Solid hydrogen target for missing mass spectroscopy in inverse kinematics

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A collaboration of RIKEN, Kyoto University, Tohoku University, and KEK has developed a solid hydrogen target system called as: Solid Hydrogen Target for Recoil detection In Coincidence with Inverse Kinematics (SH TRICꓘ) [1]. The system using para-H_2 is called as SpH TRICꓘ. The development has great merit to perform missing mass spectroscopy with radioactive ion beams. If a $(CH_2)_n$ foil is used as a reaction target, knockout protons from carbon might mask true events, and we might consume half of the beam time to measure backgrounds with a carbon target. In the experiments of quasi-free (p,pN) reactions in inverse kinematics, size of the target is 30–40 mm in diameter and 5 mm in thickness. On the other hand, in the experiments of elastic scattering of protons with radioactive ion beams (ESPRI), size of the target is 30 mm in diameter and 1 mm in thickness. These sizes are desirable because the size and the intensity of the radioactive ion beam are generally large and low, respectively. It has been difficult to make such thin and large targets due to thermal radiation from environment and non-uniformity of the target thickness. Recently, we overcame these difficulties by using highly concentrated para-H_2 and a mechanical press [2].

Our cryogenic system uses a two-stage Gifford-McMahon refrigerator (Sumitomo Heavy Industries, RDK-415). The SHT is made in a cell bored in a thin copper plate by flowing H_2 gas into the cell. The cell is attached to the 2nd stage of the refrigerator. The second stage has a refrigeration capacity of 1.5 W at a temperature of 4.2 K. Several-μm-thick aramid films cover the cell by epoxy resin (Stycast,1266) to prevent the H_2 gas leaking from the cell. The backgrounds from the film material are negligible compared with the protons from solid H_2. The cell is surrounded by a copper radiation shield. The radiation shield is attached to the first stage of the refrigerator where temperature is below 50 K.

Due to the radiation from the openings of the radiation shield to areas at room temperature, the central area of the SHT sublimates when we use normal-H_2. However, when we use para-H_2, the SHT doesn't sublimates because the thermal conductivity is 100 W/m·K at a temperature of 4 K, which is more than 100 times larger than that of normal H_2. Therefore, we made a ortho-para converter with a catalyst to enhance the conversion rate to para-H_2. As a catalyst, we use Iron (III) oxide (Aldrich, hydrated, catalyst grade, powder, 30–50 mesh). The concentration of para-H_2 was confirmed to be close to 100% by Raman spectroscopy.

In addition to the thermal problem, we needed to solve non-uniformity of the target thickness. Due to the pressure of H_2 gas flowing into the cell, the central region of the target can be several times thicker than the target periphery, and it makes the missing mass resolution and the systematic error worse. In order to maintain the uniform surface, we fabricate a mechanical press, which consists of aluminum plates, and neodymium magnets.

Finally, we succeeded in making homogeneous pure H_2 targets by using para-H_2 and a simple mechanical press. By using the SHTs, we have performed ESPRI experiments at HIMAC, GSI, and RIBF [3, 4, 5]. In my presentation, I will show the development and the experimental results. Furthermore, I will also talk about recent newly development for some experiments using the cryogenic system at RCNP.

References

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