ALLEGATO
2 al III VERBALE
BUSTA D

Menzioni almeno uno strumento per misure di tensione meccanica specificando le precisioni ottenibili

ALLEGATO
2b III VERBALE

BUSTA 1

Menzioni almeno uno strumento software per la realizzazione di grafici/tabelle su Personal Computer

ALLEGATO
2b III VERBALE

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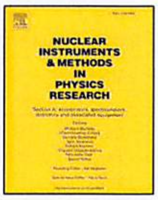

Corrosion of solid lithium on copper/tantalum/silicon carbide at elevated temperatures for AB-BNCT target

Jinglun Li [a,b,c], Yupeng Xie [a,b,c], Xin Du [a,b,c], Yaocheng Hu [a,b,c], Xiaobo Li [a,b], Sheng Wang [a,b,c,*]

[a] *School of Nuclear Science and Technology, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, 710049, Shaanxi, China*
[b] *XJTU-Huzhou Neutron Science Laboratory, Science Valley Medium-sized Building #1, Huzhou, 313000, Zhejiang, China*
[c] *HBNCT Co., Ltd., Shangcheng District, Hangzhou 310000, Zhejiang, China*

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ABSTRACT

To assess the service life of BNCT lithium targets, the corrosion of solid lithium on copper, tantalum, and silicon carbide at elevated temperatures was studied in this work. Copper was corroded at 125 °C, with its corrosion level significantly higher than tantalum which however could be corroded by lithium. In contrast, silicon carbide is resistant to corrosion from lithium. This study elucidates the corrosive behavior of solid lithium at elevated temperatures, which potentially contributes to the decrease in thickness of the BNCT target during its use. Additionally, silicon carbide was proposed as a new material for the lithium target anti-blistering layer.

1. Introduction

As a cancer treatment, Boron Neutron Capture Therapy (BNCT) was first proposed by Locher in 1936 [1]. The principle of the BNCT involves injecting a boron drug into patients' body, which concentrates in cancer cells. and then the cancer cells will be killed by the ^{10}B (n, α) ^{7}Li reaction caused by neutron irradiation. Compared to traditional radiotherapy, this method can eradicate cancer cells while minimizing the damage to healthy cells by selectively enriching boron. Earlier, the reactor's neutron sources were utilized, which was a challenge to implement in hospitals due to their substantial footprint and high operational costs [2]. In recent years, there has been extensive interest in Accelerator-based BNCT (AB-BNCT), which can produce neutrons through an accelerator, due to its advantages of low capital investment, ease of operation, and easy implementation in hospitals [3–6]. Neutrons can be produced by the ^{9}Be (p, n) ^{9}B reaction [7,8], which typically demands the employment of accelerators that can generate high-energy proton beams. Because of the neutron yield of ^{7}Li (p, n) ^{7}Be is higher than ^{9}Be (p, n) ^{9}B for same energy of proton (< 10 MeV), the ^{7}Li (p, n) ^{7}Be reaction is more commonly used. The primary approach to neutron production is to bombard a lithium target with protons accelerated to an energy of about 2.8 MeV [3]. In most of the lithium target structures, the lithium layer is deposited directly onto the copper plate [9–13]. In some other target structures, a layer of anti-blistering material is also added between the lithium layer and the copper substrate layer [6,14]. Astrelin [15] et al. found that Ta had the most outstanding anti-blistering performance compared to several materials in irradiation experiments. The AB-BNCT facility at XJTU-Huzhou Neutron Science Laboratory, named X-BNCT [16], is presently under construction. The structure of the lithium target system used in X-BNCT consists of an antioxidant layer, a lithium layer, an anti-blistering layer and a copper substrate with cooling system in sequence. The purpose of the antioxidant layer is to prevent failure of the lithium target due to oxidation during transport and assembly. Due to silicon carbide's excellent antioxidant properties [17,18], it is employed in X-BNCT lithium targets as the antioxidant layer.

Many researchers have found that after use for a period of time, the neutron yield decreases [12–14], which makes the neutron beam no longer meet the treatment requirements. And the neutron yield is directly determined by the thickness of the lithium [12]. In multi-layer structures that contain lithium, the reduction in thickness of the lithium layer could be caused by the penetration of lithium into other layers, thus leading to the corrosion by lithium. Many research has been carried out on the effect of lithium on the corrosion of materials. Meng [19–21] et al. studied the corrosion of liquid lithium on stainless steel and copper, compared the corrosion of liquid lithium on stainless steel at different temperatures, observed porous corroded morphologies on the surface of 304SS samples, and concluded that the corrosion mechanisms

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[*] Corresponding author. School of Nuclear Science and Technology, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, 710049, Shaanxi, China.

E-mail address: shengwang@xjtu.edu.cn (S. Wang).

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Table 1
Physical property of the base materials of Cu, Ta and SiC [25–30].

Materials	Melting point (°C)	Thermal conductivity (W/m·K)	Hydrogen diffusing coefficient (m^2s^{-1})
Cu	1083	400	1.1×10^{-6}
Ta	2996	57	4.4×10^{-8}
SiC	2730	72–114	2.99×10^{-7}

of 304SS in static liquid lithium were comprised of physical dissolution and chemical corrosion. In terms of copper, they found that intergranular corrosion was the primary mechanism responsible for the corrosion. Moreover, Meng [22] et al. also studied the corrosion of liquid lithium on molybdenum and TZM alloys at 623 K, and found that the corrosion of TZM was more severe than that of Mo in liquid Li. Lu [23] et al. compared the corrosion behavior of several metals and ceramics by liquid lithium through XPS. The results showed that rare earth oxides, metallic nitrides and other non-oxide ceramics could provide a higher stability in lithium corrosion situation. According to the study on the corrosion of ceramics by lithium in the vapor state, it was found that the corrosion resistance of aluminum nitride ceramics in lithium vapor depended on several factors, including the purity of the aluminum nitride, its solubility in lithium, and any potential reactions between lithium and yttrium aluminum compounds [24]. During equipment operation, proton bombardment of the lithium target will raise the target temperature. Despite the cooling structure, the target will still reach a high temperature of about 125 °C (below the lithium's melting point (180 °C)). Therefore, the author suggests that at high temperatures, lithium in X-BNCT targets can diffuse into other materials.

To the best of the author's knowledge, most research on lithium corrosion against materials has focused on liquid lithium rather than solid lithium. Combining the current background of the lithium targets of X-BNCT, the intermediate lithium layer may diffuse into adjacent materials at elevated temperatures, leading to a decrease in neutron output as a result of the thinner lithium layer. Therefore, this article investigates the corrosion of solid lithium on several different materials (copper, tantalum, silicon carbide) at elevated temperatures, revealing the corrosion mechanism.

2. Experiment

2.1. Materials

Copper serves as the target body material for AB-BNCT targets. Covering the copper plate with lithium directly is a common practice in preparing lithium targets. This lithium will consequently come into contact with the copper. Copper is thus a necessary material for this study; Additionally, certain studies suggested that tantalum can be implemented as an anti-blistering layer in BNCT lithium targets. Therefore, for the lithium target of X-BNCT apparatus, a layer of tantalum will be applied onto the copper plate first, and then a layer of lithium will be deposited on top of the tantalum layer. A decision to select tantalum is vital as lithium will inevitably come into contact with tantalum as well from a practical perspective; Moreover, silicon carbide is commonly employed as an anti-oxidizing layer due to its exceptional antioxidant properties, and this applies to the lithium target of X-BNCT as well. Therefore, in actual usage, lithium will come into contact with silicon carbide. Therefore, in the study of lithium corrosion, silicon carbide as a material has also been considered. Table 1 gives the three materials selected and their relevant physical parameters. The copper, tantalum, and silicon carbide sheets of 10 mm × 10 mm × 1 mm were purchased from Gujing Technology Co., Ltd., Shengyuan Metal Material Co., Ltd., and Kahofly Co., Ltd., respectively. The sheets underwent polishing to achieve a mirror-like surface. Before use, the samples were washed via ultrasonic cleaning by ultrapure water and ethanol to remove impurities and oil stains. Small slices of lithium particles with a purity of 99.99 % were produced by China Energy Lithium Co., Ltd. They were subsequently pressed onto the sample surface with a bench vise. Once pressed, the lithium particles would have a flat and smooth surface featuring an approximately circular shape and a diameter of 4–5 mm.

2.2. Experiment setup

Based on our previous simulation results, we have determined that the lithium target can only reach a maximum temperature of 120 °C under our working conditions. Considering simulation errors, 125 °C was selected as the experimental temperature in this study. As shown in Fig. 1, the sheets with lithium pressed on their surface were placed onto a heating table, heated to 125 °C (±2 °C), and maintained at this temperature. Copper was heated for 24, 72, 120, 168, 336, 504, and 672 h, respectively. Meanwhile, some copper samples were kept at room temperature without being heated before the lithium on their surface was washed off. Tantalum, as well as silicon carbide, was heated for 168, 336, 504, and 672 h, respectively. All experimental samples were prepared and heated inside an argon-filled glove box. After heated to the corresponding time, the samples were removed from the glove box. As the surface could be damaged if washed with water [31], the ethanol was used. Acetone as an organic solvent can be used to better clean the sample surface without damaging the sample, Therefore the samples were cleaned with ethanol and then with acetone [23,32]. And these samples after cleaning will be used for SEM XRD and XPS characterization.

2.3. Samples characterizations

The surface morphologies before and after corrosion were determined by using field emission scanning electron microscopy (FE-SEM,

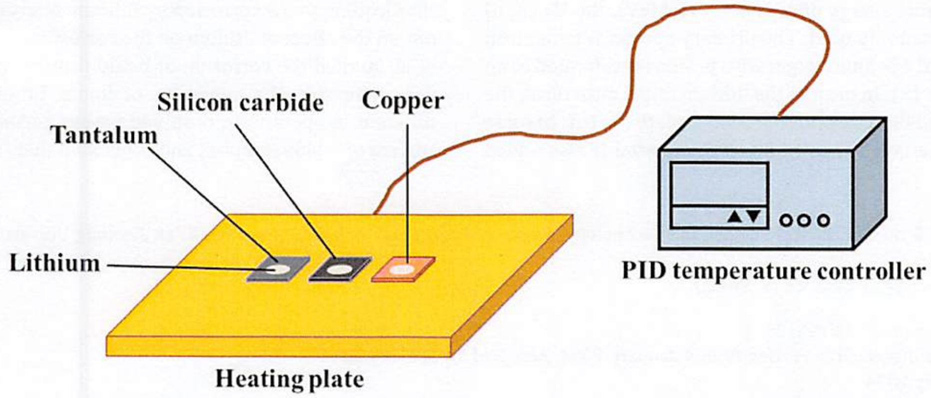

Fig. 1. Diagram of lithium corrosion experiments of copper, tantalum and silicon carbide.

ALLEGATO
3a III VERBALE

BUSTA C

Menzioni almeno uno strumento per misure precise di posizione specificando le precisioni ottenibili

ALLEGATO
3b III
VERBALE

BUSTA 3

Che cosa sono e a cosa servono le porte USB dei Personal Computer?

ALLEGATO
3b III VERBALE

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Development of hybrid resistive plate chambers

M. Tosun [a,b,c], B. Bilki [a,b,d,*], K.K. Sahbaz [a,b,e]

[a] Beykent University, Istanbul, Turkey
[b] Turkish Accelerator and Radiation Laboratory, Ankara, Turkey
[c] Yildiz Technical University, Istanbul, Turkey
[d] University of Iowa, Iowa City, IA, USA
[e] Ankara University, Ankara, Turkey

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Gaseous detectors
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Secondary emission

ABSTRACT

Resistive Plate Chambers (RPCs) are essential active media of large-scale experiments as part of the muon systems and (semi-)digital hadron calorimeters. Among the several outstanding issues associated with the RPCs, the loss of efficiency for the detection of particles when subjected to high particle fluxes, and the limitations associated with the common RPC gases can be listed. In order to address the latter issue, we developed novel RPC designs with special anode plates coated with high secondary electron emission yield materials such as Al_2O_3 and TiO_2. The proof of principle was obtained for various designs and is in progress for the rest. The idea was initiated following the achievements on the development of the novel 1-glass RPCs.

Here we report on the construction of various different RPC designs, and their performance measurements in laboratory tests and with particle beams; and discuss the future test plans.

1. Introduction

Resistive Plate Chambers (RPCs) were introduced in the 1980s [1] and have been widely used by the High Energy Physics community since then. The RPCs have been utilized in large-scale experiments mostly as triggering and precision timing detectors. The working principle of the RPCs relies on the ionization in a thin gas gap which is provided by two or more resistive plates of high resistivity like glass or Bakelite. The RPCs are provided with a high voltage on the outer surfaces so that the primary ionization is multiplied in the gas gap. The signal is picked up by either strips or pads, which are placed on the outside of the chambers. The RPCs are also utilized as the active media of the CALICE [2] (semi-)digital hadron calorimeters [3,4].

In novel designs of RPCs, only one resistive plate is used and the signal pickup is performed inside the chamber. Several 1-glass RPCs were built and tested to date, and their performance as single particle detectors as well as calorimeter active media was validated in beam tests [5]. The placement of the anode plane inside the chamber enables the possibility of exploring functional anodes by applying surface coatings on the pickup pads or strips. Given the limitations in the utilization of the common RPC gases such as r134a and SF_6 due to their high global warming potential, this functionality can be utilized to reduce or completely abandon the flow of the common RPC gases, or to introduce alternative gases with negligible greenhouse effects. In order to explore this implementation, we developed the hybrid RPCs where part of the electron multiplication is transferred from the gas layer to a solid state layer coated on the surface of the anode as a thin film. The thin film materials are chosen to have high secondary electron multiplication yields, such as Al_2O_3 and TiO_2.

Here we describe the details of the first generation hybrid RPCs and their performance measurements in laboratory tests and with particle beams; and provide a perspective for future directions.

2. Construction of the hybrid RPCs

Several 10 cm × 10 cm chambers were made with 2 mm thick glass plates and a single readout pad of size 9 cm × 9 cm. The 5 mm rim of the glass plates were masked and a mixture of a high resistivity and a low resistivity artist paint was applied with an airbrush gun to yield 1–5 $M\Omega/\square$ surface resistivity. The RPC frame was 3D-printed and the glass plates and the pad boards were glued with two-component epoxy. The gas gap was 1.3 mm. Fig. 1 shows the sketches of the RPC frame (left) and the cross sections of a regular section (top right) and a gas inlet/outlet section (bottom right).

The coating of Al_2O_3 on the pad boards was done with magnetron sputtering at Gazi University Photonics Application and Research Center, Ankara, Turkey [6]. Two different thicknesses were applied, 500 nm and 350 nm. The RPCs constructed with these pad boards were labeled as Al_2O_3-v1 and Al_2O_3-v2 respectively. The coating of TiO_2 was made in the laboratory by dissolving the TiO_2 powder in ethanol and applying the solution on the pad board with an airbrush.

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* Corresponding author at: Beykent University, Istanbul, Turkey.
E-mail address: burak.bilki@cern.ch (B. Bilki).

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ALLEGATO
4a III VERBALE

BUSTA A

Che cosa descrive la formula nota come "Bethe e Block" in fisica delle particelle ?

ALLEGATO
4b III VERBALE

A. Fulli

BUSTA B

Come disegnerebbe un rivelatore per misure di tempo di particelle cariche?

ALLEGATO
4C III VERBALE

BUSTA E

Menzioni almeno uno strumento per la misura della pressione di un gas specificando le precisioni ottenibili

ALLEGATO
4d III VERBALE

BUSTA 2

Che cosa è la RAM di un personal computer e che dimensioni hanno quelle disponibili attualmente?

ALLEGATO
4d III
VERBALE

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Development of a sealed MRPC with mylar spacers for high luminosity TOF systems

Botan Wang [a], Kai Sun [a], Yi Wang [a,*], Dong Han [a], Ingo Deppner [b], Norbert Herrmann [b], Baohong Guo [a], Xiaolong Chen [a], Daming Liu [a], Qiunan Zhang [a]

[a] *Key Laboratory of Particle and Radiation Imaging, Department of Engineering Physics, Tsinghua University, Beijing 100084, China*
[b] *Physics Institute, Heidelberg University, Heidelberg 69120, Germany*

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Aging effect
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ABSTRACT

The high luminosity Time-of-Flight (TOF) systems call for timing detectors with both good time resolution and adequate rate capability, which have been fulfilled by the Multigap Resistive Plate Chamber (MRPC) assembled with low-resistive glass electrodes. However, recent tests and operations with high rate MRPCs have given evidences to the luminosity effects, such as the dark current rise and related higher noise rate, which may vitiate the stability in experimental operations. This work discusses the results from observations and tests, and infer the fishline spacers as a source of dark current and noise problems. Then, a sealed MRPC with mylar spacers is proposed, developed and tested. The prototype showed good luminosity tolerance during the X-ray test, and its performances of 95% efficiency and 80 ps time resolution have been validated in cosmic tests.

1. Introduction

The high-energy physics (HEP) experiments utilize the collision of particles for the exploration of new particles and physics. In order to find rare probes and to accumulate statistics, high luminosity becomes a vital requirement and trend for the detector arrays in HEP experiments [1]. As a representative example, the Compressed Baryon Matter (CBM) experiment [2] aims to detect and reconstruct the heavy ion collision within an unprecedent interaction rate of 10 MHz, which results in a maximum secondary flux rate of 20 kHz/cm^2 at 10 meters downstream of the collision point, the position for the TOF wall [3]. Such a rate condition is a real challenge for the detectors.

MRPC [4] is a timing detector with a typical resolution below 100 ps, and has the competitive advantage in costs and large area application. The rate capability of MRPC is correlated negatively with the resistivity of the electrodes [5]. For MRPCs assembled with commonly used float glass electrodes, the average rate capability reach a level of 1 kHz/cm^2. Our group has successfully developed a novel type of *low-resistive glass* electrode for which the bulk resistivity declines for 2 orders of magnitude, to a 10^{10} Ω cm level. A beam test study has been carried out on a set of high-rate MRPC prototypes assembled with this type of electrodes, and the results showed that the counters reach a consistent rate capability up to 60 kHz/cm^2 [6]. Such results mark an expand for the application of MRPCs on high luminosity experiments.

Along with the high-rate operation for MRPCs, the high intensity of avalanche in gas gaps results in the accumulation of chemically active products, which becomes a vital problem named as the pollution effect for the stable operation of high-rate MRPCs. Such an effect has not shown its importance until the negative behavior in terms of noise rate and dark current were observed in experimental operations and in long time laboratory tests [7,8]. MRPC is a type of gaseous detector which usually works in a standard gas mixture of Freon/iC_4H_{10}/SF_6 = 90/5/5. The principle of gas pollution effect is the low exchange rate of ionization pollutants caused by the narrow gas gaps. Both simulation [9,10] and practice results [7] indicated that decreasing the dimension of the gas box would help to promote the gas exchange. Many efforts have been done, based on the same idea, to enclose the detector, or to flush the gas directly to the gas gaps. Among the above, our solution is a sealed MRPC enclosed with a 3D-printed sealing frame [11]. With almost 100% of the gas volume in sensitive area, the detector showed stable noise and current behavior with maintained efficiency and time precision during the test [8].

Benefit from the continuing evaluations of high-rate MRPCs in laboratory and facilities such as mCBM [12], we are able to collect and analyze more results. Some evidences that possibly come from the abnormal discharge around spacers have been observed. The commonly used spacer is the cylindrical nylon fishline. The fishline has a 10^{14} Ω cm level resistivity and hold the gas gap in a uniform thickness. The usage of fishline has been validated in many of the existing experiments under the common rate condition. However, in high-rate conditions

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* Corresponding author.
E-mail addresses: wbt19@mails.tsinghua.edu.cn (B. Wang), yiwang@mail.tsinghua.edu.cn (Y. Wang).

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