Smart magnetic materials for energy efficiency and biomedicine

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Magnetic materials are widely used in several important applicative sectors related to energy conversion, electric power generation, transportation, power electronics and information technology and play a crucial role in the realization of technologies aimed at energy saving and CO_2 emission reduction. Hard and soft magnetic materials find for example different applications in permanent magnets and in the generation and conversion of electric power. On the other hand, multifunctional magnetic materials have great potential for the development of new technologies, such as solid-state refrigeration, energy harvesting and remote actuation and hold a great promise in new-concept biomedical applications.

In the present talk I will introduce the main activities of the Multifunctional Magnetic Materials Group at IMEM-CNR on materials for energy and biomedicine and in particular I will focus on ferromagnetic shape memory materials. It is an emerging class of materials that, tanks to the strong interplay between magnetism and structure at the different length-scales, show “giant” magneto/elasto-caloric and thermo/magneto-mechanical effects. These effects can be driven by external stimuli, such as magnetic field, temperature, pressure and stress and pave the way to novel energy-efficient and smart technologies.

One of the most promising applications of these materials is magnetic refrigeration, an eco-friendly technology alternative to gas-vapour compression. It works without gas-based refrigerants and allows higher efficiency. Magnetic materials heat up or cool down in response to the application or removal of a magnetic field. Materials with a critical temperature near room-temperature are the basis for the design of caloric refrigeration devices. On the other hand, actively heating these materials with “waste” heat can produce electric power in a device, making caloric materials an attractive alternative energy source. Implementation of such technology requires highly responsive materials with operation temperatures between room temperature and 400 K.

Our research has been focused both on bulk materials and thin films for their possible exploitation in macro and micro devices. More recently we have also produced ferromagnetic shape memory free-standing nanostructures (i.e. nanodisks) and demonstrated their possible actuation by the combined application of T and magnetic field. The achieved areal strain (up to 5.5 %,) is reversible and tunable in intensity and sign (i.e. an areal contraction or expansion can be obtained on cooling, depending on the application of a magnetic field). A temperature or magnetic field induced change of shape could enable new mechanisms for cells manipulation, cellular remote control and drug delivery, and tissue engineering. In general, magnetic shape memory free standing nanostructures, suitably functionalized, could be the active elements of a new generation of multifunctional systems such as synthetic liquids for different applications, ranging from nano-harvesting to nano-bioactuation.