Spectroscopic characterization of nanomaterials

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Nanomaterials science is currently one of the most important and promising field of research. Getting down to nanometer dimensions, materials can in fact show peculiar and different properties from those of bulk one, that can be at the base of applications in many fields. Two classes of zerodimensional magnetic objects may be distinguished: magnetic nanoparticles (MNPs), which can be considered to be derived from a top down approach, and molecular nanomagnets (MNMs), which are obtained through molecular techniques in a bottom up approach. Theoretically, MNMs are described by quantum mechanics, with a treatment that starts from the single ion, while MNPs are described classically, based on parameters derived from bulk materials. The need for a unified view of such systems has been proposed, which may provide greater insight into their properties [1, 2]. The promise offered by this approach, by comparing the magnetic behaviour of the two classes of systems, has already shown fruitful results. In particular, single molecule magnets (SMMs), belonging to MNM class, show magnetic bistability at the molecular level due to the existence of a double-well potential hampering the reversal of the magnetization: this makes them ideal candidates for the creation of devices for quantum storage of information [3, 4].

The aim of this work is the spectroscopic characterization of magnetic nanomaterials. This study is based on two different techniques, having in common the possibility to evidence the electronic structure of these materials at cryogenic temperatures. These techniques are Mössbauer and Electron Paramagnetic Resonance (EPR) spectroscopies.

The first method grounds on the Mössbauer effect and concerns the resonant absorption of gamma rays from a radioactive source. EPR lies instead on the magnetic interactions between the unpaired electrons in a material and an external magnetic field. Spectra in reflection configuration are registered by applying a radiation in the GHz range while varying the intensity of the magnetic field in the sample region. From the analysis of the spectra of these systems the spin energy level structure and the internal magnetic fields can be obtained [5, 6]. In particular, EPR has been a key tool in demonstrating the similarities in the behaviour of MNPs and MNMs, enabling recognition of the experimental signature of quantum behaviour in small MNPs [6, 7].

The first example of SMM under study is Fe4, a molecular cluster made up of four iron (III) ions. This molecule is an ideal candidate for spintronic devices, as it retains magnetic bistability when deposited on a surface [8]. Previous works dealing with standard Mössbauer spectroscopy on powder samples studied the spin dynamics of the system in a low-temperature regime [9, 10]. To understand the coupling between the molecule and the substrate, which may lead to a different dynamics with respect to the powder sample, Fe4 deposited on a surface is currently under study by Mössbauer spectroscopy with synchrotron light. The apparatus set at the ID18 line of the

European Synchrotron Radiation Facility in Grenoble seems to show the necessary sensibility to complete this study.

Another attractive class of magnetic materials are the magnetoelectric ones, where magnetoelectric cross-coupling allows for an electric (magnetic) control and modulation of magnetic (electric) responses [11]. In order to better characterize these materials for applications in the field of encoding and manipulation of quantum information, it is set to implement an X-band EPR spectrometer (0.3 T, 9.5 GHz) in a way that the sample be subjected to an intense electric field (of the order of 10 kV/mm) during the measurement.

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