Development of room-temperature thermal-muonium-emitting material for ultra-slow muon production

S. Okada,[*1] P. Bakule,[*2] G.A. Beer,[*3] Y. Fujiwara,[*1,*4] K. Ishida,[*1] M. Iwasaki,[*1] S. Kanda,[*1,*4] H. Kawai,[*5] N. Kawamura,[*6] R. Kitamura,[*4] W. Lee,[*7] G.M. Marshall,[*8] Y. Matsuda,[*9] T. Mibe,[*10] Y. Miyake,[*6] S. Nishimura,[*4] Y. Oishi,[*1] A. Olin,[*3,*8] N. Saito,[*4,*10] K. Shimomura,[*6] P. Strasser,[*6] M. Tabata,[*5,*11] D. Tomono,[*12] K. Ueno,[*10] E. Won,[*7] and K. Yokoyama[*13]

Ultra-slow muons, which are positive muons having an energy of a few electron volts, are useful tools for producing variable-energy muon beams with extraordinarily small energy spread by accelerating them through an electrostatic field. This technique will extend μSR (muon spin rotation and relaxation) studies to thin films, surfaces and interfaces, and nanostructures, which has not yet been achieved by the conventional μSR technique using surface muons. This technique has also attracted attention for use in measuring the muon anomalous magnetic moment g-2 and electric dipole moment at J-PARC[1)], which requires an intense muon beam having an extremely small transverse momentum.

Ultra-slow muon production has been realized by two-photon resonant laser ionization of thermal muonium atoms (μ^+e^-, Mu) emitted into vacuum, where tungsten foils heated to 2300 K have been employed as a Mu-emitting material[2)].

On the other hand, silica (SiO_2) powder is known as a Mu-emitting material at room temperature[3)]. The room-temperature target resulting in even lower Mu energies than that from a hot tungsten target (2300 K $\rightarrow$ 300 K) has the following significant merits:

- Experimentally easy to handle in terms of the operation temperature (no large radiant heat)
- Smaller emittance of the ionized source due to the lower energies
- Smaller spatial spread and smaller Doppler broadening of the resonant line for Mu excitation (as a result of the lower Mu energy distribution), leading to a more efficient use of the available laser power

Despite the many advantages, silica powder has not yet been employed for ultra-slow muon production. This is simply because powdery materials are not self-standing and are generally unfavorable in terms of handling and vacuum pumping.

In the TRIUMF S1249 experiment, we have investigated the possible use of a silica aerogel that has the same chemical composition as silica powder but is a self-standing solid with extremely low density.

In the earlier measurement of S1249, Mu emission from silica aerogel into vacuum has been successfully observed[4)], and the recent measurement (in Oct 2013) yielded promising results in terms of the Mu emission yields with aerogels having a surface with submillimeter structures such as pores (which increase surface area), e.g., laser-drilled aerogel, as shown in the insets of Fig. 1. This result indicates that Mus produced near the surface of the aerogel are essential for vacuum emission. Detailed data analysis is now in progress.

For practical-scale development, we are now preparing an ultra-slow muon beamline dedicated to the research and development of practical ultra-slow muon production with room-temperature targets at RIKEN-RAL port3.

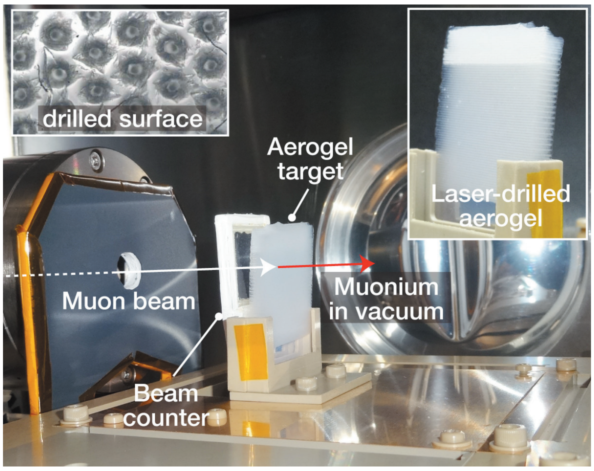

Fig. 1. Photograph of the experimental setup of the recent TRIUMF S1249 experiment. The insets show a laser-drilled aerogel used as a Mu-emitting material (right) and the surface (left).

*1 RIKEN Nishina Center
*2 ELI Beamlines Project Division, FZU
*3 Department of Physics and Astronomy, UVic
*4 Department of Physics, The University of Tokyo
*5 Department of Physics, Chiba University
*6 IMSS, KEK
*7 Department of Physics, Korea University
*8 Science Division, TRIUMF
*9 Department of Basic Science, The University of Tokyo
*10 IPNS, KEK
*11 ISAS, JAXA
*12 Department of Physics, Kyoto University
*13 School of Physics and Astronomy, QMUL

References

1) T. Nagae (ed): Prog. Theor. Exp. Phys., Special issue 2 (2012).
2) K. Nagamine et al.: Phys. Rev. Lett. **74**, 4811 (1995); P. Bakule et al., NIM B **266**, 355 (2008).
3) G. A. Beer et al.: Phys. Rev. Lett. **57**, 671 (1986).
4) P. Bakule et al.: Prog. Theor. Exp. Phys., 103C01 (2013).