Radiopurity studies of tin-lead and tin-bismuth alloys for the development of a cryogenic bolometer

A. Mazumdar[1,2],* G. Gupta[3], A. Garai[1,2], H. Krishnamoorthy[1,2], A. Reza[3], V. Nanal[3], R. G. Pillay[3†], A. Shrivastava[2,4], and A. Thamizhavel[5]
[1] *INO, Tata Institute of Fundamental Research, Mumbai - 400005, India*
[2] *Homi Bhabha National Institute, Anushaktinagar, Mumbai - 400094, India*
[3] *DNAP, Tata Institute of Fundamental Research, Mumbai - 400005, India*
[4] *NPD, Bhabha Atomic Research Centre, Mumbai - 400085, India and*
[5] *DCMP&MS, Tata Institute of Fundamental Research, Mumbai - 400005, India*

Introduction

Superconducting bolometers are known to have excellent energy resolution and are well suited as detectors for experiments such as neutrinoless double beta decay (NDBD) and dark matter (DM) searches. In India, the *TIN.TIN* group has initiated the development of cryogenic tin bolometers to study NDBD in ^{124}Sn [1, 2]. One of the challenges in making a cryogenic tin bolometer is the occurrence of tin pest [3], an occasional phase transition of tin which results in the disintegration of the tin sample. It has been reported that tin pest can be suppressed by alloying tin with elements such as lead and bismuth [3].

As mentioned in a previous work on tin-indium [4], in addition to suppression of tin pest, the radiopurity of the alloy candidates is crucial for the purpose of a rare decay experiment such as NDBD. It is interesting to note that one of the alloying elements used in the present work, ^{209}Bi (natural isotopic abundance ∼100%) was long thought to be the heaviest stable isotope. In 2003, using bolometric techniques, it was found to be an alpha emitter with $T_{1/2} = 1.9 \times 10^{19}$ yr [5]. This paper reports the radiopurity measurements of tin-lead and tin-bismuth alloys using gamma ray spectroscopy in the TiLES set-up [6, 7]. In order to understand the effect of the alloying element, measurements were carried out on samples which were alloyed ∼9% by weight.

Experiment and data analysis

Samples of the tin-lead and tin-bismuth alloys were prepared at TIFR using high purity natural tin, lead and bismuth (7N, 5N and 6N, respectively). The alloying was done at ∼9% by weight for both the samples. The oxide layers on the tin and lead (starting materials) were etched with dil. HCl and dil. HNO_3 respectively, followed by washing with de-ionised water and acetone. The materials were then vacuum sealed in baked quartz tubes and were melted in a box type furnace. The melt was carefully cooled at 1°C/hr till it crystallized. A single crystal of tin was synthesized using the Bridgman technique. It was inferred from the Laue X-ray diffraction pattern that the tin sample is a single crystal. Both the tin-bismuth and tin-lead samples showed stability against tin pest in the cooling tests.

Table I gives the details of the spectroscopic measurements on the samples. For the radiopurity measurements, each sample was counted in the TiLES set-up at a distance of ∼1 cm from the face of the detector. The spectra were analysed using LAMPS [8].

TABLE I: Details of the measurements.

Sample	Mass (g)	Runtime (days)
background (bkg)	-	4.8
tin	21.3	2.9
tin-lead	3.6	5.9
tin-bismuth	4.0	4.9

†Present address: Department of Physics, IIT Ropar, Rupnagar, Punjab - 140001, India
*Electronic address: mazumdar.aparajita@gmail.com

TABLE II: Intensities of the prominent gamma rays which were observed. The sources of the lines are listed in bold below their respective energies.

Energy keV	bkg cts/d	tin cts/d	tin-bismuth cts/d	tin-lead cts/d
661.7 **^{137}Cs**	218 (12)	183 (15)	209 (13)	210 (13)
669.6 **^{63*}Cu**[a]	18 (5)	28 (9)	24 (7)	26 (9)
962.1 **^{63*}Cu**[a]	36 (8)	21 (6)	24 (6)	27 (7)
1460.8 **^{40}K**	31 (6)	30 (7)	36 (6)	43 (6)
2614.4 **^{208}Tl**	17 (5)	16 (5)	16 (4)	14 (6)

[a]neutron induced reaction in the Cu shielding

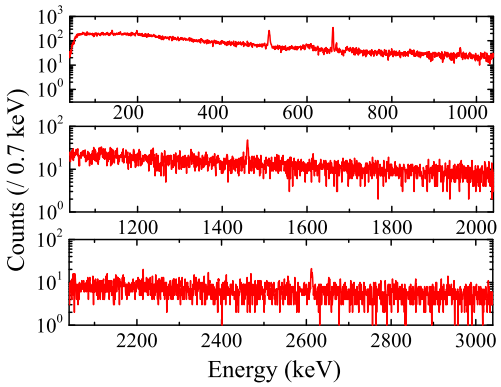

FIG. 1: Spectrum of the tin-bismuth sample ($\sim$ 5 days data).

Table II lists the time normalized counts of the prominent gamma rays observed in the spectra of the background, tin, tin-bismuth and tin-lead samples. A typical spectrum of the tin-bismuth sample is shown (see Fig. 1). At the sensitivity level of TiLES, no new gamma lines apart from the background lines were observed in the spectra of the samples. No enhancements were seen in these lines in comparison to the background or tin.

Conclusion

Tin-lead and tin-bismuth alloys have shown stability against tin pest and are presently being investigated as candidates for a cryogenic bolometer. Radiopurity measurements of tin-lead and tin-bismuth alloys (alloyed $\sim$9% by weight) were carried out using the TiLES set-up. No new gamma lines or enhancements were observed in the spectra of the tin-bismuth or tin-lead samples in comparison to the background or the tin sample, at the sensitivity level of TiLES .

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