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Development of Self-Luminous Glass Tube (SLGT) Manufacturing Technology

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1. Introduction

Tritium produced from the Wolsong Tritium Removal Facility (WTRF) will be a radioactive waste when it is stored in the vault inside the WTRF, which requires maintenance cost and is a troublesome waste such that it cannot be sent to the radioactive waste disposal facility. However, when tritium is utilized it can be valuable resource for many applications. As a starting point to utilize tritium we tried to domesticate the self-luminous glass tube (SLGT) manufacturing technology.

As a hydrogen isotope, tritium has similar chemical properties to hydrogen but slightly different physical properties. Due to its unstable nature, tritium emits beta rays, which are streams of electrons, with 0~18.6 keV (5.7 keV in average) energies and 12.323 years of a half-life.

$$T \rightarrow {}^{3}He^{+} + \beta^{-} + \upsilon_{e} + 18.6\ keV$$

The energy level of tritium is relatively low and the biological effects of tritium to the human body are not significant, which makes tritium a popular radioactive isotope for use in industries [1]. The electrons in a beta ray collide with phosphor to produce light so that tritium sealed in phosphor coated glass tubes can make the tubes glow without an external supply of energy (Figure 1). To manufacture these SLGTs, 4 core technologies are needed: coating technology, tritium injection technology, laser sealing/cutting technology and tritium handling technology.

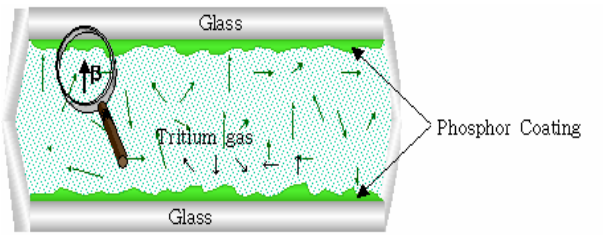

Figure 1. Structure and operating principle of SLGT

2. Development of the Technologies

2.1 Coating Technology

As a starting point for the tritium technology research, this study is focused on the analysis and the reproduction of commercially available SLGT products [2].

We found that the commonly used phosphor for SLGTs is ZnS:Cu, Al, and the mean particle size was 4~5 μm through ICP (Inductively Coupled Plasma) and SEM (Scanning Electron Microscopy) analyses. And also, the coating thickness varied widely among the commercial products, and the thickness of our target products was 10~100 μm.

To improve the coating quality with more uniform thickness and improved adhesiveness to the glass, one of the most advanced and well established coating technologies used in manufacturing CCFL (Cold Cathode Fluorescent Lamp), which is used in the back light units (BLU) for LCD (Liquid Crystal Display) panels is adopted. We selected a suitable binder for the phosphor, and prepared screen-printed samples on ITO glass plates to establish the optimal coating conditions. We used cathodoluminance (CL) devices (energy: 0~10 keV, electron flux: ~nA) to simulate the β -rays emitted from tritium. The optimal calcinating conditions were determined as 580~600 ℃ and 30 minutes to remove the binder without degrading the phosphor by a heat. After all the coating conditions such as the phosphor, binder package, coating thickness, and calcinating temperature have been determined, a pilot-scale coating system was developed and tested to establish the optimum conditions for mass production.

2.2 Tritium Injection Technology

Figure 2 is the conceptual design of the tritium injection loop. All of the purchased tritium gas in the uranium-bed shipping container (USC) is transferred into U bed-A (one of the tritium storage vessels) by heating the USC. The tritium storage vessels (TSVs, U bed-A and U bed-B) are double walled containers to reduce the leakage of tritium. The space between the TSV walls is evacuated while TSVs are heated to remove any potentially leaked tritium and the evacuated gas is sent to the tritium recovery system (TRS). Uranium is chosen as the tritium storage metal for its low equilibrium pressure at room temperature and the high tritium storage capacity. The low equilibrium tritium pressure at room temperature enables uranium to reduce the chance of tritium leakage and to be used as a vacuum pump to remove the tritium from the manifolds in other applications [3].

The tritium is analyzed by gas chromatograph (GC) when the tritium is transferred from USC to TSV. The required amount of tritium is injected to the glass tubes

through the manifold by heating U bed-A. The residual tritium in the loop after the injection is recovered to U bed-B. Trace of tritium left in the loop is evacuated to the TRS while the tritium concentration in the loop is monitored by a tritium monitor (TM).

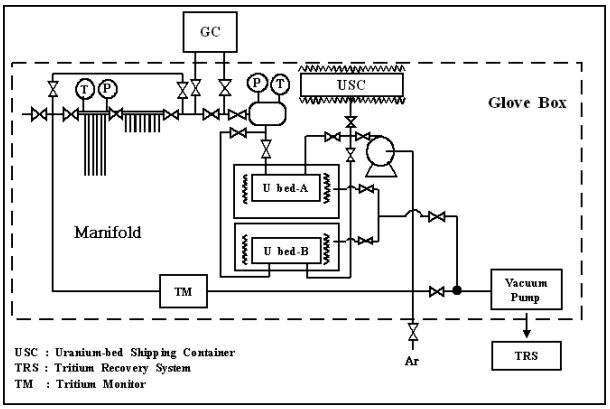

Figure 2. A conceptual design of the tritium injection loop

2.3 Laser Sealing/Cutting Technology

Laser sealing/cutting technology using CO_2 pulse laser is developed to cut and seal tritium filled pyrex tubes for better quality of sealed surface and automation of the process instead of conventional torch technology. The sealing/cutting is a 2-stage process. In the first stage the tubes are sealed and cut while tritium gas is being injected into the tubes on the manifold. Then the tritium filled sealed tubes are being rotated and sealed/cut into the desired length in the second stage. Since the tritium pressure can be considerably lower than that of the GB, finding the right condition was not easy. Moreover, annealing after sealing/cutting is a must since the sealed area became very fragile due to the thermal stress occurred during the sealing/cutting process.

Currently we are about to finalize the optimization of the conditions such as the pulse intensity and pulse duration for both stages.

2.4 Tritium Handling Technology

Tritium, the energy source of SLGT, is a ß−ray emitting radioactive hydrogen isotope, which requires special handling facility. The facility is composed of a GB, a fume hood, a TRS and an exhaust system, which consists of exhaust blowers and a TM. The design basis of the tritium handling facility is to minimize the operator's exposure to tritium uptake and the release of tritium to the environment [4]. To fulfill these requirements, major tritium handling components are located in the secondary containment such as the GBs and/or fume hoods. To prevent tritium releases into the room, the Ar filled GB is designed to maintain an equal or slightly lower pressure than the room atmosphere. In addition to the GB clean up system, a TRS is installed to recover tritium from GB atmosphere and effluents from the GC and the injection loop. The TRS is composed of a molecular sieve adsorption bed, a nickel catalyst bed, a metal getter, tritium monitors, and a circulation pump. The TRS is in operation all the time when the GB is in use to reduce the risk of tritium release and to recover any released tritium. Zr-Fe alloy (ST198) is used as the tritium getter material.

3. Conclusion

SLGTs from commercial products were analyzed with a low power optical microscope and a scanning electron microscope. The coating material is green ZnS phosphor with Cu as an activator and Al as a co-dopant. Instead of the existing torch technology, a new technology using a CO_2 pulse laser is developed for sealing/cutting. At present, the optimal conditions including the pulse intensity and the pulse duration are almost complete. A tritium injection loop and a tritium handling facility to handle several thousands Curies or more of tritium was designed and installed. The design basis of the facility is to minimize the operator's uptake and the release of tritium to the environment. Argon was chosen for the GB atmosphere in consideration of its effects on the phosphor and the tritium getter materials. The TRS is in operation all the time when the GB is in use to reduce the risk of tritium release and to recover any released tritium. The stack is monitored for the tritium concentration level with an on-line tritium monitor.

The SLGT manufacturing laboratory is about to be completed and the procedures and documents for the Korea Institute of Nuclear Safety (KINS) license for the use of tritium are being prepared.

REFERENCES

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