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Positron annihilation spectroscopy: pursuing point defects in superconducting film

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"Positron annihilation spectroscopy (PAS) is a precise probe of point defects in nanomaterials. It enables to sense defect densities in the range of 1015-1019cm-3. Positrons localize in the neutral and negatively charged open volume defects, i.e. vacancies and their agglomerations, extended defects or pores. The time to annihilation of the positron with an electron depends on local electron density and it scales with the open volume size. The annihilation process itself leads to emission of gamma radiation, which is subsequently measured. Positrons pre-accelerated to a given kinetic energy can be implanted into solids, allowing depth profiling. In a defect positron lifetime increases and the energetics of the annihilation photons changes. These characteristics are measured using two main measurement techniques, namely positron annihilation lifetime (PALS) and coincidence Doppler broadening spectroscopy (cDBS), respectively. Both techniques are available at the user facility ELBE (HZDR, Germany). PALS allows to evaluate the defect size and concentration, while cDBS is sensitiv to the local atomic chemistry.

This contribution discusses the role of defects in superconducting materials, candidates for coatings of SRF cavities. The advantages of using PAS to evaluate defect concentration and chemistry in Nb have been demonstrated for vacancy-hydrogen complexes during low temperature baking [1] as well as in case of vacancy kinematics and evolution of native Nb oxides for baking at larger temperatures [2]. A combination of PAS and DFT calculations has transformed the experimental results into defect types/sizes and highlighted the role of vacancy complexes and Nb oxides onto performance of cavities. We will present the most recent evaluation of defect microstructure in DC- and HiPIMS-sputter deposited Nb, NbN, and NbTiN films.

[1] M. Wenskat et al., Sci. Rep. 10 (2020) 8300

[2] M. Wenskat et al., Phys. Rev. B. 106 (2022) 094516"

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