Effects of Physical- and Chemical-Adsorbed Water near Grain Boundaries in Modified MgO-Al$_2$O$_3$ Nanoceramics Tested with Positron-Positronium Trapping Algorithm

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The positron annihilation lifetime (PAL) spectroscopy method based on the fact that the unstable positron-electron system (positronium Ps) is repelled from ionic cores of atoms and tends to location in open pores. In the ground state, the Ps exists as singlet para-positronium p-Ps and triplet ortho-positronium o-Ps. In the case of oxide water-immersed ceramics, two channels of PAL should be considered – the positron trapping and o-Ps decaying [1]. In general, these processes are independent ones. However, if trapping sites will appear in a vicinity of grain boundaries neighbouring with free-volume pores, they can become mutually interconnected resulting in a significant complication of the measured PAL spectra. This occurs provided the input of one of the above annihilation channels will be significantly changed. In addition, adsorbed water influences on process of physical and chemical adsorption of water near grain boundaries in the MgO-Al$_2$O$_3$ ceramics.

To clarify this feature, we shall study the PAL characteristics of modified MgO-Al$_2$O$_3$ ceramics affected to water sorption treatment enhancing o-Ps decaying over positron trapping modes using positron-positronium trapping algorithm [2].

The ceramic pellets were sintered in a special regime with maximal temperatures ($T_s$) of 1100, 1200, 1300 and 1400 °C during 2 h [1]. The PAL measurements were performed with an ORTEC spectrometer ($^{22}$Na source) placed between two sandwiched samples. PAL spectra were fitted on four components with positron lifetimes $\tau_1$, $\tau_2$, $\tau_3$ and corresponding unity-normalized intensities $I_1$, $I_2$, $I_3$. The third components in the measured lifetime spectra are due to “pick-off” annihilation of o-Ps atoms in ceramics nanopores filled with adsorbed water. It is established that the $\tau_3$ lifetime increases with $T_s$, while its intensity $I_3$ decreases. These changes correspond to the increased nanopore size and smaller amount of nanopores. In all water-immersed samples, the intensity of third component $I_3$ significantly increases as compared with dried samples indicating a large content of absorbed water present in ceramics.

To apply positron-positronium trapping algorithm it was shown that the chemical-adsorbed water vapor modifies structural defects located at the grain boundaries in a vicinity of pores, this process being accompanied by void fragmentation during water adsorption and agglomeration during water desorption after drying. The physical adsorbed water not modified grain boundaries in oxide MgO-Al$_2$O$_3$ ceramics located only in nanopores.