IMPROVING THE MAGNETIG ENERGY PRODUCT: SOFT MAGNETIC ALLOYS FOR SPRING MAGNETS

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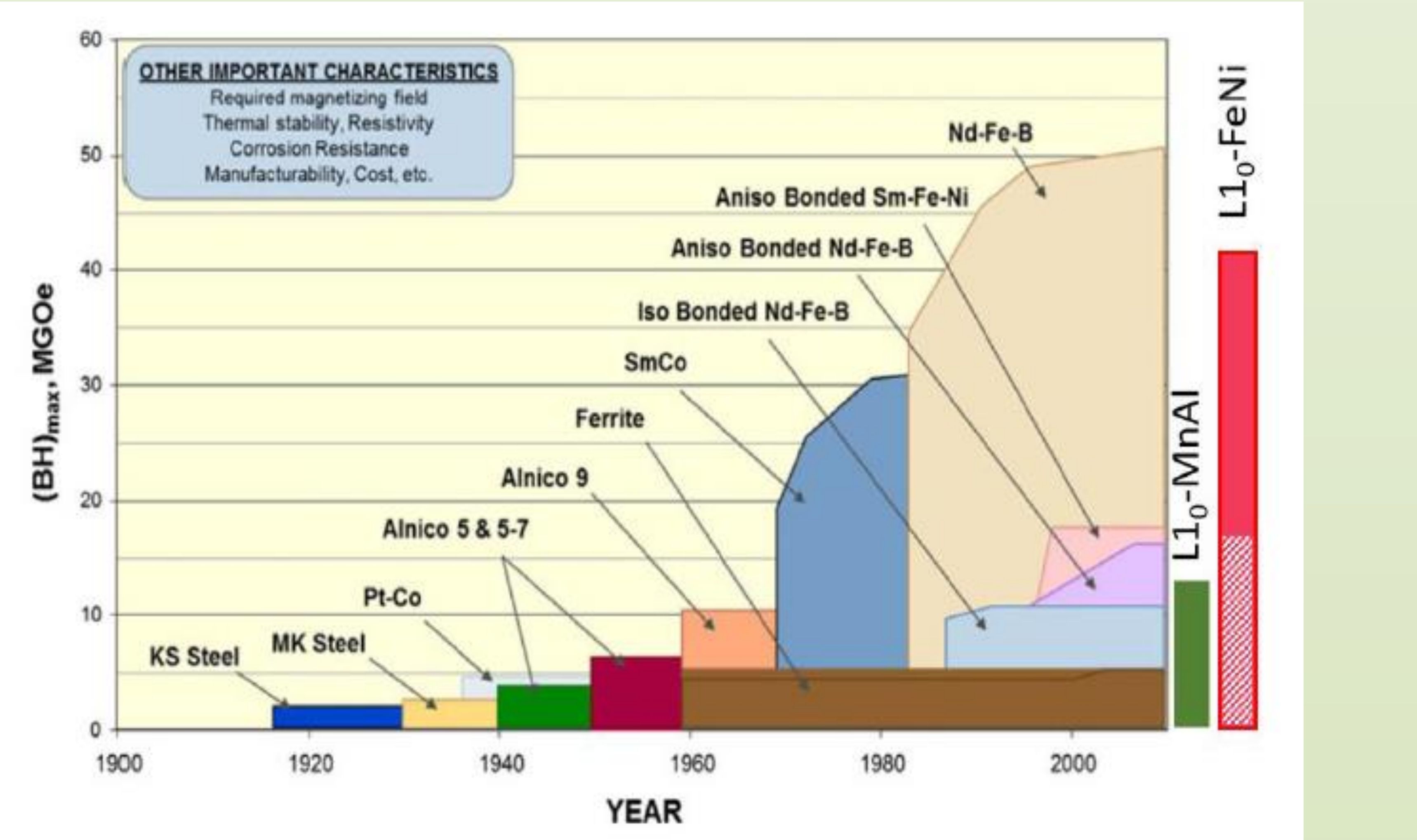
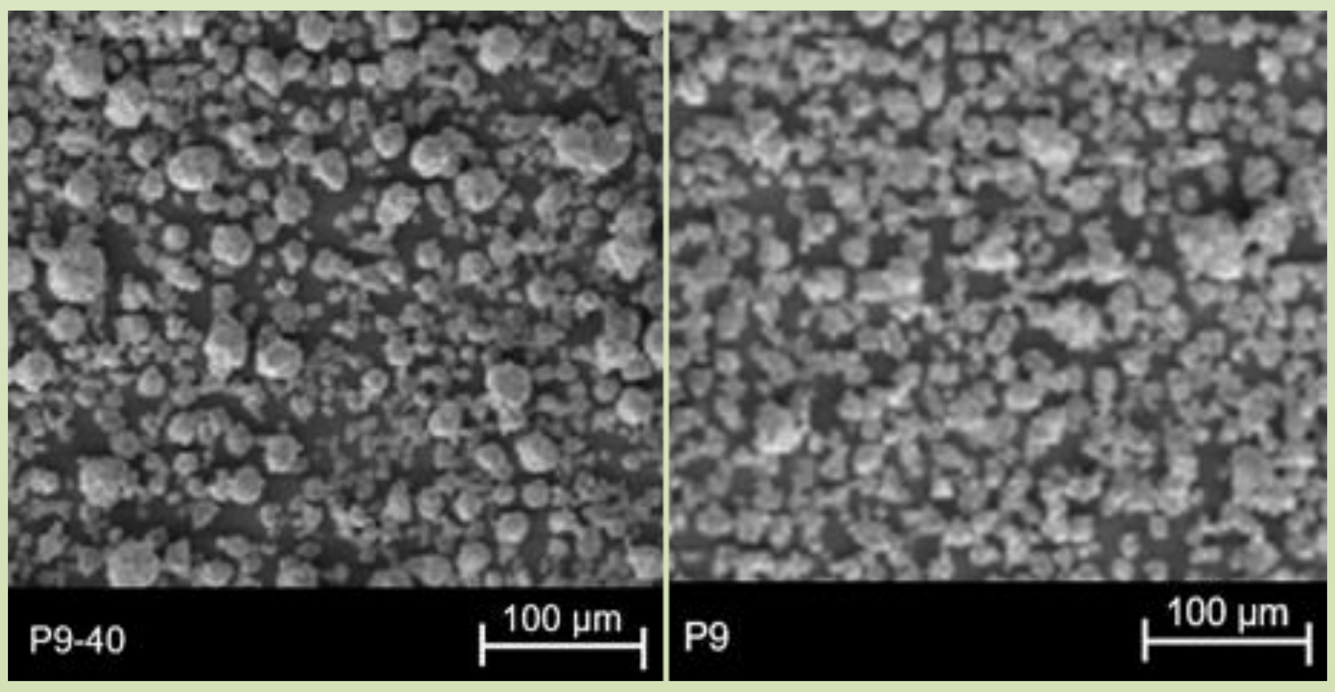
In the present study, we present results of soft magnetic alloys (produced by mechanical alloying) that are candidates to be used in composite materials (soft-hard) with the aim of increasing the saturation magnetization of the hard phase (without significantly decreasing its coercivity). Thus, optimizing the magnetic energy product. In magnetism, the magnetic energy product is a figure-of-merit linked to the strength of a permanent magnet material. It is energy by unit volume.

Some Fe based nanocrystalline soft ferromagnetic alloys have good magnetic properties: High effective permeability (~20,000) and low coercivity (<3 A/m) and core loss (<100 W/kg) at room temperature[1]. Recent magnetic results on Fe rich powdered alloys were analyzed and compared with those previously reported in Fe-Co and Fe-Mn based alloys[2].

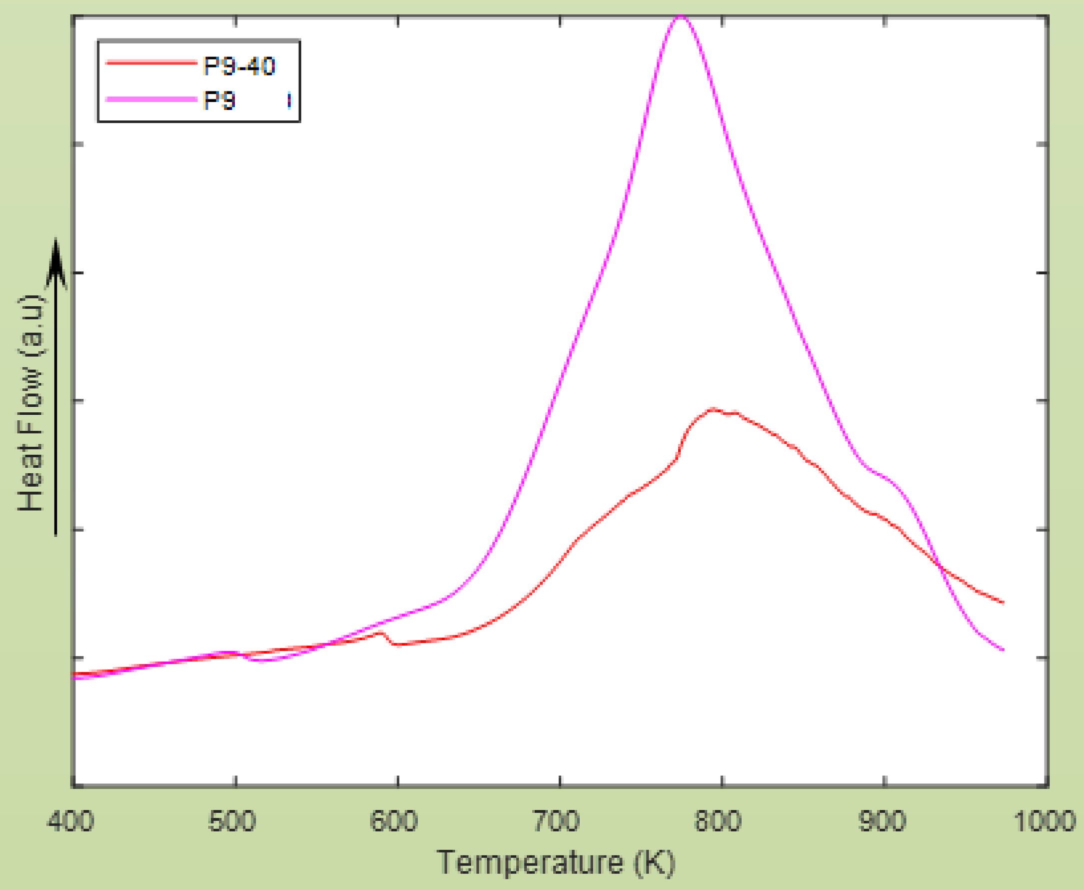
It is found that the controlled addition of Co, Ni, B, Nb or Zr permits the adjustment of the magnetic response. Complementary chemical analysis confirms low contamination from the milling tools. The bcc Fe rich solid solution is always formed (crystalline size 10 – 12 nm). Furthermore, thermal analysis has been performed. The annealing at low temperatures (600 K) favors the thermal stability (> 870 K) and the reduction of the coercivity to ~5 Oe: without a significant change in the magnetization of saturation (~170 emu/g). These alloys will be applied in the development of soft-hard $L1_0$ spring magnets. If the exchange coupling is controlled and optimized, theoretic approach indicates that the magnetic energy product will increase a factor 1.5.



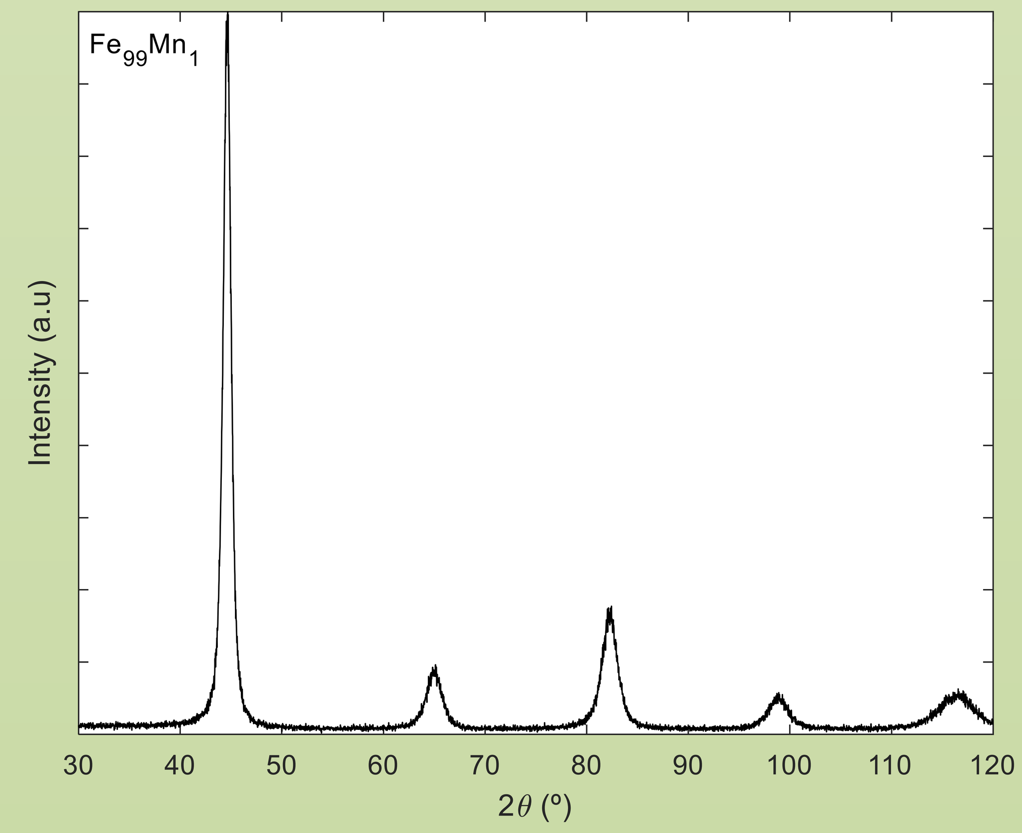
Adapted from: M.J. Kramer et al., *JOM 64, 752 (2012)*

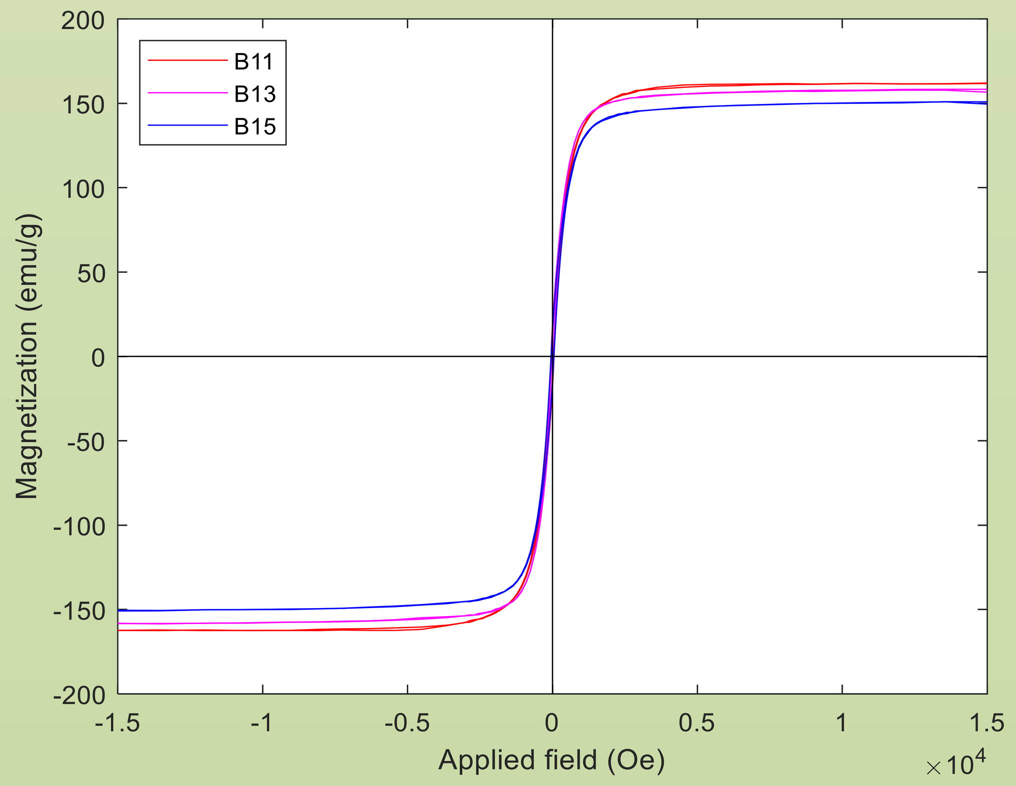


SEM micrographs

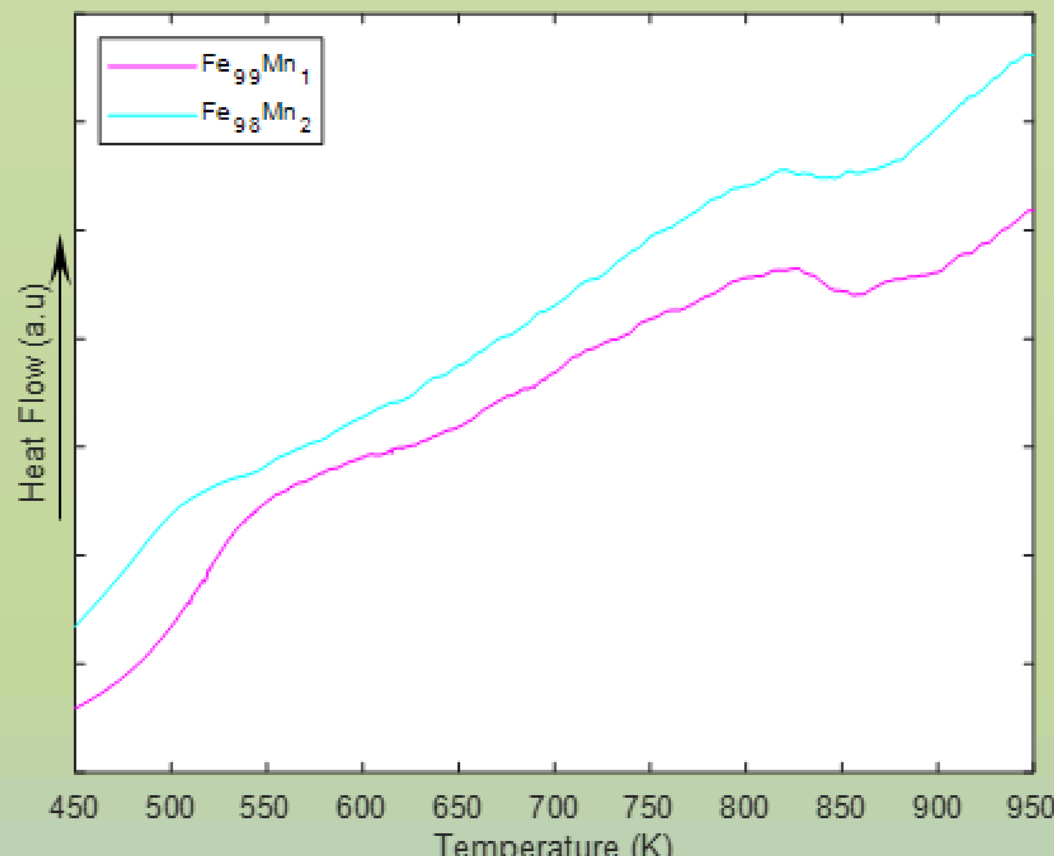


DSC: Finemet alloys

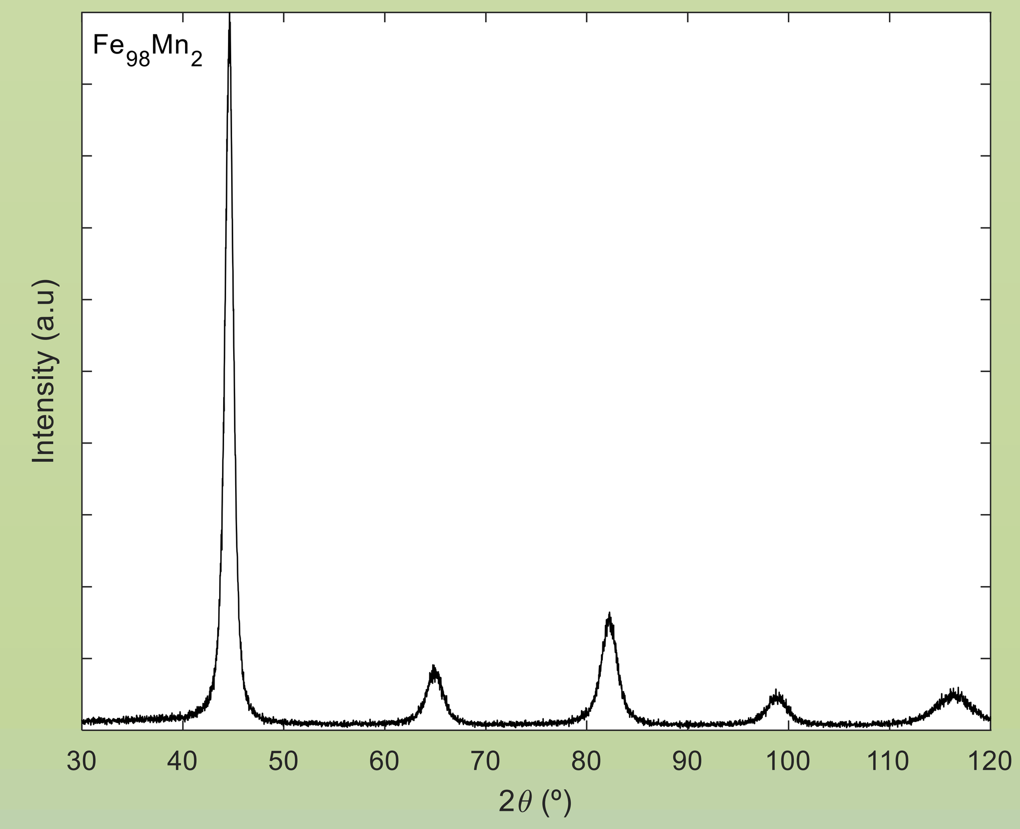




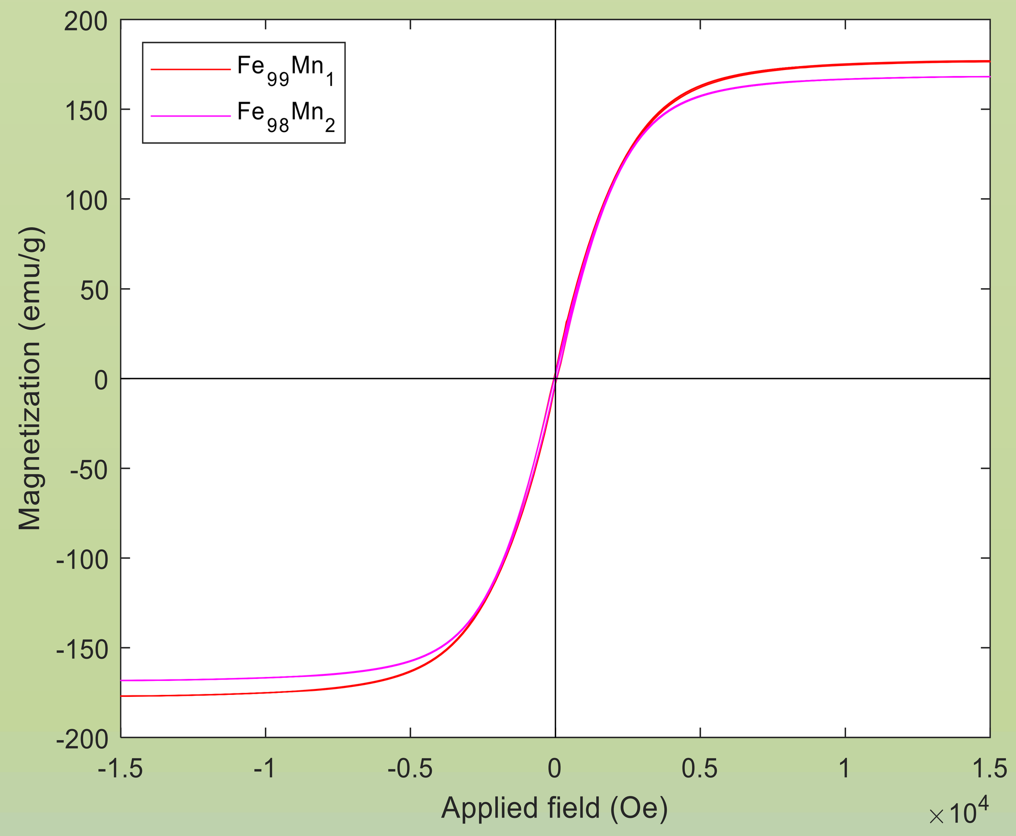
Hysteresis: Finemet alloys



DSC: Fe-Mn alloys



XRD: Fe-Mn alloys



Hysteresis: Fe-Mn alloys

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[1] A. Carrillo, J. Daza et al. *Materials.* **2021**, 14, 1896.

[2] J. Daza, W. Ben Mbarek et al. *Metals.* **2021**, 11, 1896.

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