Titanium vs. Aluminium 6061 as Backing Plate for TiT_2-Based D–T Fusion Neutron Sources in ^{64}Cu Production: A Review

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Abstract

Titanium tritide (TiT_2)-based deuterium–tritium (D–T) fusion neutron sources offer potential for medical radioisotope production, including ^{64}Cu through the $^{64}Zn(n,p)^{64}Cu$ reaction. The backing plate plays an important role in supporting the TiT_2 target and transferring heat to the cooling system. This study presents a comparative review of titanium (Ti) and aluminium alloy 6061 (Al-6061) as candidate backing plate materials, based on technical property data obtained from Goodfellow. The results show that Al-6061 has substantially higher thermal conductivity (152–169 W m^{-1} K^{-1}) than Ti (21.9 W m^{-1} K^{-1}), indicating greater potential for heat spreading under comparable conditions. Al-6061 also has a lower density and higher specific heat capacity, whereas Ti exhibits a higher melting point, lower thermal expansion, and generally higher reported tensile strength. However, the larger CTE of Al-6061 may contribute to thermal expansion mismatch at the target interface. Overall comparisons, Al-6061 is identified as a promising candidate when heat dissipation is prioritized, particularly when integrated with an appropriately designed cooling system. Further thermo-mechanical analysis is required to evaluate target temperature, interfacial stress, and operational reliability under D–T irradiation conditions.

Keywords: neutron generation; backing plate; titanium; aluminium 6061; D–T fusion neutron sources

I.INTRODUCTION

Copper-64 (^{64}Cu) is a radioisotope with a half-life of 12.7 hours. It decays to ^{64}Zn with a probability of 38.5 % through the emission of beta-minus (β^-) particles with an energy of 579 keV and to ^{64}Ni with a probability of 61.5 % through positron (β^+) emission with an energy of 653 keV (17.5 %) or electron capture (44 %), as illustrated in Figure 1.

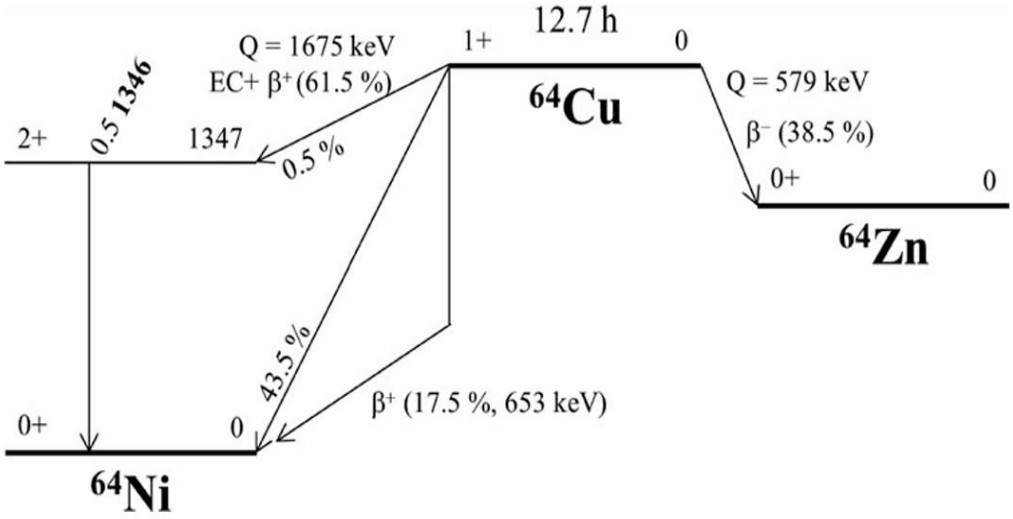

Figure 1. Decay modes of the ^{64}Cu radioisotope(Kin et al., 2017)

The positron-emitting capability of ^{64}Cu can be utilized for Positron Emission Tomography (PET) imaging for diagnostic. When the emitted positrons interact with electrons in body tissues, they annihilate, producing two gamma photons, each with an energy of 511 keV, that travel in nearly opposite directions and can be detected by PET detector(N. Yang et al., 2024). The relatively long half-life of ^{64}Cu makes it highly suitable for more accurate and precise PET imaging of biomolecules, such as antibodies(Li et al., 2025; Usui et al., 2025; X. Yang et al., 2025). Its relatively long half-life also enables the distribution of ^{64}Cu to PET facilities located far from the production site. In addition to positron emission, ^{64}Cu can also emit beta particles, making it suitable for localized radiation therapy(Ando et al., 2025; Ferrari et al., 2015; Pinto et al., 2024; Zhou et al., 2015).

Despite its strong theranostic potential, the widespread clinical application of ^{64}Cu remains limited by production constraints. The conventional production of ^{64}Cu is commonly carried out via the ^{64}Ni(p,n)^{64}Cu reaction using a cyclotron(Jauregui-Osoro et al., 2021; Ohya et al., 2016). However, the use of enriched ^{64}Ni targets entails relatively high target-material costs. Therefore, alternative production routes based on fast-neutron-induced reactions have been investigated as a potential approach. One relevant reaction is the ^{64}Zn(n,p)^{64}Cu reaction(Auditore et al., 2017; Kambali et al., 2025; Kambali & Febrianto, 2021), in which fast neutrons interact with a natural zinc (^{nat}Zn) or enriched ^{64}Zn target to produce ^{64}Cu.

The $^{64}Zn(n,p)^{64}Cu$ reaction can be effectively induced by fast neutrons, making deuterium–tritium (D–T) fusion a promising neutron source for ^{64}Cu production. The D–T fusion reaction produces neutrons with an energy of 14.1 MeV(Payudan et al., 2016; Rajput et al., 2023). According to the TENDL-2021(Koning et al., 2019), the $^{64}Zn(n,p)^{64}Cu$ reaction is predominantly governed by the fast-neutron spectrum, as illustrated in Figure 2, where the corresponding cross section attains its maximum value at 11.5 MeV. Although D–T fusion produces neutrons with a characteristic energy of approximately 14.1 MeV, neutron scattering in surrounding materials may reduce their energies toward the region around 11.5 MeV. The use of D–T-based neutron generators also enables the development of accelerator-driven neutron sources that can be integrated with target systems for ^{64}Cu radioisotope production.

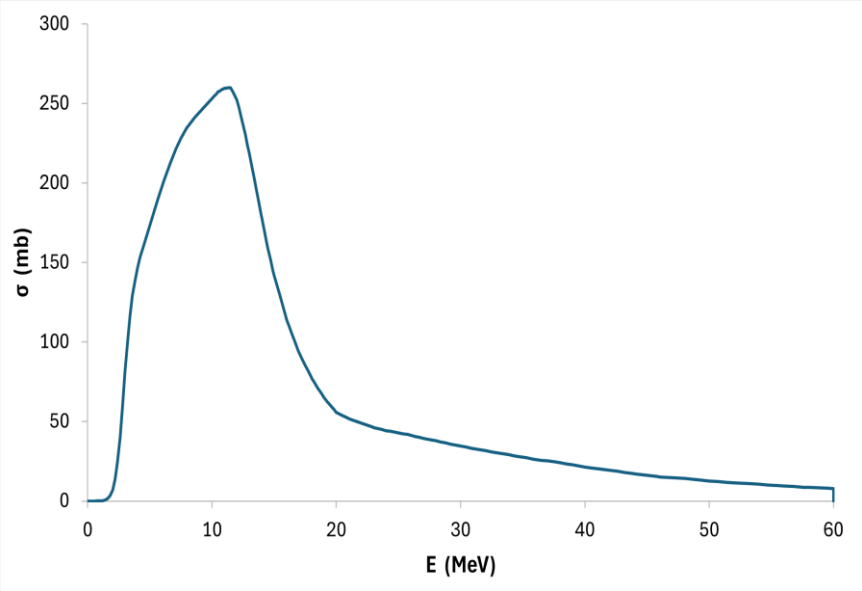

Figure 2. Nuclear cross-section of the ^{64}Zn (n,p) ^{64}Cu reaction(Koning et al., 2019)

In TiT_2-based D–T neutron sources, the incident deuteron beam deposits energy in the target, generating heat. At sufficiently high beam power, the resulting temperature rise may promote tritium release from the target(Liu et al., 2026). In the target system considered in this study, deuterons are accelerated to 1.514 MeV/u, corresponding to a total kinetic energy of 3.028 MeV per deuteron. At a beam current of 1 mA, the incident beam power reaches approximately 3.028 kW. Because the TiT_2 layer is only 50 μm thick, heat management is an important engineering consideration, although the actual power deposited in the target assembly depends on the energy-loss distribution of the incident deuterons. Therefore, the backing plate must provide adequate mechanical support for the TiT_2 layer while facilitating heat transfer to the cooling system. Titanium and Al-6061 are relevant

candidate materials because they offer different thermal conductivity, mechanical properties, and thermal expansion characteristics. Their comparative assessment is essential for identifying the trade-offs involved in the thermal management and structural integrity of D–T fusion neutron targets for ^{64}Cu production.

II. METHOD

This study employed a comparative analysis of material properties based on technical data provided by Goodfellow. The analysis focused on aluminium alloy 6061 (Al-6061) and titanium as candidate backing plate materials for TiT_2-based deuterium–tritium (D–T) fusion neutron sources.

Material data were collected from the Goodfellow website, including density, specific heat capacity, melting point, thermal conductivity, coefficient of thermal expansion, and mechanical strength, where available. The collected data were organized into comparative tables to identify differences in the physical, thermal, and mechanical characteristics of the two materials. The comparison was interpreted in terms of heat transfer capability, thermal expansion compatibility, and mechanical stability under thermal loading. These properties were discussed in relation to their potential implications for heat dissipation, structural integrity, and operational performance of TiT_2 based D–T neutron targets. The analysis was limited to the material data available from Goodfellow and did not involve additional experiments or numerical simulations.

I. RESULTS AND DISCUSSIONS

A. Physical Properties

The physical properties of backing plate materials are important considerations in the design of TiT_2-based D–T fusion neutron targets. Material density determines the mass of the backing plate for a given volume, while material composition and grade may influence its performance under operating conditions. A comparison of the physical properties of Ti and Al-6061, based on the technical data provided by Goodfellow, is presented in Table 1. Images of the titanium and Al-6061 discs obtained from the Goodfellow product catalogue are shown in Figures 3 and 4, respectively.

Table 1. Comparison of the Physical Properties of Titanium and Aluminium 6061(*6061 Aluminum Disk*, n.d.; *Titanium Disc*, n.d.)

Element	Unit	Titanium (Ti)	Aluminium 6061 (Al-6061)
Density	gr cm^{-3}	4.5 at 20°C	2.7



Figure 3. Titanium (Ti) disc. Source: Goodfellow.(*Titanium Disc*, n.d.)



Figure 4. Aluminium alloy 6061 (Al-6061) disc. Source: Goodfellow.(*6061 Aluminum Disk*, n.d.)

As shown in Table 1, titanium has a higher density than aluminium 6061. Based on the reported values, the density of titanium is approximately 1.67 times that of Al-6061. Therefore, for the same backing plate volume, titanium would result in a greater material mass. This difference may be relevant when considering the overall mass of the target assembly. However, density alone is insufficient to determine the suitability of either material, as thermal performance and mechanical stability must also be considered.

B. Thermal Properties

The thermal properties of backing plate materials are important considerations in the design of TiT_2 based D–T fusion neutron targets. A comparison of the Thermal properties of Ti and Al-6061, based on the technical data provided by Goodfellow, is presented in Table 2.

Table 2. Comparison of the Thermal Properties of Titanium and Aluminium 6061(*6061 Aluminum Disk*, n.d.; *Titanium Disc*, n.d.)

Element	Unit	Titanium (Ti)	Aluminium 6061 (Al-6061)
Melting point	°C	1660	585
Specific heat	$J\ K^{-1}\ kg^{-1}$	523 at 25°C	878-914
Thermal conductivity	$W\ m^{-1}\ K^{-1}$	21.9 at 0-100°C	152-169
Coefficient of thermal expansion	$x10^{-6}\ K^{-1}$	8.9 at 0-100°C	22.7-23.9
Maximum use temperature in air	°C	-	130-150

As presented in Table 2, Al-6061 exhibits substantially higher thermal conductivity than titanium (Ti), with reported values of 152–169 W m^{-1} K^{-1} for Al-6061 and 21.9 W m^{-1} K^{-1} for Ti over the specified temperature range. This difference indicates that Al-6061 has a greater capacity for conducting heat through the backing plate under comparable conditions. In a TiT_2-based D–T neutron target, this property may facilitate heat transfer from the irradiated target layer toward the cooling system. Nevertheless, the resulting target temperature cannot be determined from thermal conductivity alone, because it also depends on the incident beam power, energy deposition profile, plate thickness, interfacial thermal resistance, and coolant-side heat-transfer conditions.

Al-6061 also has a higher specific heat capacity than Ti, with reported values of 878–914 J kg^{-1} K^{-1} and 523 J kg^{-1} K^{-1} at 25 °C, respectively. A higher specific heat capacity indicates that more energy is required to increase the temperature of a unit mass by one degree. However, this property does not independently establish which backing plate will exhibit the smaller temperature rise. The thermal response also depends on the mass and geometry of the plate, as well as its heat-transfer characteristics. Thermal diffusivity, defined as the ratio of thermal conductivity to the product of density and specific heat capacity, provides an additional parameter for evaluating the rate at which temperature disturbances propagate through a material.

An important difference between the two materials is their coefficient of thermal expansion. The reported values for Al-6061 ($22.7–23.9 \times 10^{-6}$ K^{-1}) are higher than those for Ti (8.9×10^{-6} K^{-1}). When the backing plate is heated, this difference may produce differential thermal deformation between the backing plate and the TiT_2 layer. If the materials are mechanically constrained or strongly bonded, the mismatch may contribute to interfacial stress, potentially affecting the integrity of the target assembly during repeated heating and cooling. The actual stress magnitude, however, depends on the temperature distribution, elastic properties, bonding conditions, and mechanical constraints.

Titanium has a substantially higher reported melting point than Al-6061, approximately 1660 °C compared with 585 °C. This difference provides Ti with a greater margin against melting, assuming comparable local temperature conditions. However, the melting point should not be interpreted as the maximum permissible operating temperature of the backing plate. In particular, the mechanical properties of Al-6061 and the stability of the TiT_2 layer and their interface may become limiting before the backing plate reaches its melting point.

Overall, the thermal properties reveal a trade-off between heat-transfer capability and thermal expansion compatibility. Al-6061 offers substantially higher thermal conductivity and specific heat capacity, whereas Ti exhibits lower thermal expansion and a higher melting point. These differences identify the principal considerations for material selection but do not establish the superiority of either material under actual operating conditions. Quantitative evaluation of the target temperature and thermally induced stress would require a thermal or coupled thermomechanical analysis incorporating the beam heat load, target geometry, interface properties, and cooling conditions.

C. Mechanical Properties

The mechanical properties of backing plate materials are important considerations in the design of TiT_2 based D–T fusion neutron targets. A comparison of the mechanical properties of Ti and Al-6061, based on the technical data provided by Goodfellow, is presented in Table 3.

Table 3. Comparison of the Mechanical Properties of Titanium and Aluminium 6061(*6061 Aluminum Disk*, n.d.; *Titanium Disc*, n.d.)

Element	Unit	Titanium (Ti)	Aluminium 6061 (Al-6061)
Tensile strength	MPa	230-460	124-290
Yield strength	MPa	140-250	-
Bulk modulus	GPa	108.4	-

The mechanical stability of the backing plate under thermal loading is essential to maintain structural integrity during neutron generation. As shown in Table 3, Titanium exhibits significantly higher tensile strength (230-460 MPa) compared to Al-6061 (124-290 MPa). Higher tensile and yield strengths allow Titanium to withstand greater mechanical and thermal-induced stresses without undergoing permanent deformation.

D. Comparison of Titanium and Aluminium 6061 as Backing Plate Materials

Titanium and Aluminium 6061 (Al-6061) offer different advantages and limitations as backing plate materials for TiT_2-based D–T fusion neutron sources. Al-6061 has a relatively high thermal conductivity, typically around 152–169 W m^{-1} K^{-1}, which facilitates heat spreading from the irradiated target toward the cooling system. Its relatively low density and good machinability are additional advantages for target assembly fabrication and integration with cooling channels. However, Al-6061 has a lower melting temperature than titanium and a greater coefficient of thermal expansion than the titanium-based target layer. These characteristics may increase thermal deformation and interfacial stress under non-uniform or cyclic heating. Its suitability also depends on its mechanical strength at the operating temperature and its activation characteristics under neutron irradiation.

Titanium, in contrast, offers a closer thermal expansion match to the TiT_2 layer, potentially reducing thermally induced mismatch stresses at the interface. It also has a higher melting temperature and can provide favourable mechanical performance under appropriate operating conditions. Nevertheless, titanium has a substantially lower thermal conductivity, approximately 21.9 W m^{-1} K^{-1} over the 0–100 °C range, than Al-6061. Consequently, heat spreading through a titanium backing plate may be less effective under otherwise comparable conditions. Titanium may therefore require careful thermal management to prevent excessive temperature increases during irradiation.

Considering these trade-offs, Al-6061 is a promising candidate for the backing plate of a TiT_2-based D–T fusion neutron source, particularly when effective heat removal is a primary design consideration. Its higher thermal conductivity can facilitate heat transfer from the target assembly to an appropriately designed cooling system. A cooling channel or cooling structure positioned behind the backing plate can further enhance heat removal, provided that sufficient thermal contact and coolant flow are maintained. However, the larger CTE of Al-6061 may contribute to thermal expansion mismatch at the target interface. The limited availability of directly applicable CTE data for TiT_2 further complicates the assessment of interfacial thermal stress. Therefore, Al-6061 is selected as the preferred candidate for the proposed configuration because of its heat-transfer advantages and its

potential integration with a dedicated cooling system. Nevertheless, this assessment is based on material data rather than direct experiments or numerical simulations. Further thermo-mechanical analysis is required to evaluate target temperature, interfacial stress, and operational reliability under D–T irradiation conditions.

II. CONCLUSION

This comparative review indicates that aluminium alloy 6061 (Al-6061) is a promising candidate for the backing plate of TiT_2-based deuterium–tritium (D–T) fusion neutron sources intended for ^{64}Cu production via the $^{64}Zn(n,p)^{64}Cu$ reaction. Compared with titanium, Al-6061 offers substantially higher thermal conductivity and specific heat capacity, together with lower density, which may support effective heat spreading and integration with a dedicated cooling system. However, its higher coefficient of thermal expansion and lower melting point present potential challenges related to interfacial thermal stress and temperature tolerance, whereas titanium offers better thermal expansion compatibility with the titanium-based target layer and a higher melting point, but considerably lower thermal conductivity. Based on the available material-property data, Al-6061 is therefore preferred for the proposed configuration when heat dissipation is the primary design consideration, provided that appropriate cooling and interfacial stress management are implemented. Nevertheless, this preference remains preliminary because the present study does not include experimental testing or numerical simulations. Further thermal and thermo-mechanical analyses are required to quantify the target temperature, temperature distribution, interfacial stress, and structural reliability under D–T irradiation conditions before the suitability of Al-6061 can be established for practical operation.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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