Localized states in advanced dielectrics from the vantage of spin- and symmetry-polarized tunnelling across MgO.

F. Schleicher¹, U. Halisdemir¹*, D. Lacour², M. Gallart¹, S. Boukari¹, G. Schmerber¹, V. Davesne¹, P. Panissod¹, D. Halley¹, H. Majjad¹, Y. Henry¹, B. Leconte¹, A. Boulard¹, D. Spor¹, N. Beyer¹, C. Kieber¹, O. Cregut¹, M. Ziegler¹, F. Montaigne², E. Beaurepaire¹, P. Gilliot¹, M. Hehn², M. Bowen¹

1 IPCMS UMR 7504 CNRS, Université de Strasbourg, 23 Rue du Loess, BP 43, 67034 Strasbourg Cedex 2, France
2 Institut Jean Lamour UMR 7198, CNRS—Université de Lorraine, BP 70239, F–54506 Vandoeuvre les Nancy, France.

Advanced materials such as ferroelectric or multiferroic perovskites are the focus of intense research due to promising applications. Yet studies on these materials rarely address the impact of defects on the expected materials property. We revisit the comparatively simple oxide MgO as the model material system used to study spin-polarized solid-state tunneling and present a defect-mediated tunneling potential landscape of localized states due to identified defect species, against which we examine the bias and temperature dependence of magnetotransport. We rationalize spectroscopic signatures of these localized states in the bias dependence of the decrease in tunneling magnetoresistance with increasing temperature.

Oxygen vacancies in crystalline network of MgO can be classified as single (F) or double (M) vacancies, which may occur in their grounded, charged (denoted +) and/or excided (denoted *) states. Each of these occupies respective energy level within the bandgap with certain energetical distance from the conduction band minimum[1]. If the crystalline MgO is incorporated into a magnetic tunnel junction, these levels will also be positioned in certain distances from the Fermi level, which in our system we identify as -1.2eV (F/F+), +0.7eV (F*), +1.6eV (F*) and -0.4eV (M)[2]. We provide and highlight an explicit description of thermally-activated defect-assisted magnetotransport by utilizing solid-state tunneling spectroscopy[3] to probe the ground and excited states of oxygen vacancies. In order to do so, we extend the I-hat method developed by Rottlander et al.[4] to its relative case, i.e. we study the evolution of junction within small (down to ΔT=3K) temperature intervals. I-hat peak positions in such transport measurements correspond to the effective barrier height within a respective temperature range. We observe that the spin-polarized transport across our MgO-based MTJs with a low density of M centers reproducibly proceeds with respect to F+ center at low temperature and F* centers with increasing temperature. This is associated, with increasing temperature, with an abrupt switchover between a F/F+-dominated TMR decrease and a F*-dominated TMR decrease. We will discuss how our results and analysis resolve the contradiction between low barrier heights and large values of TMR in MgO MTJs. In the process, we shall emphasize a very important nuance to the generally accepted, intuitive paradigm that reducing defect densities will lead to improved TMR ratios.