Abstract 050

Operating RbCl Targets Beyond the Boiling Point? – Work in progress

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The 100 MeV Isotope Production Facility (IPF) at Los Alamos National Laboratory produces the medical isotope Sr-82 on a large-scale. For routine production runs, RbCl salt targets are encapsulated in electron beam welded Inconel® 625 capsules and irradiated in a typical target stack consisting of two RbCl targets for Sr-82 production and one gallium target for Ge-68 production [1] (see Fig.1). These two-inch diameter targets are cooled on their faces with water flowing through 5 mm wide cooling channels that separate the targets. Systematic target performance studies of similar encapsulated targets under extended bombardment with intense proton beams are not available in the literature. Routine production experience at LANL shows that while the unexpected failure of a gallium target after an extended irradiation is often associated with radiation damage and other cumulative effects in the niobium capsule material [2], the abrupt early failure of a RbCl target is usually associated with the thermal effects occurring in the encapsulated target material. Numerous Sr-82 production runs were performed at IPF over a period of six years. Almost one hundred RbCl targets were irradiated with production beam currents of up to the facility administrative limit of 250 µA. Target performance statistics indicate that these targets can reliably accept production beam currents of between 230 µA and 240 µA. At higher beam currents, occasional early target failures are likely to occur. Excessive bulging of the two adjacent RbCl target capsules interrupts the water flow in the cooling channel between the targets and leads to sudden loss of cooling, causing the two target capsules to fuse together (see Fig. 2).

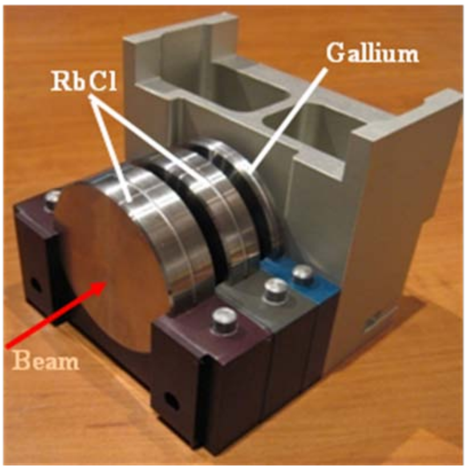

Fig. 1. Typical target stack for production of Sr-82 and Ge-68

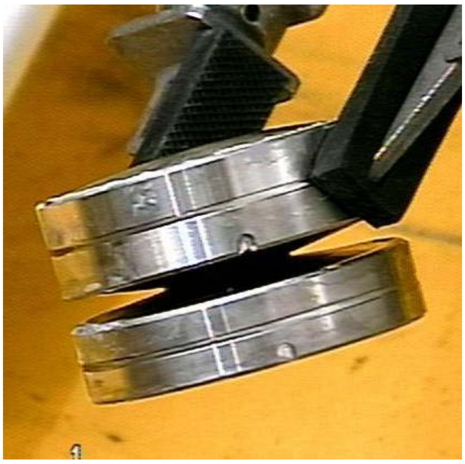

Fig. 2. Failed RbCl targets

In a recent development, the administrative limit of the IPF facility was increased from 250 µA to 450 µA, increasing the production capacity of the facility by almost a factor of two. In December of 2009 a preliminary high current test was conducted using a test stack consisting of three aluminium targets. During this test, the IPF demonstrated that the facility can safely operate at 360 µA. A follow-up high current test is now planned for the 2010 run cycle in order to demonstrate facility operation at the authorized current limit of 450 µA. Since most of the facility beam time is consumed by the large scale production of Sr-82, this new development sparked the desire to better understand the RbCl target failure mechanisms in order to push the in-beam performance of the targets beyond their present beam current limit.

The existing failure theory assumes that the observed target bulging results from internal pressure driven by localized boiling of the RbCl salt, which has a boiling point of 1390 °C. In one controlled experimental irradiation, a set of RbCl targets were driven to the point of failure by systematically increasing the beam current. The targets were inspected before each beam current increase. During this experiment, a thermal performance limit for the RbCl targets was established at 275 µA. It should be noted that occasional thermal failure under production conditions could occur at beam currents as low as 245 µA. In a separate, more theoretical effort, a detailed thermal analysis (see Fig. 3) predicted localized RbCl boiling at a beam current of 250 µA, suggesting that the thermal performance limit should be at 250 µA. The analysis took into account the major coupled thermal processes outside and inside the target, such as the water cooling of the target faces by means of forced convection, heat conduction through the solid and molten materials, and natural convection in the molten part of the salt. These results, together with data gained from the few target failures experienced during production runs, tend to support the theory that failure occurs when the maximum temperature reaches the boiling point of RbCl.

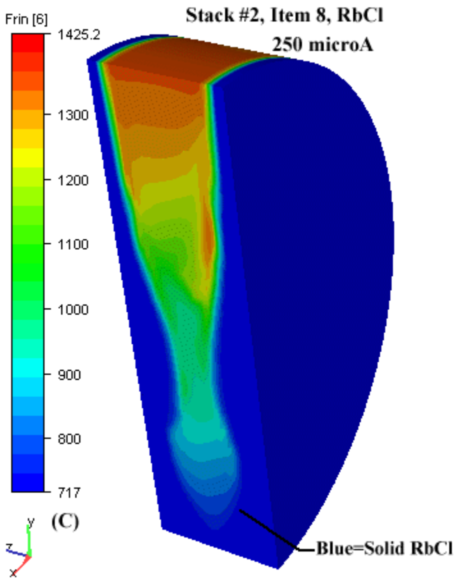

Fig. 3. Predicted temperature distribution in a RbCl target

However, some evidence also suggests that the maximum temperature must be much higher than the boiling point at the time of failure. For example, it is known that bulging is observed in most of the production targets but that abrupt target failure occurs only when the cooling channel is sufficiently disturbed. This suggests that failure occurs when the bulging windows of the two adjacent RbCl targets touch, meaning the deflection of a single window reaches 2.5 mm. Based upon hydraulic deflection tests of capsule windows, a deflection of 2.5 mm corresponds to an internal capsule pressure in excess of 30 bar. Assuming that the internal pressure is caused by RbCl vapour, the high pressure value suggests a maximum internal target temperature in excess of 2100 °C, which does not correlate with the thermal analysis results.

Considering the growing demand for Sr-82 and the recent increase in the IPF administrative beam current limit, there is renewed interest in increasing the existing beam current limit imposed on our RbCl targets. Efforts to gain a still better understanding of the failure mechanisms occurring in these high-power targets through improved analysis and capsule design changes are in progress.

[1] F. M. Nortier, J. W. Lenz, C. Moddrell and P. A. Smith, “Large-scale Isotope Production with an Intense 100 MeV Proton Beam: Recent Target Performance Experience”, Proceeding 18th International Conference on Cyclotrons and their Applications, edited by D. Rifuggiato and L.A.C Piazza, Presso la C.D.B. di Ragusa (2008) 257.

[2] H.T. Bach, T.N. Claytor, J.F. Hunter, B.E. Dozier, F.M. Nortier, D.M. Smith, J.W. Lenz, C. Moddrell, and P.A. Smith, Ultrasonic and Radiographic Imaging of Niobium Target Capsules for Radioisotope Production. Proc. 35th Annual Review of Progress in Quantitative Nondestructive Evaluation; AIP Conference Proceedings 1096 (2009) 674.