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Positronium probing of pores in zirconia nanopowders

I. Prochazka[1,*], J. Cizek[1], F. Lukac[1], O. Melikhova[1], P. Hruska[1], W. Anwand[2], O. Liedke[2], T.E. Konstantinova[3] and I.A. Danilenko[3]

[1]*Department of Low Temperature Physics, Faculty of Mathematics and Physics, Charles University, V Holesovickach 2, CZ-180 00 Praha 8, Czech Republic*
[2]*Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany*
[3]*National Academy of Sciences of Ukraine, Donetsk Institute for Physics and Engineering Named after O. O. Galkin, Luxemburg Street 72, 83114 Donetsk, Ukraine*

[*]email: ivan.prochazka@mff.cuni.cz

Zirconium di-oxide (ZrO_2 , zirconia) receives nowadays a big attention because of a variety of advantageous properties which make zirconia-based materials useful in numerous fields of practice, in particular, in ceramic industry and other high-temperature applications. To make high-temperature phases of zirconia stabilised down to room temperature, doping of the host lattice by proper metal cations has to be usually performed. Nanopowders are currently focused on as starting substances for manufacturing ZrO_2-based ceramics by sintering, because well-homogenised materials of a low porosity can be produced more easily. Nanometer-sized defects associated to grain boundaries (GBs) become then to play an enhanced role in nanopowders due to enlarged volume fraction of GBs. Positrons and positronium (Ps) atoms can serve as efficient probes of different structures encountered in particular stages of manufacturing ZrO_2-based functional materials.

In the present contribution, conventional positron and Ps lifetime measurements were carried out on a variety of zirconia-based nanopowders and ceramics obtained by sintering these nanopowders. Nanopowders studied were doped with various metal cations (Y^{3+}, Cr^{3+}, Ce^{4+}, Mg^{2+}) and differed also in thermal treatment prior sintering. Lifetime experiments were conducted in air or in vacuum and combined with Doppler broadening measurements using slow-positron beam and supplemented with X-ray diffraction (XRD) and mass-density (MD) measurements. In Figure, variability of the lifetime spectra observed is illustrated. In a range of lifetimes from a few ns to ≈ 70 ns, up to three individual lifetime components could be identified, see Figure, (a) and (b). Such observations unambiguously testified Ps formation with subsequent ortho-Ps annihilation. On the other hand, an absence of the ortho-Ps components was found in certain nanopowders giving thus an evidence of a strong Ps inhibition, see Figure, (c).

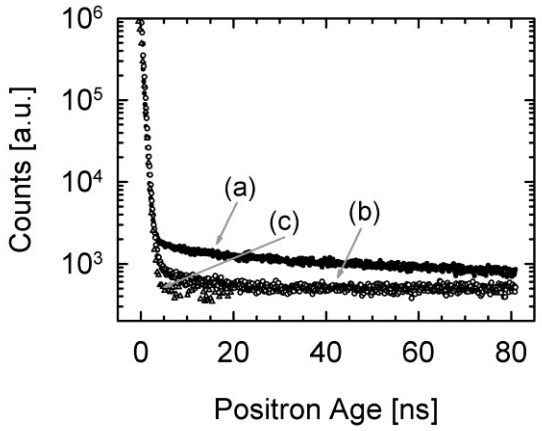

Figure. Lifetime spectra measured in air for ZrO_2 nanopowders doped with (a) 10 mol.% MgO, (b) 12 mol.% CeO_2 and (c) 3 mol.% Cr_2O_3 .

Pore sizes were estimated using current models of correlation between observed ortho-Ps lifetime and pore size. Origins of pores will be discussed on the basis of the ortho-Ps data in combination with the results of slow-positron beam, XRD and MD measurements.