STUDY ON TECHNOLOGY FOR MANUFACTURING ALLOY (LEAD - TIN - BISMUTH - CADMIUM) HAVING LOW MELTING TEMPERATURE (≤ 80^0C) USED TO SHIELD RADIOACTIVE RAYS FOR TREATING CANCER

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ABSTRACT: Up to now, hospitals in Vietnam have mostly imported radioactive equipments from America, German, France, England to treat cancer. Accompany with those equipments, alloy, namely Cyroben having low melting temperature (≤ 80^0C) is used to cover patients' good tissues in order to protect them against harmful rays and help radioactive rays get through the cast hole to kill cancer cells. This project is carried out for determining chemical compositions and melting temperatures of researched alloy to create alloy having low melting temperature (≤ 80^0C) to meet demand for treating cancer in Vietnam.

Key words: Processing flow sheet, name element: Lead (Pb); Tin (Sn); Bismuth (Bi); Cadmium (Cd).

INTRODUCTION

The Cyroben alloy (Pb – Sn – Bi – Cd) used to cover the cancer has to meet 3 basic demands:

- Meet technique characters of radioactive treating: can cover 92-95% of radioactive rays (compared with open radiation source) in order to keep those harmful rays out of patients' good tissues as few as possible.

- Have low melting temperature (≤ 80^0C), easy to melt and to cast in complex shapes.

- Prevent workers, patients and doctors from harmful rays.

EXPERIMENT RESULTS AND DISCUSSION

After analyzing chemical compositions, measuring melting temperatures of imported alloy samples, we have received following technique parameters. We have used these parameters as well as studied foreign reference documents for carrying out experiments. The results are shown on the table 1.

Table 1: Chemical compositions of imported alloy samples

No	Composition,%				Melting temperature ^{0}C	Ability to cover radioactive rays
	Bi	Pb	Sn	Cd		
1	51.5	28	10	10.32	80	95%

Table 2: Chemical compositions and characters of some alloy having low melting temperature

LOW 117	Typical End Use	**Melt Temp: 117°F (47°C)**	**Density: 0.3200 lb/in^3**
	Bismuth 44.7%, Lead 22.6%, Tin 8.3%, Cadmium 5.3% , Indium 19.1%		

LOW 136	Typical End Use	**Melt Temp: 136°F (58°C)**	**Density: 0.3253 lb/in^3**
	Bismuth 49%, Lead 16%, Tin 12%, Indium 21%		

LOW 158	Typical End Use	**Melt Temp: 158°F (70°C)**	**Density: 0.3390 lb/in^3**
	Bismuth 50%, Lead 26.7%, Tin 13.3%, Cadmium 10%		

LOW 158-190	Typical End Use	**Melt Temp: 158-190°F (70-88°C)**	**Density: 0.3541 lb/in^3**
	Bismuth 42.5%, Lead 37.7%, Tin 11.3%, Cadmium 8.5%		

LOW 203	Typical End Use	**Melt Temp: 203°F (95°C)**	**Density: 0.3502 lb/in^3**
	Bismuth 52.5%, Lead 32%, Tin 15.5%		

LOW 217-440	Typical End Use	**Melt Temp: 217-440°F (103-227°C)**	**Density: 0.3660 lb/in^3**
	Bismuth 48%, Lead 28.5%, Cadmium 14.5%, Antimony 9%		

1. Materials and equipments

- A small well stove has capacity of 5 kg/batch and temperature control. Maximal temperature is 1000^{0}C.

- A refractory glass has capacity from 100g to 2000g/batch. A Hg thermometer can measure temperature to 500^{0}C, trays made of stainless steel, glass or plastic are used to contain products.

The results of analyzing materials are shown on the table 3.

Table 3: The first material compositions

No	Signs of samples	Norms of anlysis(%)				
		Pb	*Sn*	*Bi*	*Cd*	*Others*
1	M01	99.85	-	-	-	-
2	M02	99.87	-	-	-	-
3	M03	-	99.94	-	-	-
4	M04	-	-	99.95	-	-
5	M05	-	-	-	99.86	-

2. Research on alloying process of metals (Pb-Sn-Bi-Cd)

The 1st experiment: Use mixture of 500 gram of metals (Pb-Sn-Bi-Cd). The first ratio of mixing is shown on the table 4.

Table 4: The first ratio of mixing

Element	Bi	Pb	Sn	Cd	Others
Ratio %	50	30	10	10	-

Melt mixture of Pb and Sn first, when temperature of mixture increases to 270^0C, it melts completely. Continue increasing temperature to 300^0C (average increasing speed: 12^0C/ minute), add Bi and Cd to the mixture slowly, keep stirring to avoid Bi and Cd to float on the surface of the liquid mixture. Melting process of Bi and Cd makes temperature of the mixture (Pb-Sn-Bi-Cd) decrease, so we can obtain alloy having low melting temperature. After melting Bi and Cd completely, maintain melting temperature in 5 minutes, keep stirring the mixture and skim slag out of the stove.

Pour the mixture in to the clean stainless steel tray, let hot mixture cool, we obtain alloy (Pb-Sn-Bi-Cd).

The experiment results:

Cut this alloy sample and analyze its chemical compositions. The results are shown on the table 5.

Table 5: The result of analyzing chemical compositions of alloy sample

No	Alloy	Chemical composition, (%)			
		Pb	*Sn*	*Bi*	*Cd*
1	Pb – Sn – Bi – Cd	31.6	9.5	48.3	9.2

Measure density of the alloy, then melt it again to check its melting temperature. Use the Hg thermometer. The results are shown on the table 6.

Table 6: The result of checking alloy sample

No	Alloy	Melting temperature, ^{o}C	Density, g/cm^3
1	Pb – Sn – Bi – Cd	78	9.90

3. Research on influence of experiment temperature on recover efficiency and melting temperature of alloy (Pb-Sn-Bi-Cd)

The 2nd experiment:

- Choose the ratio of metals: 50% Bi – 30% Pb – 10% Sn – 10% Cd

- Carry out 3 experiments with 3 samples having the same weight: 200g.

When temperature of the mixture increases to 270^0C, Pb and Sn melt completely, keep on increasing temperature to 300^0C and add a half of Bi and Cd to the mixture, stir it continuously. After 5 minutes, the mixture becomes liquid. Skim slag out of the stove and add the rest of Bi and Cd to the mixture. Wait for 4 minutes, the mixture melts completely, skim slag out of the stove and maintain melting temperature in 5 minutes, turn of the stove. Pour the mixture into the clean stainless steel tray to let it cool, we obtain alloy (Pb-Sn-Bi-Cd).

- Carry out 2 experiments with 2 other samples having the same weight: increase temperature to 350^0C and 400^0C, then add Bi and Cd to.

Let the hot mixture cool, weigh products for checking their recovery efficiency, then bake them for checking melting temperature of alloy. The results are shown on the table 7.

Table 7: Check melting temperature and recover efficiency of alloy samples

No	**Alloy**	**Experiment temperature, ^{o}C**	**Melting temperature,^{o}C**	**Recovery efficiency (%)**
1	Pb – Sn – Bi – Cd	300	78	95
2	Pb – Sn – Bi – Cd	350	80	92
3	Pb – Sn – Bi – Cd	400	85	90

The results show that experiment temperature affects recover efficiency and melting temperature of alloy obviously. The higher experiment temperature is, the lower recovery efficiency is. At high temperature, Bi and Cd are oxygenized easily to create oxide, so amount of Bi and Cd diminishes, this makes melting temperature of alloy increase. Therefore, Bi and Cd play an important role in the experiments, they decide low melting temperature of the alloy.

4. Research on influence of time on melting temperature of alloy(Pb-Sn-Bi-Cd):

<u>The 3rd experiment:</u>

Ratio of mixture: 50% Bi – 30% Pb – 10% Sn – 10% Cd. Melt completely mixture of Pb and Sn. Add Cd and Bi to the mixture, stir it continuously. Then maintain temperature of the stove at 330^0C. After 15 minutes without stirring, a layer of black slag creates and floats on the surface of the mixture. Skim all of slag out of the stove, it weighs 22 g, accounts for 11% in total of alloy. Pour alloy into the cool tray. Cut this alloy sample and analyze its chemical compositions, measure its melting temperature. The results are shown on the table 8.

Table 8: Chemical compositions and melting temperature of alloy sample

No	**Keeping temperature time, minute**	**Melting temperature, ^{o}C**	**Chemical composition, %**			
			Pb	***Sn***	***Bi***	***Cd***
1	15	87	40.8	10.3	41.5	7.3

The results show that: melting time affects melting temperature of alloy. The longer melting time lasts, the higher melting temperature is.

The 4th experiment:

Carry out the same experiment with keeping temperature time is 30 minutes without stirring. After 30 minutes, a layer of black slag creates much more and floats on the surface of the mixture. It weighs 32 grams and accounts for 16% in total of alloy.

Table 9: Chemical composition and melting temperature of alloy

No	Keeping temperature time, minute	Melting temperature, ^oC	Chemical composition, %			
			Pb	*Sn*	*Bi*	*Cd*
1	30	116	41.8	14.2	37.7	6.2

Conclusion: We should stop carrying experiment when the mixture melts completely, the most appropriate melting time is from 5-7 minutes with stirring continuously to alloy metals in the mixture completely.

5. Research on co-additional order of alloying process (Pb –Sn –Bi -Cd)

The 5th experiment:

Use 300 grams of mixture (150 grams Pb; 130 grams Sn; 10 grams Bi; 10 grams Cd) to carry out this experiment. After melting bismuth, add tin, lead and cadmium to the mixture. This process is carried out in the well stove without guard air. After 26 minutes, temperature of the stove increases to 290^0C, all of 150 grams Bi changes into brown oxide bismuth completely. So, when Bi is a member metal of the research alloy, it is impossible to melt it first.

The 6th experiment:

Use 300 grams of mixture (150 grams Pb; 130 grams Sn; 10 grams Bi; 10 grams Cd). Melt Cadmium first, then add Tin, Lead and Cadmium to the mixture. This process is carried out in the well stove without guard air. Cadmium becomes liquid at 325^0C, but a part of it is changed into Oxide. So, if we maintain stove's temperature at ≥ 325^0C, Cadmium slowly changes into Oxide Cadmium. This experiment shows that: if we melt Cadmium first, recovery efficiency is low because cadmium is lost during melting. Low content of Cadmium makes temperature of the alloy higher.

6. Analysis results: Analysis results are shown on the table 10.

Table 10: Result of analyzing alloy's chemical compositions

Order	Sample sign	Chemical composition, %				
		Pb	*Sn*	*Bi*	*Cd*	*Others*
1	SP01	30.1	19.4	49.2	-	-
2	SP02	31.6	9.5	48.3	9.2	-
3	SP03	40.8	10.3	41.5	7.3	-
4	SP04	41.8	14.2	37.7	6.2	-
5	SP05	35.17	5.08	49.17	9.27	-

6	SP06	30.28	10.49	44.53	14.68	-
7	SP07	40.49	9.32	45.28	4.73	-
8	SP08	39.73	5.26	39.61	9.71	-

7. Use Cyroben alloy to measure parameters and check its ability to cover radioactive rays of on the radiation source of Center for radioactive safety and environment-Institute for nuclear science and techniques

Use 2 kilograms of alloy (melting temperature: 78^0C) from the 2nd experiment. Melt and then cast it with thickness of 10 mm. Stick alloy sample on the plastic tray and set it in front of the radiation source to check the ability to cover radioactive rays at Center for radioactive safety and environment.

* Measure coefficient transmit of the tray: Measure R_{tray} and R_{open} in the water, use the plastic tray, standard radiation field (10x10 cm)

- The 1st measure: Use open resource without covering, coefficient transmit of the tray

R_{open}= 573.3. Then we use a transparent plastic tray to cover the radioation source, coefficient transmit of the source R_{tray}= 541.3. So, coefficient transmit of the source decreases from 573.3 to 541.3 if we use the tray. We have a result: only 95.4% radioactive rays of the source can go through the tray, it means the transparent plastic tray can cover 4.6% of radioactive rays.

- The 2nd and 3rd measure are carried out in the same way as the 1st: 96.2% of the radioactive rays go through the tray, it means the transparent plastic stray can cover 3.8 % of the radioactive rays .

The results are shown on the table 11.

Table 11: Coefficient transmit of the tray

Order	**Result**	R_{open}	R_{tray}
1	95.4%	573.3	541.3
2	96.2%	573.3	551.4
3	96.2%	556.1	535.1

*Measure the coefficient transmit of the block: Measure R_{tray} and $R_{tray + block}$ in the water, we use Cyroben with radiation field 8 x 8 mm.

- The 1st measure: use a transparent plastic tray to cover the source, coefficient transmit of the source R_{tray} = 534.6. Then we use a plastic tray with Cyroben alloy to cover radioactive source in the small radiation field 8 x 8 mm, the source's coefficient transmit decreases to 42.82 accounts for 6.0% of the source going through. So, if we use the plastic tray with Cyroben alloy, it can cover 94% of radiation source (compared with open radiation source).

The 2nd and the 3rd measure: the plastic tray with alloy Cyroben can cover 94% of the radiation source. The results are shown on the table 12.

Table 12: The coefficient transmit of the block

Order	Result	$R_{tray + block}$	R_{tray}
1	6.0%	42.82	534.6
2	6.0%	42.84	535.1
3	6.0%	42.81	535.4

8. Result and discussion

- Alloy meets the best quality when it contains 20-30% Pb, 10-15% Sn, 50-55% Bi, 10-12 %Cd. With those contents, alloy has low melting temperature and can cover 94-95% of radiation source (compared with open radiation source).

- We have obtained the first results: making alloy having low melting temperature ($\leq 80^0$C) to meet the requirements of treating cancer.

- Alloy newly created can cover 94-95% of radiation source (compared with open radiation source) to save good tissues from damaging.

9. Conclusion

- Using materials and equipments in Vietnam, we have succeeded in melting alloy which has low melting temperature ($\leq 80^0$C) and are similar to imported alloy used to cover radioactive for treating cancer. So, hospitals in Vietnam don't have to import this alloy.

- This project has advertised on the newspapers of Vietnam foundry and metallurgy science and technology association (VFMSTA).

REFERENCE

[1]. Nguyen Khac Xuong. "metal of materials".

[2]. Phung Viet Ngu, Pham Kim Dinh, Nguyen Kim Thiet, melting metal alloy, 11/1997.

[3]. B. N. ARZAMAXOV, metal alloy, 2000.

[4]. Crystal Structure of phases of binary alloy Systems, compiled by Donald. T. Hawkisc information scientist, bell laboratories, murray hill, N.J.

[5]. Pro. Y. LAKHTIN, ENGINEERING PHYSICAL METALLURGY, translated from the Russian alloy Nicholas Weinstein, MIR PUBLISHERS, MOSCOW. 1968.

[6]. D.A. Porter Rautaruukki Oy Research Centre Raahe Finland, Phase transformations in Metals and alloys, second edition. London-Glasgow-New York-Tokyo-Melbourne-Madras.