Soft magnetic FeBZr metallic glasses for application in thermomagnetic energy harvesting

M. Solzi[1,2*], F. Cugini[1,2], G. Garulli[1], A. Amurri[1], J.Y. Law[3], V. Franco[3]

[1] University of Parma, Parma (Italy) [2] IMEM-CNR Institute, Parma (Italy) [3]University of Sevilla, Sevilla (Spain)
*massimo.solzi@unipr.it

Thermomagnetic power generation (TMG), utilizing magnetic materials, has gained recognition as an innovative approach to harnessing and converting significant amounts of low-grade waste heat from sources operating below 100°C [1]. While the concept of TMG has been understood for over a century, substantial research efforts in recent years have concentrated on advancing materials and designing prototypes. Nevertheless, the full potential of this technology remains untapped. Ideal material candidates for this application should have high saturation magnetization, a magnetic transition temperature near/above room temperature, possibly tuneable by composition, and a large magnetization variation near the magnetic transition. Moreover, they should ideally be composed of cheap and non-critical elements. In an effort to find new materials of potential interest for low-grade waste heat energy harvesting applications, Fe-B-Zr based amorphous alloys are worth to be explored, because they exhibit a soft ferromagnetic behaviour with a high saturation magnetization and a tuneable Curie temperature by varying the Fe content [2]. They are also formed by abundant and non-critical elements and have a large thermal conductivity. A series of four $Fe_xB_{0.31(100-x)}Zr_{0.69(100-x)}$ samples (x= 83, 84, 85, 86) was produced by melt spinning. The Fe/Zr ratio from EDX spectra was found to be in good agreement with respect to the nominal compositions. The thickness of the ribbons resulted to be between 10 and 30 µm. All the as-cast samples exhibit a second order Curie transition in the 290-315 K range, without signs of the presence of secondary magnetic phases or other magnetic or magneto structural transitions (Fig. 1.a). The Curie temperature increases while decreasing the Fe content at a rate of approximately 7K/%. Below T_c, all the samples exhibit excellent soft-magnetic behaviour, with a coercivity below 40 A/m and a large saturation magnetization, in the range of 128-155 Am^2/kg. The magnetocaloric effect of the alloys, calculated from isothermal magnetization measurements, exhibits peak values near the Curie temperatures. These peak values scale with Fe content, similar to the saturation magnetization of the alloy series. The thermomagnetic performance of the samples has been directly assessed in a laboratory-scale prototype of TMG, designed as a versatile test bench for the in-operando evaluation of thermomagnetic materials [3]. To this aim, rotors of the alloys have been produced by rolling the ribbons in a plastic support connected to the shaft of the generator. The mechanical and electrical power output from the generator has been measured varying the temperature of the warm thermal source and the load (Fig. 1.b). This work received financial support from European Union - NextGenerationEU (PRIN 2022 PNRR Project "STEve" P2022KMXBL, CUP: D53D23019360001).

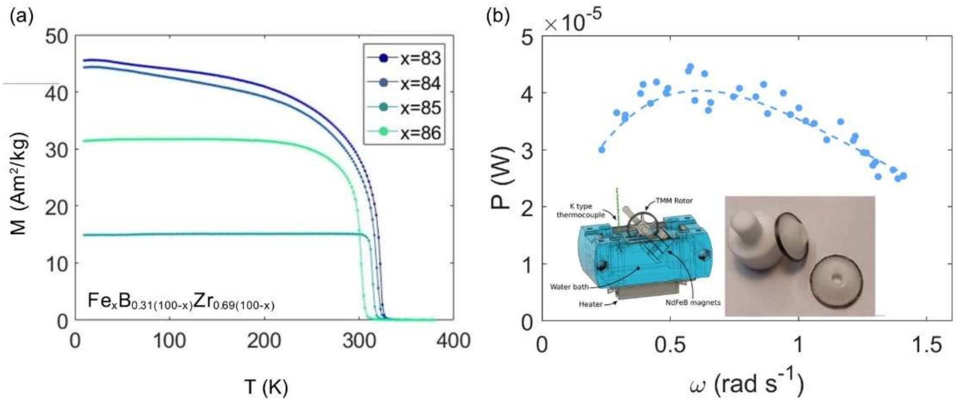

Figure 1. (a) Magnetization of the as-spun FeBZr amorphous alloys vs temperature, with μ_0H=0.01 T. (b) Mechanical power output of a TMG prototype using the x=86 alloy, vs the speed of rotation. Inset: schematic of the prototype and photograph of the tested rotor, which was fabricated with the alloy ribbon.

References

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