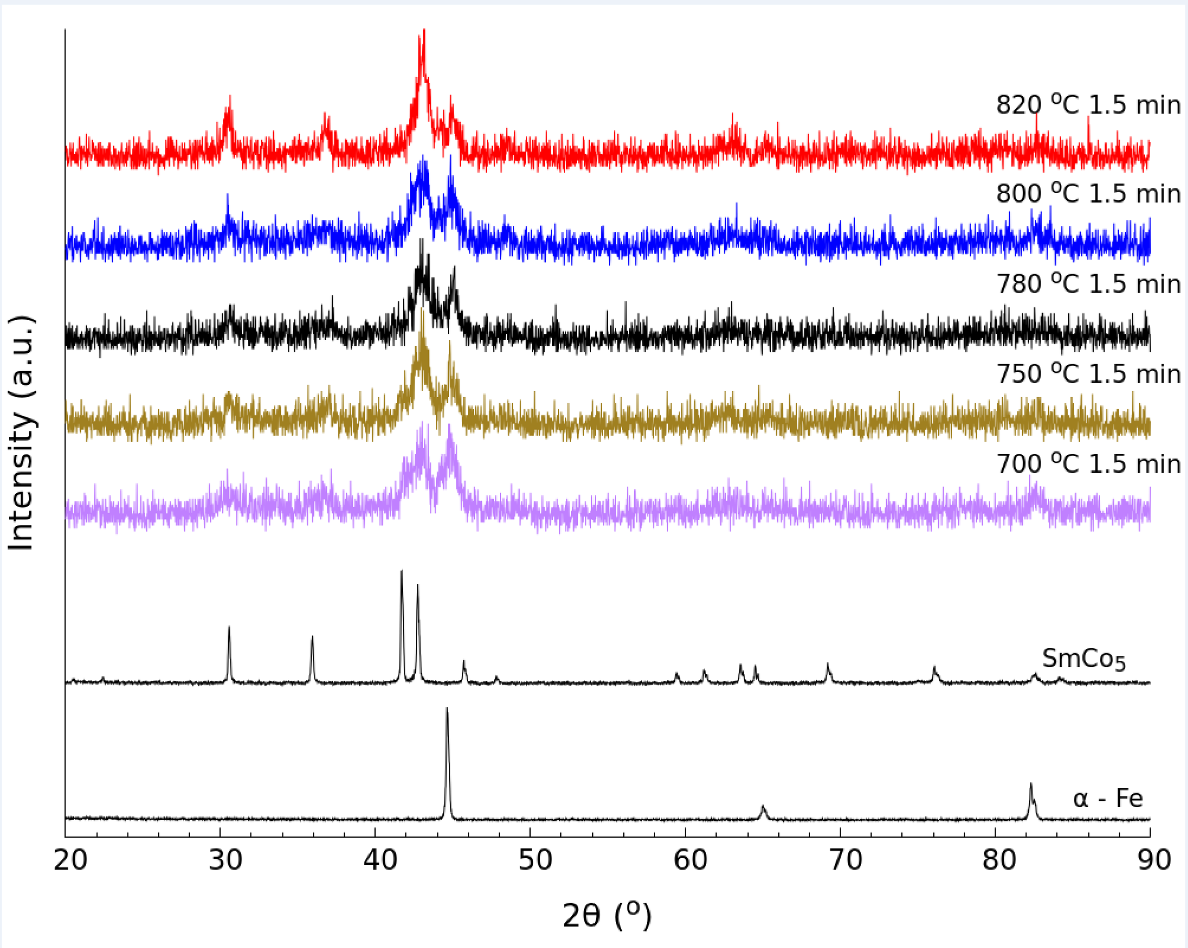
- The **$SmCo_5$ phase** was prepared : induction melting (under purified Ar gas) → annealing in vacuum for 72 h at 950 °C. → ground to a fine powder under 500 μm.
- The **α–Fe phase** consisted of NC 100.24 commercial Fe powder Höganäs product fine powder under 100 μm
- **Nanocomposite synthesis**: starting powder 80wt% $SmCo_5$ + 20wt%Fe → 6h MM → Annealing
- **The milling energies** [2] : 34 mJ / impact, 39 KJ/g for the entrire 6h duration.
- **X-Ray diffraction** measurements were performed on a Brüker D8 Advance diffractometer using Cu - Kα radiation.
- **Magnetic measurements** were carried out on powder fixed in epoxy resin at 300 K in applied fields up to 10 T.
- **Internal Field:** demagnetization factor of 1/3

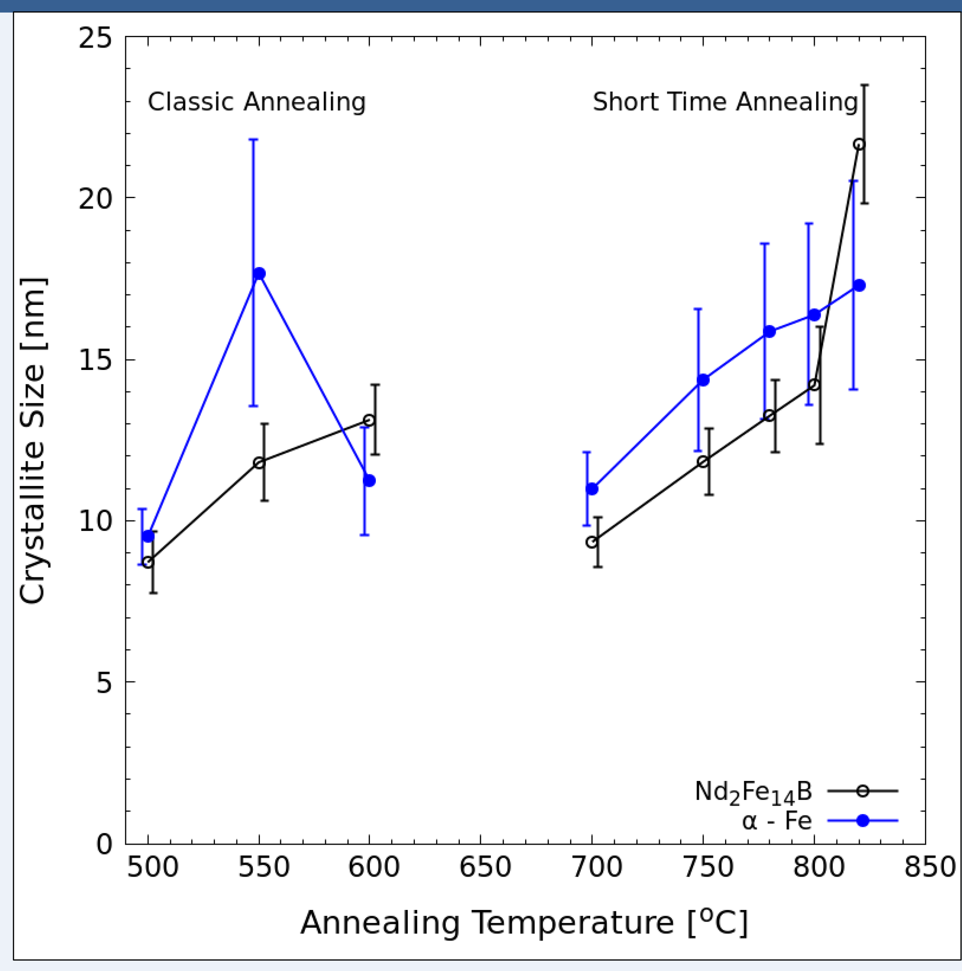
Results and Discussions:

Classic Annealing | **Short Time Annealing** | **Discussion**

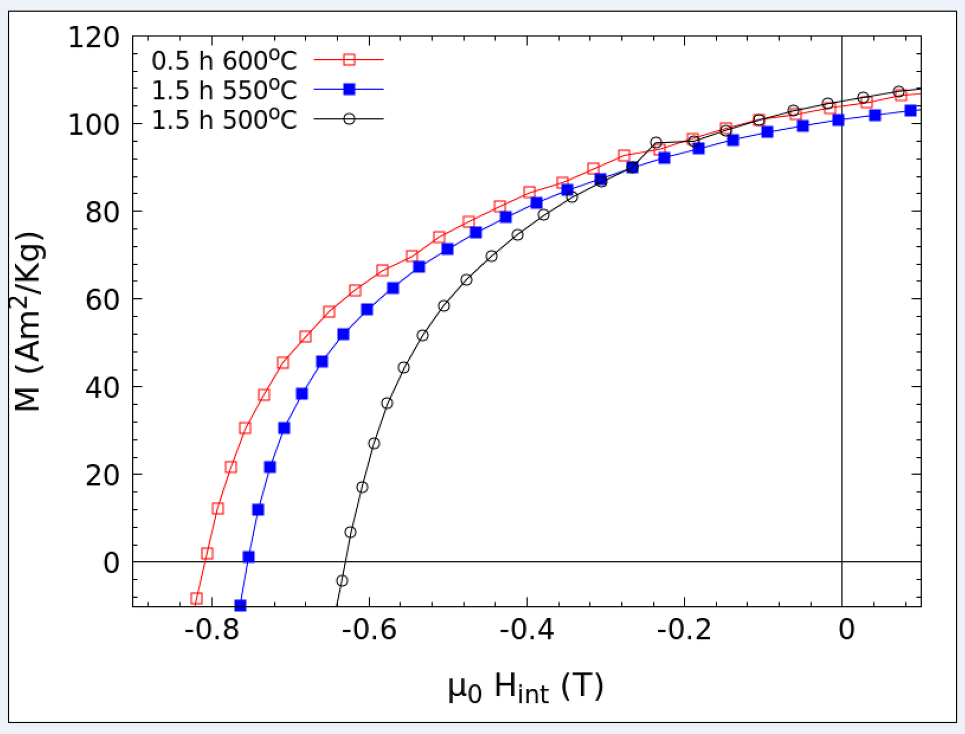
Structure and Microstructure

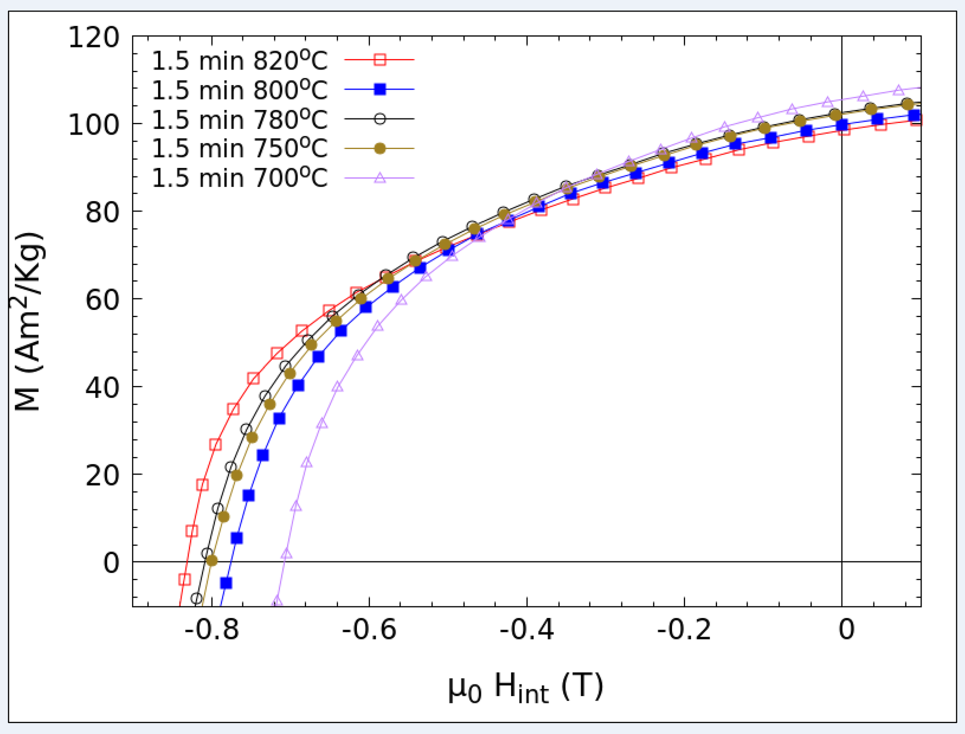


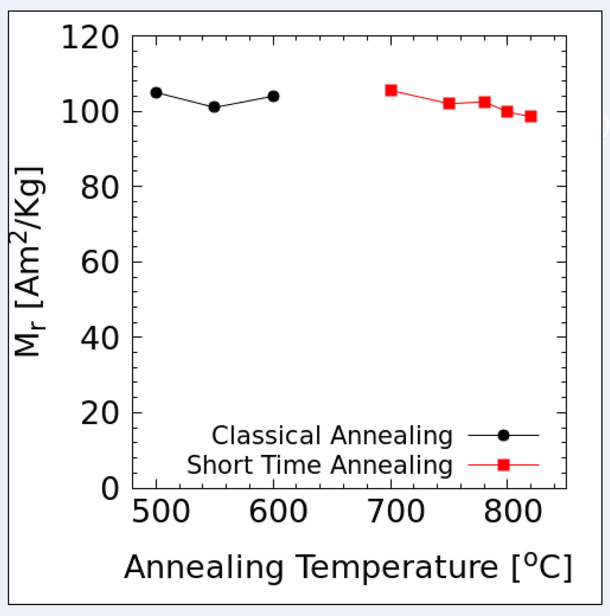


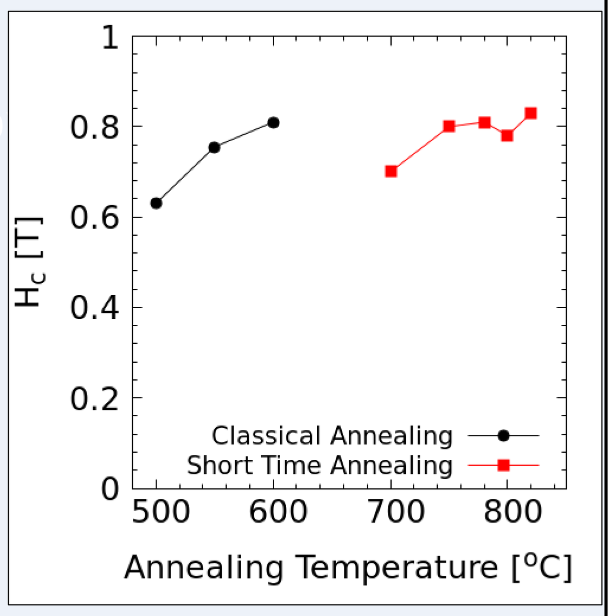


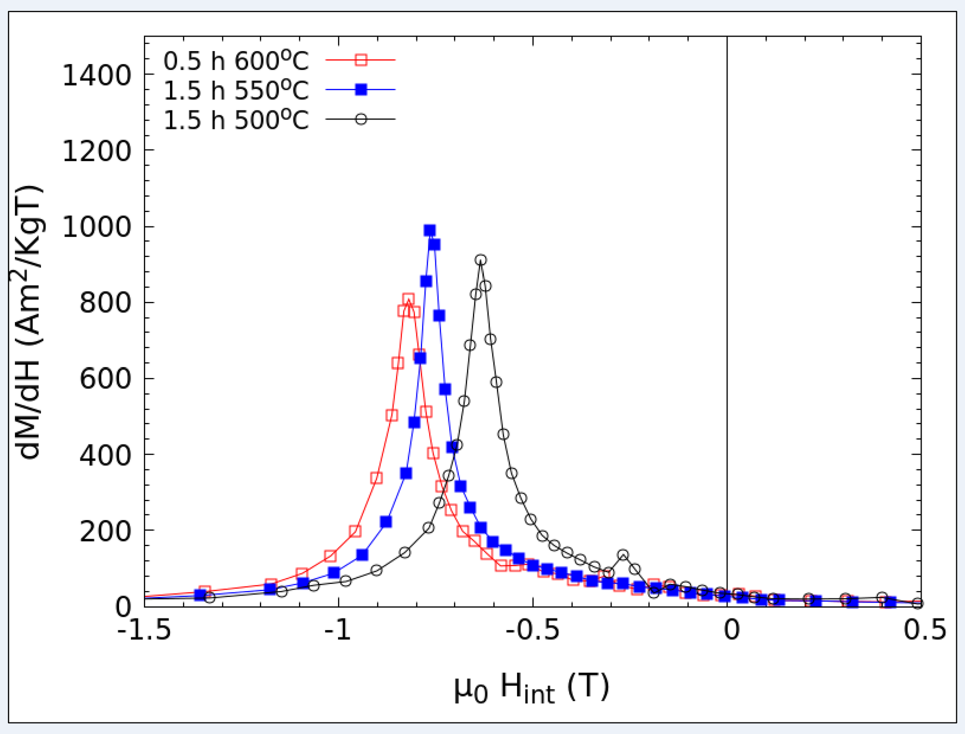
Magnetic Proprieties

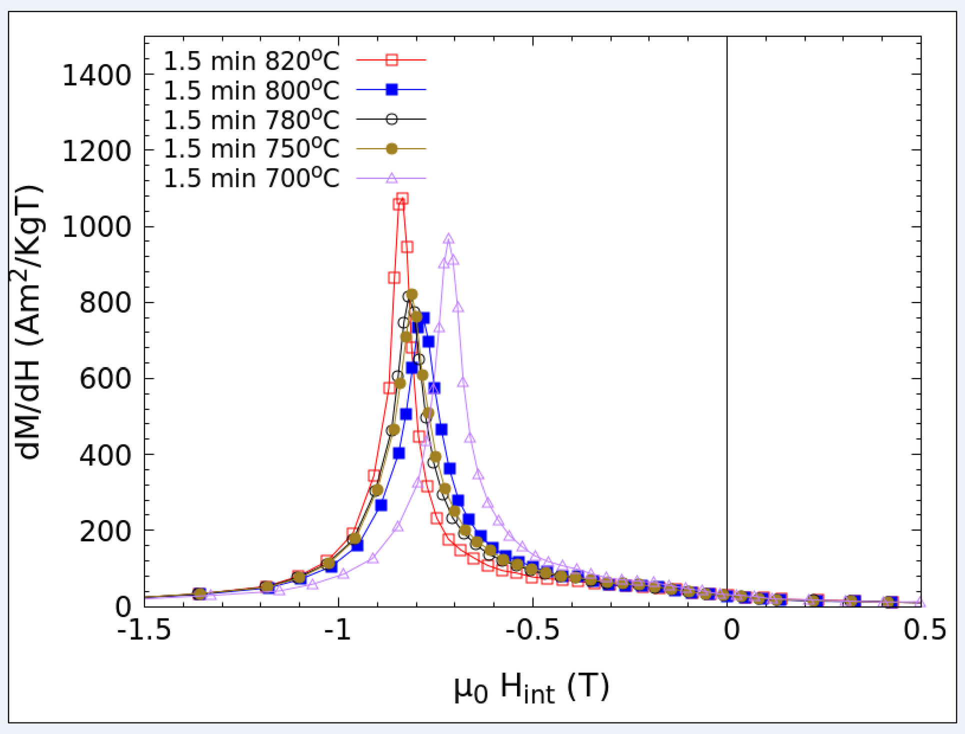


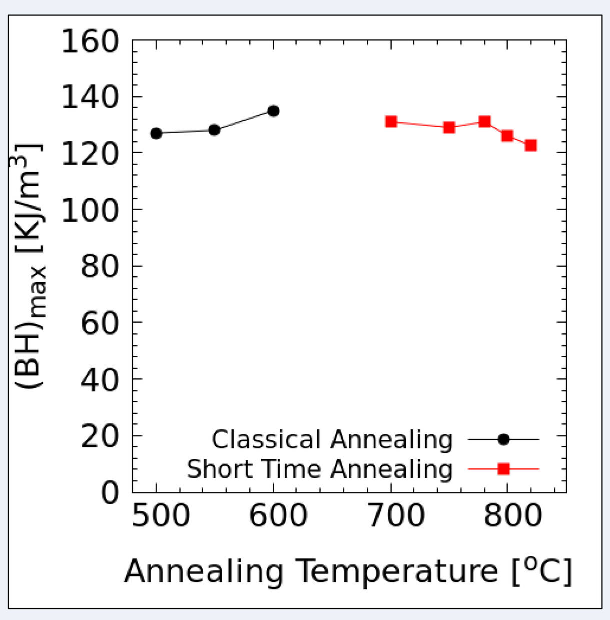


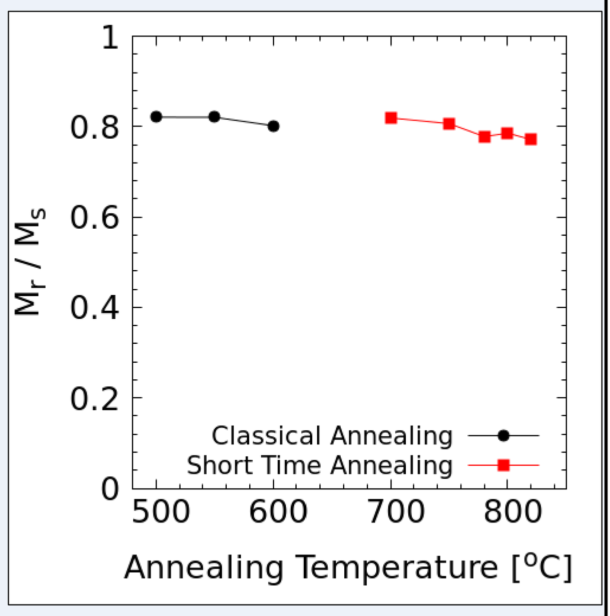












Conclusions:

- **MM + short time annealing → effective** synthesis route for exchange coupled $SmCo_5$/α-Fe nanocomposite magnets.
- The mean **crystallite size** (of both hard and soft phases) are **strongly affected by annealing** temperature and duration.
- α-Fe crystallite sizes increase → energy product decreases
- Both **classic and short time annealing** routes are **effective**, **in contrast to** materials where pinning mechanisms are important in coercivity (**$Nd_2Fe_{14}B$ / α-Fe** [1][3])

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[2] M. Abdellaoui, Acta. Metall. Mater, vol. 43, no. 3, pp. 1087-1098, 1995.
[3] K. Raviprasad, Journal of Applied Physics 83, 916 (1998).

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