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


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 pSR (muon spin rotation and acceleration) studies to thin films, surfaces and interfaces, and nano-structures, which has not yet been achieved by the conventional pSR 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-PARC1, 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 material2).

On the other hand, silica (SiO2) powder is known as a Mu-emitting material at room temperature3). The room-temperature target resulting in even lower Mu energies than that from a hot tungsten target (2300 K → 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 observed4), and the recent measurement (in Oct 2013) yielded promising results in terms of the Mu emission yields with aerogels having a surface with sub-millimeter 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 RIKENRAL port3.

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References