Report on the "Development of experimental techniques and applied research with slow monochromatic positron beams (PAS)" project

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Positrons are sensitive and selective probes of open volume defects (vacancies, voids) in solids. Beyond defect spectroscopy, they are used for various applied and fundamental studies, with a solid user community and regular international meetings. The aim of the project is to develop a slow monochromatic positron beam based experimental system.

The main achievement so far is the successful construction and exploitation of a variable energy slow positron beam based spectrometer ("Specialized slow monochromatic channel") with Doppler broadening spectroscopy as detection method. To generate slow positrons, a sodium-22 radioactive isotope based source was constructed already in 2015, with state-of-the-art solid neon moderator. A conventional positron lifetime spectrometer (PALS) was implemented in 2017 and an ion etching system installed to help to study thin film samples. The development of a beam-based positron lifetime system is underway.

In the last two years the project had a very good publication activity. Measurements performed using the instrumentation of the project have been used in nine scientific papers, published in quality journals (Applied Surface Science, 2 in Vacuum, NIM B, 2 in Metals, Optical Materials, Materials, Physica B). All papers are dated from 2020-2021, in a relatively short time after the commissioning of the "specialized slow monochromatic positron channel". Five of the publications presented results using the monochromatic positron beam, four of them studied irradiation or implantation induced defects in various solids. Further four published papers contains results of conventional positron lifetime or Doppler broadening measurements, one of them is completed with ab initio calculation of positron lifetime. One PhD and one DSc thesis have been defended in the topics of the project. Presentations at international meetings were hindered by the COVID-19 pandemic. The publications are centered on studies of open-volume defects in solids, which is one of the major applications of positron annihilation spectroscopy. It is obvious from the publications that the spectrometer is a competitive instrument, which can yield well publishable results.

The group plans to continue measurements with the present system, along with the development of an "ordered positron beam", a pulsed monochromatic slow positron beam which allows positron annihilation

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lifetime measurements as a function of the positron energy, i.e., as a function of the depth near the sample surface. Such a device can yield more information on the environment of the positron at the time of annihilation than Doppler broadening measurements.

There are no details in the report about the actual status of this development, only a reference to a buncher system, with some details in earlier publications. There are some open questions (a) regarding the efficiency of this device with the relatively broad kinetic energy distribution of the present positron source and (b) about the way to achieve the high signal to noise ratio needed for good quality positron lifetime measurements. However, I believe that these questions can be solved, (a) possibly with the implementation of a "Surko-trap", a Penning trap system that has been demonstrated to yield high quality positron beams with narrow energy spread and (b) with the careful design of the experimental chamber and perhaps by an additional chopper stage. The group reported that an earlier attempt to develop a Surko trap failed, which may be attributed to some problem with the instrumentation.

There are no details about the planned purchases but the requested budget seems to me realistic. The work force available for the construction of the pulsed system is adequate. However, the 1.5 FTE total researcher time may be somewhat limited for both the scientific supervision of the construction work and the exploitation of the existing spectrometer.

Summary

I very much appreciate the recent published results of the project and I fully support the plan to continue research activity with the Doppler-broadening measurement based spectrometer. There is a shortage of well working and accessible slow positron spectrometers internationally. Collaboration with groups with expertise in positron spectroscopy but no access to depth-dependent measurements can yield high quality scientific results. In addition, continuation of the collaboration with laboratories specialized in materials science should be continued and strengthened. I also support the aim to develop the positron lifetime system based on the "ordered positron beam", which would be one of the very few such spectrometers worldwide and therefore a highly competitive system. As concerning the existing conventional positron lifetime (PALS) spectrometer: is a standard device, which can be found in many small laboratories but it will be important for the development of the lifetime beam, as it can be used for calibration and comparisons with standard measurements.

I recommend funding the project as Category A (excellent projects, which should be fully funded with adequate resources and encouraged to continue and expand their impact).

(Remark: there is a mistype in the Cost estimate for the project: The full cost of 3. Travel expenses should be 30 k$, not 20 k$)

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