Development of 3D Printed Radioactive Sources and Their Applications

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Introduction

Modern nuclear metrology requires customizable, high-precision reference materials to validate calibration software and develop realistic calibration sources. This study utilizes Stereolithography (SLA) to produce volumetric radioactive sources by spiking UV-curable resins with ^{152}Eu following its chemical separation. By adhering to defined digital designs, this process overcomes conventional geometric constraints to enable the on-demand production of specialized sources. This research establishes a versatile platform for the physical verification of mathematical efficiency calibrations and medical physics applications.

Methods

Step 1: Radionuclide Separation

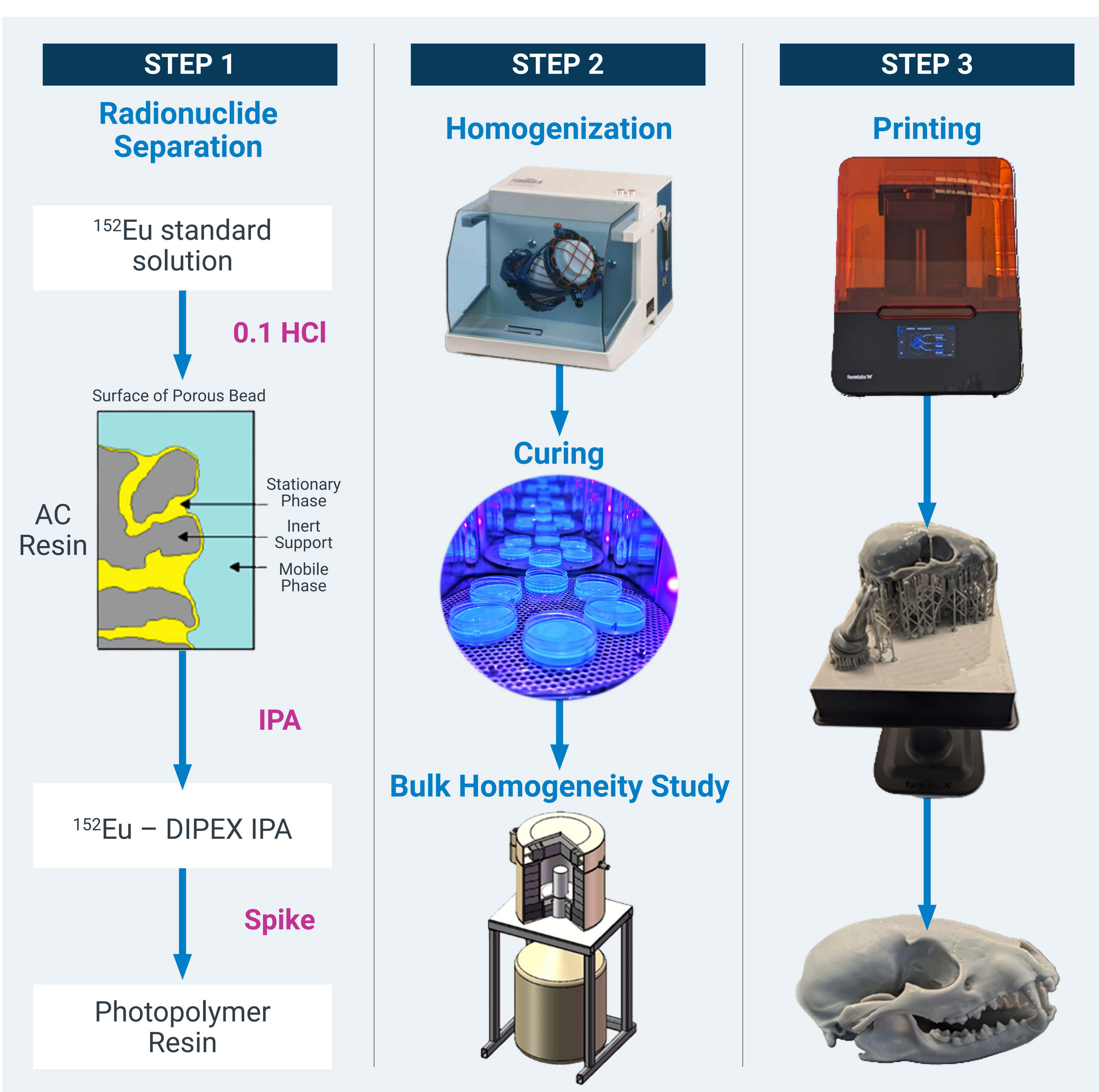
- ^{152}Eu was separated from the aqueous acid matrix using AC extraction chromatography resin. AC resin provide high Kd (10^5 - 10^7) for a range of radionuclides.
- ^{152}Eu was quantitively eluted using anhydrous isopropanol (IPA) to ensure compatibility with the organic resin.
- 224.92 g of Formlabs V4 Gray Resin was spiked with the concentrated ^{152}Eu fraction.

Step 2: Homogenisation

- The batch was mixed using a Turbula mixer for 1 h.
- Six subsamples were cured in the plastic containers and measured on an HPGe detector.

Step 3: 3D Printing

- Volumetric sources were printed via SLA (Formlabs Form 3).
- Objects underwent UV-thermal curing for mechanical and chemical stability.



Discussion

The obtained homogeneity of the spiked resin was below 2% for the primary ^{152}Eu photopeak, signifying a high level of uniformity across the bulk volume. This consistent activity distribution is a direct consequence of the chemical compatibility established between the isopropanol carrier and the resin monomers, which ensures that no phase separation occurs during the spiking process. Furthermore, the successful fabrication of complex structures demonstrates that the radiochemical integration does not inhibit UV-initiated polymerization or compromise the structural integrity of the printed objects. These results indicate that the developed preparation technique is a reliable and scalable approach for producing standardized volumetric sources with high spatial uniformity.

Results

A preliminary assessment of the bulk homogeneity was performed by analysing six independent subsamples of the cured radioactive resin. The measurements were conducted using the HPGe BE5030 detector, and the net counts were corrected for decay and sample mass to establish the count rate per unit mass (cps/g) for the ^{152}Eu peaks 121.8 keV and 344.3 keV.

Sample ID	Mass (g)	Net area (121.8 keV)	± σ (%)	Net area (344.3 keV)	± σ (%)	Decay corrected cps/kg (121.8 keV)	Decay corrected cps/kg (344.3 keV)
1	6.69	5120	1.40%	1590	2.51%	765.32	237.67
2	7.12	5310	1.37%	1693	2.43%	745.79	237.78
3	7.67	5738	1.32%	1801	2.36%	748.11	234.81
4	5.56	4210	1.54%	1359	2.71%	757.19	244.43
5	5.81	4482	1.49%	1319	2.75%	771.43	227.02
6	5.77	4471	1.50%	1363	2.71%	774.87	236.22

Basic statistical parameters	Peak 1 (121.8 keV)	Peak 2 (344.3 keV)
Average =	760.45	236.32
Median =	761.25	236.94
Min value =	745.78	227.02
Max value =	774.87	244.42
Max/min =	1.039	1.08
Std. dev =	12.08	5.63
Rel. std. dev =	1.59%	2.38%
Avg. rel. unc. =	1.44%	2.58%

Conclusion

This research establishes a traceable pathway for fabricating volumetric radioactive sources and highlights the unique value of 3D printing for producing complex-geometry calibration sources and reference materials. By developing a stable, homogeneous radioactive resin, the study overcomes key geometric and chemical limitations of conventional manufacturing and provides a versatile platform for the physical verification of mathematical efficiency calibration software.

Future Work

- Printing irregular “wine glass” shapes for direct empirical comparison against efficiency simulations.
- Spiking with ^{241}Am and ^{207}Bi following individual chemical separation to cover a broader energy range for gamma-ray spectrometry calibration.
- Organizing an IAEA Proficiency Testing Exercise using 3D-printed geometries to provide broad, independent validation of the material’s stability for broader calibration applications.

References

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