Simulation Driven Design Changes for Increased Production of ^{211}At via ^{209}Bi(α,2n)^{211}At

Stokely, M.H.[1¶], Peeples, J.L.[1], Bida G.T.[2], Wieland B.W.[1], Zalutsky M.R.[2]

[1]Bruce Technologies, Inc., Cary NC [2]Dept. of Radiology, Duke University Medical Center, Durham NC

¶Corresponding author email address: stokely@brucetech-targets.com

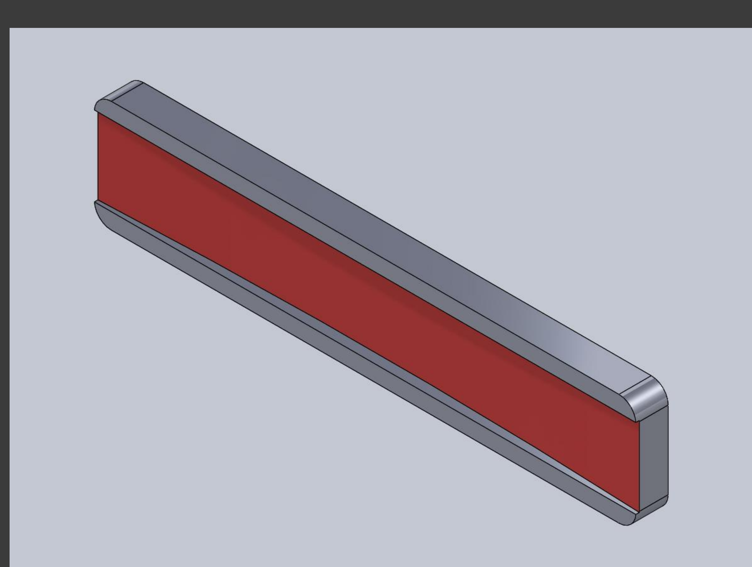
Background and Objectives

While the α-emitting radionuclide ^{211}At has shown excellent potential for targeted radiotherapy, its availability has been limited due to the small number of accelerators capable of producing α-particle beams of ≥28 MeV, which are required for production via the ^{209}Bi(α,2n)^{211}At reaction[1-5]. A DOE funded project at the Duke University Medical Center aims to increase the production capacity of the cyclotron and internal target system. The system has historically been operated at beam currents below 60 μA. The target capacity is limited by the relatively low melting point of the metallic bismuth target (~500°F). The objectives for this study were to predict the power level at which melting will occur in the original design and to determine if gains in thermal margin can be realized through design modifications. This was accomplished using a computational model for the target medium, target holder and cooling water system.

Methods

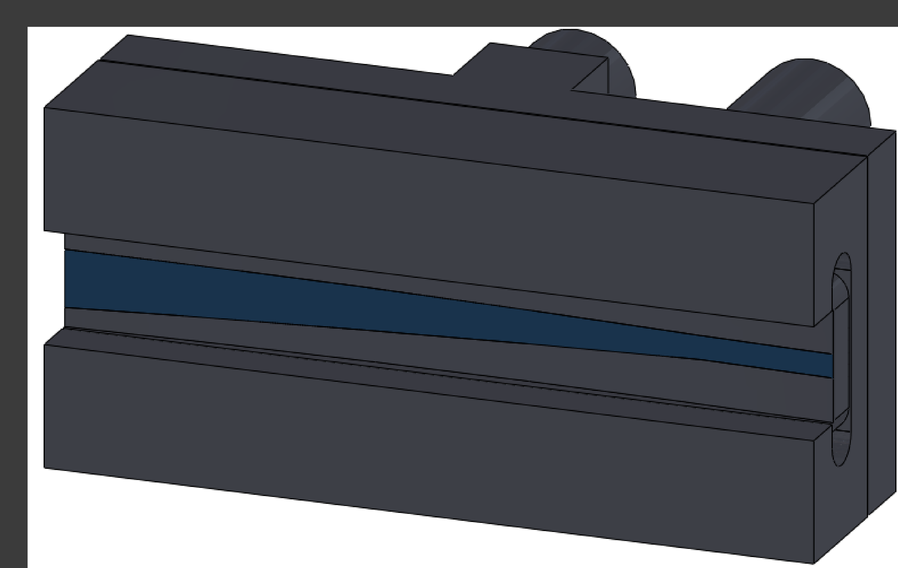
The prepared target consists of a uniform thickness of metallic bismuth bonded to a curved depression in an aluminum target holder. The beam strike area was approximated using measurements from an irradiated aluminum target (with no plating). Beam intensity was assumed to be uniform over the entire beam strike. The heat input was modeled using a conservative surface heat flux boundary condition.

Solid Model of Target Holder
Plated Surface shown in Red



Photograph of Target Holder
Beam Strike Evident (60 μA)

Solid Model of Target Assembly
Beam Strike shown in Blue



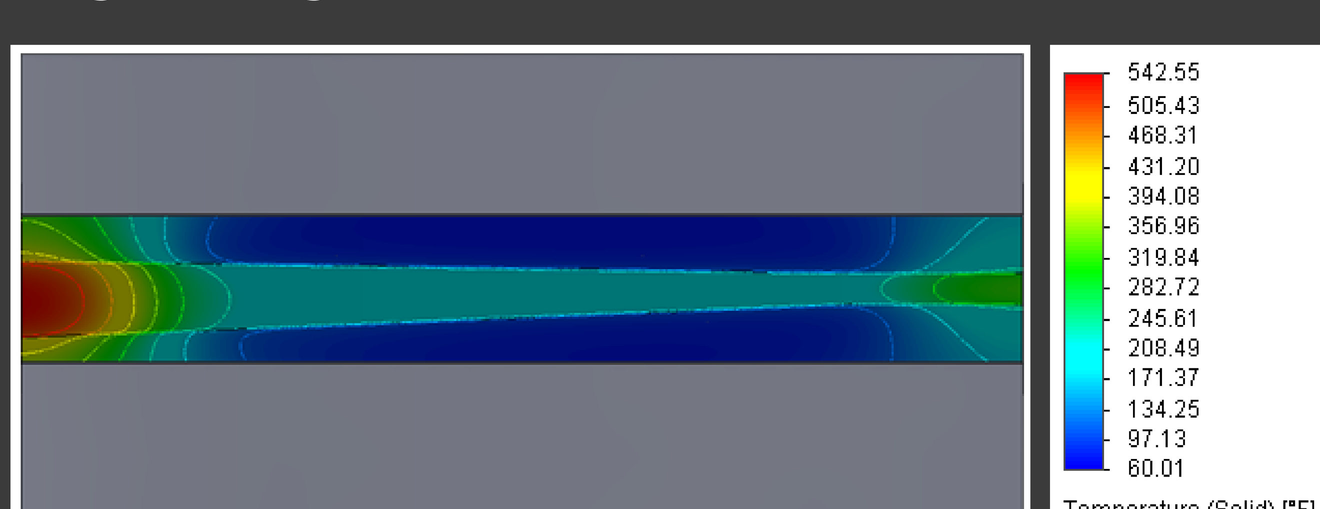
Computational Model

Measurements of 14 prepared targets indicated an average thickness of the bismuth layer of 85μm and a maximum thickness of 116μm. The maximum thickness was selected as the limiting case for the computational model.

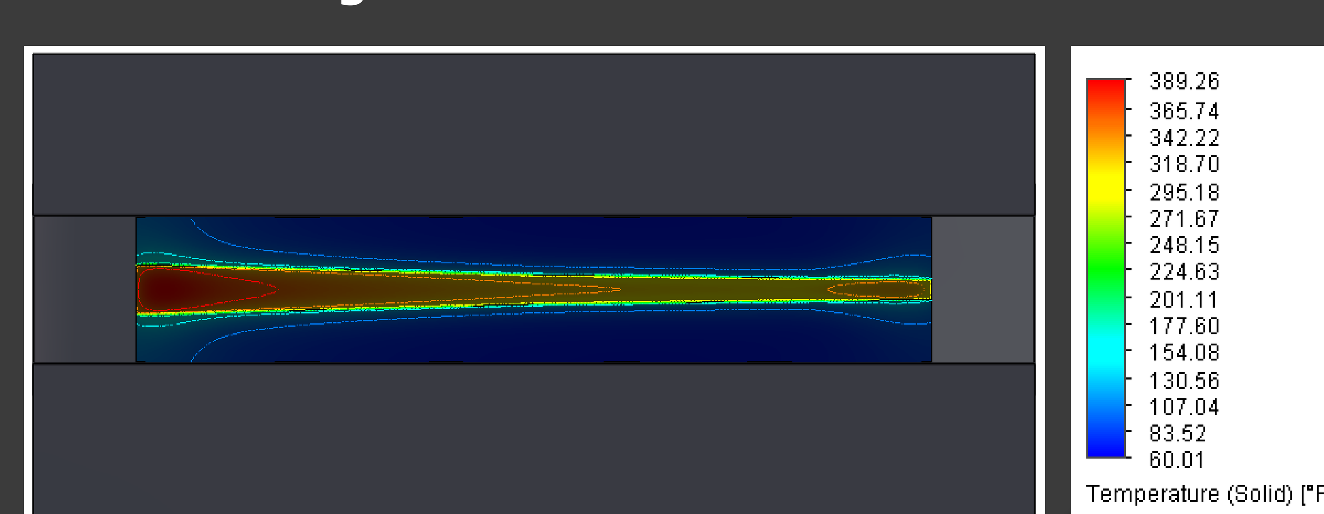
A conjugate heat transfer analysis was employed using SolidWorks Flow Simulation 2012. Maximum temperature for each part of the assembly was determined, as well as the maximum heat input to result in melting of the bismuth. The following figure shows the surface temperature of the bismuth exceeding the melting point with a heat input of approximately 1500 W, or 107 μA. The simulation indicates that no melting will occur at or below 1400 W, or 100 μA.

The position of maximum temperature occurs at the edge of the target, where the conduction length from the target to the cooling water is greatest. As a result, the target holder was chamfered to eliminate the beam striking near the edges of the assembly. This results in a significant increase in thermal margin, with a maximum temperature of 390°F at 1500 W.

Bismuth Temperature Distribution at 1500 W
Original Target



Bismuth Temperature Distribution at 1500 W
Modified Target



Results and Discussion

Simulations indicate that the bismuth melting temperature will not be exceeded at power levels up to 1400 W. The maximum power can be increased to roughly 2100 W, or by about 25%, by implementing the chamfered aluminum target holder.

References

1. R.H. Larsen,B.W. Wieland, and M.R. Zalutsky, *Appl. Radiat. And Isot.* ***47***, 135-143 (1996).
2. K. Gagnon, R. Risler, *et al*, *J. Labelled Compounds and Radiopharmaceuticals* **55**, 436-440 (2012).
3. O. Lebeda, R. Jiran, *et al*, *Appl. Radiat. And Isot.* ***63***, 49-53 (2005).
4. R. Freifelder, A. Kachur, *et al, AIP Conf. Proc.* ***1509***, 129-134 (2012).
5. U. P. Schwarz, P. Plascjak, *et al*, *Nuclear Medicine & Biology* **25**, 89-93 (1998).