Novel functional oxides for electronic and spintronic applications

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The remarkable miniaturization trend worldwide known as Moore law has been so far achieved through a continuous scaling down of metal-oxide–semiconductor field-effect transistors allowing an always increasing density and speed in the new integrated circuits. However, to further increase device performance, innovations on materials and architectures are required. In this frame, during the last year, we focused on the study of functional oxides for their exploitation in electronic semiconductor devices and spintronics. In particular we investigated high-k and multiferroic materials [1] which belong to the perovskite family.

Concerning high-k materials, Y_2CuTiO_6 was investigated in collaboration with Prof. D.D. Sarma group at the Indian Institute of Science in Bangalore [2]. This activity was focused on the morphological characterization of thin films by SEM analysis and on their dielectric characterization. Bulk YCTO is interesting since it shows high dielectric constant (ε') and small dielectric loss (tan δ), important properties to improve the gate stack technology as well as the miniaturization of resonators, antennas and transmitters. In literature there aren't studies on this material in thin film form. Here a systematic characterization was carried out to find the best growth conditions for achieving improved properties. The oxygen pressure in the deposition chamber was varied ranging from 0.05 Pa to 1Pa. A strongly dependence from the PO_2 has been found. It was recorded a reduction of dielectric constant from 90-100 to 18 at 1MHz going from 0.05Pa to 0.5Pa. A comparison between YCTO and most common oxides was also performed. For all measured frequencies, the dielectric constant of YCTO thin films was found to be considerably higher than both SiO_2 and MgO thin films, deposited and characterized in similar device structures. In addition, a new strategy was developed for the extraction of the dielectric constant value from each set of junctions realized on the same film. The goal was to remove all the possible artefacts resulting from spurious capacitance decoupling the parasitic contributions from the intrinsic ones. This objective was achieved by plotting the measured capacitance as a function of the different area of the junctions and performing a simple linear fit on the curves at each different frequency value.

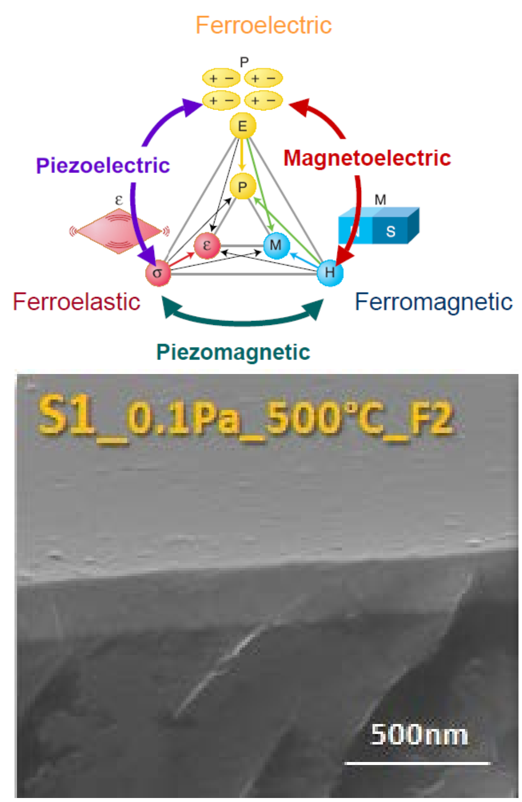

Figure 1. (a) Multiferroic materials.(b) SEM image of a BFO film.

Concerning $BiFeO_3$ (BFO), a promising multiferroic material, our activity ranged from the synthesis of bulk BFO up to the structural, morphological, dielectric and ferroelectric characterizations of both its bulk and thin film forms. Structural characterization was performed using X-Ray Diffraction and FT-IR spectroscopy. A dielectric spectroscopy characterization was carried out in order to check its permittivity and magnetic measurements to check its magnetic response. The dielectric constant and tangent loss were found to be ≈ 57.3 and 0.04 at 1MHz, in agreement with the literature. Magnetization measurements were performed on bulk BFO ceramic samples using a VSM. A linear dependence of magnetization on the applied field was observed for pure BFO, in agreement with the expected antiferromagnetic ordering. A systematic study was also performed in order to understand the role of each parameter, such as substrate temperature, oxygen pressure, fluency, number of pulses, in the structure and impure phase formation (critical aspect) during BFO deposition in thin film form. It has been found that starting from a non-stoichiometric target is possible to limit the effect of bismuth losses and contain the impure phase formation. On the other hand increasing the oxygen pressure from 0.5Pa to 1Pa improved dielectric properties have been observed, due to the decreasing number of the oxygen vacancies.

All this work on BFO and YCTO is coming now to conclusion with the submission of two manuscripts.

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