Study on microstructure control and performance optimization of ZCuPb20Sn5 alloy by rare earth La

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Abstract: ZCuPb20Sn5 alloy is a cast lead-tin bronze alloy. Due to its high lead content, it has excellent comprehensive properties such as friction reduction and wear resistance, high fatigue strength, good thermal conductivity, and good wear resistance. It is widely used in automobiles, Aerospace industry and other fields. Therefore, this article selects ZCuPb20Sn5 alloy as the research object. By adding rare earth La to ZCuPb20Sn5 alloy solution, the metallographic structure and mechanical properties are observed, and the effect of rare earth La on the microstructure and properties of ZCuPb20Sn5 alloy material is analyzed. The results show that with the increase of La content, the tensile strength, elongation and hardness of lead-tin bronze alloys all increase first and then decrease. Without the addition of rare earth lanthanum, the tensile strength of lead-tin bronze can reach about 241.5 MPa. Adding different amounts of rare earth to the lead-tin bronze alloy can improve the tensile strength and elongation of the alloy. When 0.04 wt.% rare earth lanthanum is added, the strength and elongation reached the maximum. After several experiments, the tensile strength remained at about 267.1, the elongation remained at about 15.13%, the tensile strength increased by about 25.6 MPa, and the hardness remained at about 80 HB, with little increase.

1. Introduction

Copper is widely used in various industries due to its excellent electrical conductivity. However, due to the low strength of copper itself, its application field is limited [1]. In particular, copper-lead alloy is a bearing material with large bearing capacity, high fatigue strength and good thermal conductivity. It is widely used in the manufacture of high-power, high-speed variable-load sliding bearing parts, so it has become an ideal Bearing bush alloy [2-4]. Lead bronze has been widely used as bearing pads under high-speed and heavy loads due to its good friction reduction, high thermal conductivity and fatigue strength [5]. The research on reducing lead segregation of ordinary tin bronze with a low lead mass fraction is relatively complete, but the reduction of lead segregation in high-lead tin bronze centrifugal casting above 20% needs further study [6-8].

Rare earth elements can form refractory compounds with harmful impurities in pure copper and are discharged from the matrix, which can purify the melt and refine the structure [9]. Rare earth can remove impurities such as oxygen and sulfur in copper alloys, and improve the high temperature
performance and hot workability of copper and copper alloys. Rare earth will increase the tensile strength and elongation of the sample, and at the same time, the hardness will be improved, and the cooling processability and weldability of the copper alloy will be improved [10]. Therefore, more expectations have been placed on improving the properties of copper and copper alloys with rare earths [11]. Although many rare earth-containing copper and copper alloy materials with industrial significance and practical value have been successfully developed [12-18], more copper and copper alloys have not yet been applied with rare earth, so it remains to be developed. The new materials of copper and copper alloys of rare earths make the application of rare earths in copper and copper alloys wider and can achieve the purpose of industrial production.

Rare earth elements can improve various properties of copper alloys, but their application is not widespread enough, especially the research on the action mechanism of rare earths on copper is not enough, so it is of great significance to further study macro and micro. Because the rare earth elements are very active, causing severe burnout, the use of rare earths at room temperature and pressure will cause a great waste of resources. So choose the right process parameters to reduce losses. Future efforts are directed towards obtaining higher performance ingots.

2. Experimental

2.1. Experimental materials and preparation

The chemical composition of ZCuPb20Sn5 alloy is formulated according to table 1.1. The total amount of smelting in each furnace is unchanged, and the content of copper is adjusted by changing the different content of rare earth elements under the condition that the other contents are not changed. Among them, the raw materials of the alloy copper, lead ingot, tin ingot, zinc ingot, and pure nickel have a purity of more than 99.9%. Phosphorus and rare earth are added in the form of a copper alloy. The content of phosphorus in phosphorous copper is 13.5%. The content in the copper-lanthanum alloy is 13%. Lead-tin bronze alloys containing different alloying elements are cast in metal molds.

| Element | Cu | Pb | P   | Zn | Sn | Ni |
|---------|----|----|-----|----|----|----|
| Content (w) | bal. | 20 | 0 (0.3) | 1.75 | 5 | 2 |

2.2. Experimental method

ZCuPb20Sn5 alloy castings are smelted in a well-type resistance melting furnace (SG2-12-13), and the crucible is made of graphite. The pouring temperature is 1200 ± 20 °C, and the casting test block is a copper alloy metal mold casting test block. For specific dimensions, refer to the national standard GB / T 1176-2013 [19], as shown in figure 1. Before the rare earth is added, it is wrapped in copper foil, and it is quickly pressed into the bottom of the melt with a graphite rod to prevent oxidation. The shaded areas in the figure are sampling locations for tissue and performance analysis. After the specimens were ground, the hardness was tested with a HB-3000B Brinell hardness tester. The sampling position of the metallographic sample is the position where the shaded part is far from the
outermost part of the runner. After removing the metallographic sample, a metallographic microscope (AXIO Scope.A1) and a scanning electron microscope (SEM, SU5000) are used to observe the sample. The microstructure morphology of the surface before and after the surface corrosion. The etching solution was selected from hydrogen peroxide, ammonia and water at a ratio of 1: 1: 1. Energy Spectrometer (EDS) is used to characterize the elemental distribution of the alloy. X-ray diffractometer (XRD, Rigaku D / max-rB) and synchronous thermal analyzer (DTA, HJ-JCR-2) were used to analyze the phase composition of ZCuPb20Sn5 alloy. Electronic probes (EPMA, JXA-8100) were used to determine the main Cu3P and Ni3P phases in ZCuPb20Sn5 alloy.

![Figure 1](image)

**Figure 1.** Size and morphology of copper alloy mold.

### 2.3. Experimental program

The microstructure and properties of ZCuPb20Sn5 alloy are improved by adding different rare earths. Considering that phosphorus in lead-tin bronze also has the ability to remove oxygen and slag, there are two specific schemes. The first scheme is to deoxidize and degas without phosphorus. Effect of La Addition on microstructure and properties of ZCuPb20Sn5 Alloy. The other is the effect of different content of La on the microstructure and properties of ZCuPb20Sn5 alloy when the phosphorus content is 0.3 wt.%, and then determine whether the effect of rare earth on ZCuPb20Sn5 alloy is the same as the first, as shown in table 2:

| Factor | Cu (w) | Pb (w) | Sn (w) | Ni (w) | P (w) | La (w) |
|--------|--------|--------|--------|--------|-------|--------|
| 1      | Bal.   | 20.04  | 5      | 3      | 0     | 0      |
| 2      | Bal.   | 20.04  | 5      | 3      | 0     | 0.04   |
| 3      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0      |
| 4      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0.01   |
| 5      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0.03   |
| 6      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0.04   |
| 7      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0.07   |
| 8      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0.1    |
| 9      | Bal.   | 20.04  | 5      | 2      | 0.3   | 0.2    |
3. Results and discussion

3.1. Microstructure analysis

3.1.1 Metallographic analysis: ZCuPb20Sn5 alloy is a high-lead bronze. The distribution of lead particles in its structure directly determines the tensile strength of the lead-tin bronze alloy. The smaller and uniform the particles, the better the tensile strength and the elongation performance. The metallographic structure of ZCuPb20Sn5 alloy before corrosion can be analyzed by figure 2, where (a) and (b) are post metallographic organization with rare earth added 0 wt.% and 0.04 wt.% in the ZCuPb20Sn5 alloy without phosphorus copper added. figure 2 (c), (d), (e), (f), (g), (h), and (i) The amount of rare earth added is the metallographic photographs of ZCuPb20Sn5 alloy under the conditions of 0 wt.%, 0.01 wt.%, 0.03 wt.%, 0.04 wt.%, 0.07 wt.%, 0.1 wt.% and 0.2 wt.%. It can be seen from the figure that without the effect of phosphorus, after adding 0.04 wt.% La, the lead particles in the structure become smaller and uniform. This shows that the addition of rare earth can refine the shape of lead particles. When 0.01 wt.% P is added, the process of adding 0.0 wt.%-0.03 wt.% La does not change much of the lead particle morphology. It is mainly spherical, but the lead particles gradually become uniform and spherical. There is a tendency to become smaller. When the added amount increased to 0.04%, the spherical lead particles became smaller, more uniform, and reached the optimal state. Therefore, the mechanical properties are higher here. When the content of rare earth La is increased to 0.07 wt.%, The lead particles are particularly fine in shape and distributed uniformly, and the spheres are decomposed into worms. When the content of La continued to increase to 0.1 wt.%, The lead particles began to become spherical again, and gradually grew with the increase of the content of La, and a dendritic structure appeared in the crystal. When 0.2 wt.% of rare earth was added, the dendritic structure became more obvious and became coarser. So from the perspective of metallographic structure alone, when the added amount is 0.04 wt.%, the structure is relatively fine and uniform. With the increase of the amount of addition, the lead particles have a tendency to grow, but gradually become spherical. After the amount of addition continues to increase, columnar crystals appear.
Figure 2. Uncorroded metallographic structure of ZCuPb20Sn5 alloys with different rare earth contents (a) P:0%、La:0% (b) P:0%、La:0.04% (c) P:0.3%、La:0% (d) P:0.3%、La:0.01% (e) P:0.3%、La:0.03% (f) P:0.3%、La:0.04% (g) P:0.3%、La:0.07% (h) P:0.3%、La:0.1% (i) P:0.3%、La:0.2%.

3.1.2. **Microstructure analysis.** The corroded sample is observed and photographed under a 200x microscope as shown in Figure 3 below, where (a), (b), (c), (d), (e), (f), (g), (h) and (i) represent 0 wt.% and 0.04 wt.% of phosphorus-free copper plus rare earth in lead-tin bronze, and 0 wt.% 0.01 wt.% 0.03 wt.% 0.04 wt.% 0.07 wt.% 0.1 wt.% and 0.2 wt.% of rare earth added in both cases of phosphorous copper, Metallographic pictures of the structures of after corrosion.

It can be seen from the figure that after corrosion of the sample, with the increase of the rare earth content, the large dendritic segregation in the crystal gradually decreases, and the distribution tends to be uniform. The shape of the lead particles gradually decreased from a particularly large and uneven spherical shape and block shape. First, it became a small and uniform spherical shape, and then, as the rare earth continued to be added, it grew from a spherical shape to a large uneven block. When the content of rare earth is added to 0.07 wt.%, the lead particles in the structure are decomposed into small worm strips, and when the added amount is increased to 0.2 wt.%, columnar crystals appear in the structure. The distribution of $\alpha$ structure and copper-tin eutectoid ($\alpha + \delta$) structure based on copper...
gradually became uniform. When the added amount is 0.07 wt.%, the tissue is relatively fine and uniform, and the lead particles exist in small worm-like and strip-like shapes, because there are no large lead particles, and the entire tissue is relatively small and uniform. There are more gray \((\alpha + \delta)\) tissues. Occupy a large area.

**Figure 3.** Metallographic structure after corrosion with different lanthanum contents (a) P:0%、La:0% (b) P:0%、La:0.04% (c) P:0.3%、La:0% (d) P:0.3%、La:0.01% (e) P:0.3%、La:0.03% (f) P:0.3%、La:0.04% (g) P:0.3%、La:0.07% (h) P:0.3%、La:0.1% (i) P:0.3%、La:0.2%.

3.1.3. Phase structure analysis. Figure 4 shows the SEM data of ZCuPb20Sn5 alloy, in which the white irregular particles in the structure are lead particles, the gray structure and the dark white structure are \(\alpha\) structure and copper-tin eutectic \((\alpha + \delta)\) structure. The black-grey small block structure is the copper-nickel-phosphorus phase. Which phase is generated will be further analyzed later.

It can be clearly seen from the figure that the structure of rare earth with and without rare earth is very different. When no rare earth is added, the shape of the lead particles is relatively large floc, lumpy and spherical. There are many large massive and spherical lead particles. And the entire organization is chaotic. When 0.04 wt.% of rare earth is added, the lead particles become smaller, and become small spherical and small blocks, and the entire structure is uniformly distributed, and the distribution is more regular and dense, so the mechanical properties of the organization are better.
The structure is observed at a magnification of 1000 times, but it can be clearly seen that without the addition of rare earth, the lead particles in the structure have accumulated most impurities, forming an irregular network floc structure, which is extremely unevenly distributed. However, the addition of 0.04 wt.% After the rare earth, the lead particles became small spherical and small massive structures, clean and clear, without the accumulation of impurity components, the α structure and copper-tin eutectoid (α + δ) structure was evenly distributed.

Figure 5 shows the EDS data of ZCuPb20Sn5 alloy, in which white irregular particles in the structure are lead particles, and (b) is the diffraction data indicated by the arrow. From the diffraction data, it can be seen that the black-gray vermicelli is Cu3Ni. The gray structure and dark white structure are α-structure and copper-tin eutectoid (α + δ) structure.
3.1.4. XRD analysis

Figure 5. EDS data of the ZCuPb20Sn5 alloy.

Figure 6 is an XRD diffraction picture of lead-tin bronze. According to the analysis of the picture, it can be seen that the structure is mainly the α phase with high copper content, followed by the lead particle phase and the solid solution phase of copper and tin. According to the analysis, the α solid solution phase is dominant, and the lead particle phase is distributed therein. The δ content of copper and tin solid solutions is not much, and mainly exists in the form of (α + δ).

3.1.5. DTA Data Analysis Differential thermal analysis was performed on samples of ZCuPb20Sn5 alloy with 0.3 wt.% P and 0 wt.% rare earth La and ZCuPb20Sn5 alloy with 0.3 wt.% P and 0.2 wt.%
La, and the data was used to make a graph for analysis. As shown in 7:

Figure 7. The relationship between the heat flux of ZCuPb20Sn5 and the sample temperature.

Figure 10 is the relationship between the heat flow and the sample temperature during the heating and cooling of two samples of lead, tin and bronze. Figure 7(a) is the relationship between the heat flow and the sample temperature during heating, and (b) is the heat flow and the sample temperature during cooling. The two curves in the figure are the relationship between the temperature of the lead-tin bronze sample and the heat flow without adding rare earth, and the relationship between the temperature of the sample and the heat flow after adding 0.2 wt.% rare earth.

It can be seen from the figure (a) that when rare earth is not added, there is a peak at 325 °C, and after adding 0.2 wt.% of rare earth, a small peak appears at 315 °C, where the peak is lowered, indicating that an endothermic phenomenon occurred, and the melting point of lead was 327.502 °C. The peak here should be the melting of lead. Then, at 913 °C, there was another peak change, and the peak was still reduced, which was an endothermic phenomenon. Under standard conditions, the melting point of pure copper is 1083.4 ± 0.2 °C, and a small peak appears near this temperature, while other metals such as element tin are silver-white metals, with a melting point of 231.86 °C and a boiling point of 2270 °C. Zinc has a melting point of 419.5 °C. Because these alloys are relatively small, there is no significant peak in the melting process. After the addition of rare earth lanthanum, a relatively large peak appeared at about 914 °C, and the endotherm still decreased. Compared with the case where no rare earth was added, the peak was larger. Then, when no rare earth was added, a small peak appeared at 959.55 °C. Correspondingly, after adding 0.2 wt.% of rare earth, a peak appeared at 943 °C.

Figure 7(b) is the relationship between the heat flow and the sample temperature during the cooling process. As can be seen from the figure (b), when no rare earth is added, as the temperature decreases, a peak change occurs at 946.65 °C. The amplitude is not large, but after adding 0.2% of rare earth La, a large peak appears at 950.7 °C, and the heat flow span is large, increasing from -18µV to 15.9µV. There should be precipitation of new phases. According to the binary and metallographic diagrams of copper and lanthanum, it can be known that there may be lanthanum compounds precipitated there, and the specifics are yet to be further analyzed. Subsequently, when no rare earth
was added, another peak change occurred at 888.45 °C, and the peak still increased, which was an exothermic phenomenon, but the peak amplitude was not large. After the addition of the rare earth, a peak appeared at 879.5 °C, and the peak was not the same. Both of these should be the same material precipitation. According to the solidification characteristics of the metal, it can be judged that this place should be the precipitation of copper. Then, there was a peak at 317 °C, and after adding 0.2 wt.% of rare earth, a small peak appeared at 301.87 °C. The peak increased slightly at this point, indicating that an exothermic phenomenon occurred, which should be caused by lead. The phenomenon of crystallization.

During the cooling process, when no rare earth was added, three peaks appeared at 946.65 °C, 888.45 °C, and 317 °C. The number of peaks with and without rare earth was the same. Both were three. Near 950.7°C, the peak is particularly large, it seems to be the superposition of two peaks. After the rare earth is added, the temperature range of the second peak and the third peak is shortened.

By comparing the heat flow curves of the two schemes, it is found that both schemes have a peak change at about 315 °C during the heating and cooling processes. According to the Cu-Pb binary phase diagram[20], it can be seen that the melting point of lead is 326 °C. Therefore, it can be judged that the peak change here should be caused by the endothermic melting of lead during the temperature increase process, and the peak change here should be the precipitation of the lead phase during the temperature decrease process. The only difference between the two phases of the lead phase is that at about 950 °C, a 0.2 wt.% increase in the rare earth lanthanum solution showed a significant peak change, indicating that after adding rare earth lanthanum, new phases were formed at about 950 °C. When adding rare earth, there is no change here, it can be inferred that this new correspondence should be related to the rare earth and should be a new phase rich in rare earth.

### 3.1.6. Macro Photo Analysis

After the sample was corroded by ferric chloride and hydrochloric acid solution (5g FeCl₃ + 10ml HCl + 100ml H₂O), the photo was taken as shown in figure 2.7 below, and the macrostructure of the sample was observed. Figure 8 shows the microstructure picture of lead-tin bronze without phosphorus and nickel added at 3 wt.%. After adding different rare earths, it can be seen from the figure that the macrostructure change trend basically corresponds to the microstructure. When the rare earth is not added, the grains are relatively coarse. After adding the rare earth, the grain size becomes fine and uniform. Adding the rare earth lanthanum can refine the grains, but adding too much will make the grains coarse. With the increase of lanthanum lanthanum, the structure grains tend to be refined, but after excessive addition, the structure grains tend to grow again. When the amount of rare earth added is 0.04 wt.% -0.07 wt.%, the grains are relatively fine and uniform. It can be concluded that the addition of rare earth has the effect of refining grains.

(a) Without P and La (b) Without P and La 0.04%

**Figure 8.** Macroscopic photo of ZCuPb20Sn5 alloy without phosphorous copper.
It can be seen that when no rare earth is added, the grains in the macrostructure of lead-tin bronze are relatively large, and the grains become finer after adding 0.04 wt.% rare earth lanthanum. Therefore, it can be seen that without being affected by phosphorus, macroscopically, it can be seen that the addition of rare earth lanthanum, the grains gradually become finer and smaller.

![Figure 9](image)

**Figure 9.** Macro photos of ZCuPb20Sn5 alloys with different rare earth contents.

Figure 9 shows the macrostructure of lanthanum lanthanum with different contents under the condition of 0.3 wt.% phosphorus. It can be seen from the above microstructure that the addition of rare earth significantly refines the morphology of lead particles. Large lead particles have no time to aggregate and grow up, and are evenly distributed among the dendrites. Large dots gradually change to small spherical shapes, while alloys with spherical structures have higher mechanical properties. The intragranular structure also tends to be refined, from chaotic to equiaxed crystals with uniform distribution. The role of rare earth elements is similar to that of expanding the mixed domains of silver and nickel, which shifts the segregation point to the right in the Cu-Pb alloy equilibrium diagram, thereby improving the segregation of lead. It can be seen from the macrostructure that with the addition of rare earth, the grains are significantly refined.

### 3.2. Mechanical performance analysis

Table 3 is the mechanical properties of ZCuPb20Sn5 alloy under different conditions. Figure 2.9 is a histogram of the effect of rare earth La on the mechanical properties of ZCuPb20Sn5 alloy. Figure (a) is a histogram of tensile strength and hardness with the addition of different rare earth La. Figure (b) is a histogram of elongation. It can be seen from the figure that when the added amount is 0.07 wt.%, the tissue is relatively fine and uniform, and the lead particles exist in small worm-like and strip-like forms, because there are no large lead particles, and the entire tissue is relatively small and uniform. (A + δ) tissues occupy a large area. Therefore, its tensile strength is relatively large, but it is still not higher than that when the rare earth addition amount is 0.04 wt.%. Because the shape of lead particles is strip-shaped, it does not have the performance of small spheres, and the performance of spherical particles is better than that of small strips. Although the microstructure of lead particles can be seen when the rare earth is added at 0.04 wt.% and 0.1 wt.%, it is better, but when 0.04 wt.% is added, the tensile strength is higher.
Table 3. Mechanical properties of ZCuPb20Sn5 alloy under different conditions.

| Factor | Ni (%) | P (%) | La (%) | Tensile strength | Elongation | Hardness |
|--------|--------|-------|--------|------------------|------------|----------|
|        |        |       |        | Rm/ MPa          | A/%        | HB       |
| 1      | 3      | 0     | 0      | 185.6            | 8.0        | 67.2     |
| 2      | 3      | 0     | 0.04   | 207.5            | 14.8       | 71.1     |
| 3      | 2      | 0.3   | 0      | 241.5            | 12.8       | 79.6     |
| 4      | 2      | 0.3   | 0.01   | 242.3            | 13.0       | 85.5     |
| 5      | 2      | 0.3   | 0.03   | 252.6            | 14.5       | 80.2     |
| 6      | 2      | 0.3   | 0.04   | 267.1            | 15.1       | 87.7     |
| 7      | 2      | 0.3   | 0.07   | 253.7            | 13.3       | 82.6     |
| 8      | 2      | 0.3   | 0.1    | 247.0            | 12.8       | 83.2     |
| 9      | 2      | 0.3   | 0.2    | 235.4            | 11.3       | 81.2     |

Without the addition of rare earth lanthanum, the tensile strength of lead-tin bronze can reach about 241.5 MPa. Adding different amounts of rare earth to the lead-tin bronze alloy can improve the tensile strength and elongation of the alloy. When 0.04 wt.% rare earth lanthanum is added, the strength and elongation are the best. After several experiments, the tensile strength is maintained at about 267.1, the elongation is maintained at about 15.13%, the tensile strength is increased by about 25.6MPa, and the hardness is maintained at about 80HB.

The addition of rare earth lanthanum causes some impurities in the form of strips, flakes or even large blocks in the alloy to become point or spherical, thereby improving the mechanical and processing properties of the alloy. Some harmful impurities in the alloy (such as S, P, Pb, etc.) are concentratedly distributed between dendrites or grain boundaries, and are changed to be more uniformly distributed throughout the crystal, so that the impurities are redistributed on the microscopic
volume of the metal, or affects the macro segregation of certain impurities, resulting in various performance improvements.

3.3. Discussion
The influence of different contents of rare earth on the structure and properties of lead-tin bronze is analyzed. On the one hand, the rare earth La can react with harmful impurities (O, S, Pb, Bi, etc.) in the alloy to generate high melting point rare earth compound particles. It is uniformly dispersed in the copper matrix, and becomes a crystal core, so that the alloy structure is refined. Especially in the ZCuPb20Sn5 alloy, the lead content is relatively high. After the rare earth is added, it reacts with lead quickly to form a high melting point compound, which is evenly dispersed on the copper matrix to form a crystal core. On the other hand, the generated high melting point rare earth compound aggregates At the grain boundaries, it is easy to fill in the surface defects of the new phase grains that are being generated, forming a film that prevents the grains from continuing to grow, directly inhibiting the growth of the grains, thereby refining the grains, and the refinement of the grains increases the strength of the alloy And hardness [21]. With the increase in addition amount of rare earth elements La, increasing the concentration of rare earth elements La, great influence on the solidification structure of the copper alloy. When the content of rare earth elements is low, the compounds formed are relatively small and dispersed, and they are distributed in the form of particles. Therefore, due to the purification effect of rare earths during the solidification of the alloy, the grain growth is dominant, and the inherently coarse columnar crystals appear. And the rare earth element is added in an amount of more than 0.04wt%, enough particles, the particle crystals formed as a core, to form fine columnar crystal. If excessive rare earth is added, a large amount of rare earth compounds are formed, the supercooling effect of the rare earth atomic components is reduced, the alloy structure is coarsened, and a large number of coarse columnar crystals are present.

Rare earth lanthanum in high-lead bronze alloys can effectively prevent the specific gravity and reverse segregation of lead in the alloy, and make the particles of lead fine and uniformly distributed, reducing or eliminating dendritic crystals and columnar crystals in pure copper. It is related to the formation of refractory compounds in certain impurities in a dispersed state, which transforms them into fine equiaxed microstructures, but excessive addition will cause loose defects in the ingot structure and reduce performance.

4. Conclusions
1) Without the effect of phosphorus and copper, the addition of rare earth lanthanum tends to refine the lead particles.
2) When the added amount is 0.04 wt.%, the organization is the best. When the added amount is increased, when it exceeds 0.1 wt.%, columnar crystals appear in the tissue.
3) From a macro perspective, the addition of rare earths has refined the grain size, but it cannot be added too much, and it is best to add the amount of 0.04 wt.%. 
4) The addition of rare earth lanthanum can improve the mechanical properties of lead-tin bronze alloys, but after adding more, its mechanical properties decrease again. The optimum amount is 0.04 wt.%, the tensile strength is increased from 241.5MPa to 267.1MPa, an increase of 10.6%, and the elongation is increased from the original 12.8% to 15.1%, an increase of 18%. However, there has also been an increase of about 5HB.

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