國立成功大學
材料科學及工程學系
專題論文

銅鋅鉛合金熱處理組織特性與電化學性質研究

A Study Of The Heat-treated Structural Characteristics & Electrochemical Properties Of Cu-Pb-Zn Alloy

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● ABSTRACT

In our everyday life, we've seen a variety of metals, one of which is brass. Brass is an alloy of copper and zinc. It has many mechanical uses, and is an efficient thermal and electrical conductor.It is often applied to construct rifle cartridge shells, car radiators, junctions, optical fibers, et cetera. In this experiment, we aim to test the characteristics of brass under different heat treatment conditions. Our purpose is to make brass transition from soft to tough, while maintaining efficient electric conductance. In addition, our purpose is to simplify the cutting and processing of brass, while avoiding unnecessary chips that would enhance its brittleness.

在我們的日常生活中，充滿了各種金屬。其中常見的一種金屬為黃銅，其為銅和鋅的合金，機械性質優異，且為熱電良導體，常應用於彈殼、汽車散熱器、接頭、光纖等等。本實驗將測其在不同的熱處理加工條件下表現出的特性，使其由柔軟轉為剛硬性質，且仍保持良好的電性，使之易切削加工，使製成不會捲屑，提高脆性效應。

● INTRODUCTION

Brass has superior machinability, thread rolling and characteristics. It is easily soldered or brazed and has good resistance to corrosion.

It is made up of around 60wt.% copper and 38wt.% zinc, and 2wt.% of lead to enhance the machinability of brass. The content of zinc serves to strengthen copper and enhance its toughness. The content of 2wt.% lead in brass tends to migrate towards the grain boundaries in the form of globules as it cools from casting since lead has a lower melting point than the other constituents of the brass.

In this experiment, we utilize 2 kinds of materials, F and H. Material F is an extruded copper rod, and material H is an extruded copper rod plus heat treatment under the condition of 500 Celsius degrees and 1 hour. The purposes of heat treatment are cold work, recovery, recrystallization and grain growth, and to get isometric crystals in the process, which would be better to shape in the manufacture industry, and enhance its cold working properties.

黃銅有極佳的機械性質，可以用來做螺紋滾製、壓花紋的特性。其容易焊接，且有良好的耐腐蝕性。

其通常由60 wt.%的銅、38 wt.%的鋅、以及2 wt.%的鉛所組成，進以提高黃銅的機械性質。鋅的添加可以強化銅並提高銅的剛性；而當其從鑄造中冷卻時，因為鉛的熔點比黃銅中其他成分低，故2 wt.%鉛常以小球體的形式往晶界處遷移。而在黃銅表面生成的這些小球體增加了鉛的表面積。

本次實驗使用F材和H材做測試，F材為擠型的銅棒，而H材為擠型加上熱處理在500度、一小時條件下的銅棒。經過熱處理的好處可以消除應力、均質化，然後經過塑形、回復、再結晶、成長的過程以產出等軸晶，使銅棒在工業製造上好加工成型，提高其冷加工性。

● EXPERIMENT & METHOD

1. Materials: In this experiment, we used an original material and an annealing material.
2. Sampling: First, take the material that is to be tested and use a cutting machine to cut it into a sample which is around the length of 8mm. And then grind it with different numbers of abrasives in the order of 400, 800, 1200, 2500, 4000 to make a plane surface with minimal damage that can easily be removed during polishing for the shortest possible time.
3. Hardness test: Use Rockwell hardness test to test the sample. And choose HRB loading (100kgf) and 1⁄16-inch-diameter steel sphere to test the polished sample. For each sample, test 3 times, and get the average number.
4. Corrosion: Take the polished sample and put it in the solution of a

2wt.% of Ferrous chloride ($FeCl_2$) with alcohol as the solvent to corrode. And observe the microstructure of the corroded sample.

5. Heat treatment: Put the sample in the oven, which has been under the temperature of 600 Celsius degrees, for 1 hour. After 1 hour, take out the sample from the oven, and we get material H600. For H700, put the sample in the oven, which has been under the temperature of 700 Celsius degrees, for 1 hour. After 1 hour, take out the sample from the oven, and we get material H700.
6. Electrical property: Take the samples that have not been corroded, and test F, H, H600, H700 each. Use the 4-point probe to test their conductivity 10 times each, and calculate the average values.
7. Corrosion resistance: Take the samples that have been corroded, and test F, H, H600, H700 each under the condition of sea water (3.5 wt%). Use the methods of potentialdynamic, one of the testing methods of electrochemical tests, and draw the polarization curves.

1. 使用材料：本實驗使用的是兩種黃銅的棒材，一種為原材，另一個為退火材。

2. 試片準備：首先，取出待測的銅棒，並用切割機切成約8mm的長度。接著用不同號數的砂紙研磨試片，從400號開始，接著800、1200、2500、4000號來達到平滑的平面，再拿去拋光機以拋出光滑面使之好在光學顯微鏡下觀察。

3. 硬度測試：使用洛式硬度來測量試片的硬度，使用HRB的負重（100kgf）和直徑1/16吋的鋼頭來打試片的硬度。每個試片分別打三次硬度，並取其平均值。

4. 腐蝕：取拋光過的試片浸入2 wt.%的氯化鐵腐蝕液（酒精為溶劑）來進行腐蝕，接著在光學顯微鏡下觀察腐蝕後的微組織。

5. 熱處理: 將試片放入高溫爐中進行熱處理，一個放進預先預熱好的600度的爐子，經過一小時後再取出，則得到H600的試片；另一個放入預先預熱好的700度的爐子，經過一小時後再取出，則得到H700的試片。

6. 電性測試: 取未腐蝕過的試片，分別測量F、H、兩種熱處理材

(H600、H700)，四種試片的電性，使用四點探針分別測量10次，並取平均值。
7. 耐蝕性測試: 取已腐蝕過後的試片，分別測量F、H、H600、H700四種試片在海水(3.5 wt.%)環境下的抗腐蝕性，並使用一種電化學測試法(electrochemical tests)中的動電位極化法(potentialdynamic)，並繪出四種材料的極化曲線。

● RESULTS AND DISCUSSION

1. Hardness test:

HRB	Test 1	Test 2	Test 3	Average
F	78	76	77	77
H	77	80	80	79
H600	50	49	51	50
H700	47	47	46	47

表一: 硬度量測

2. Eatch:

(1) Material F

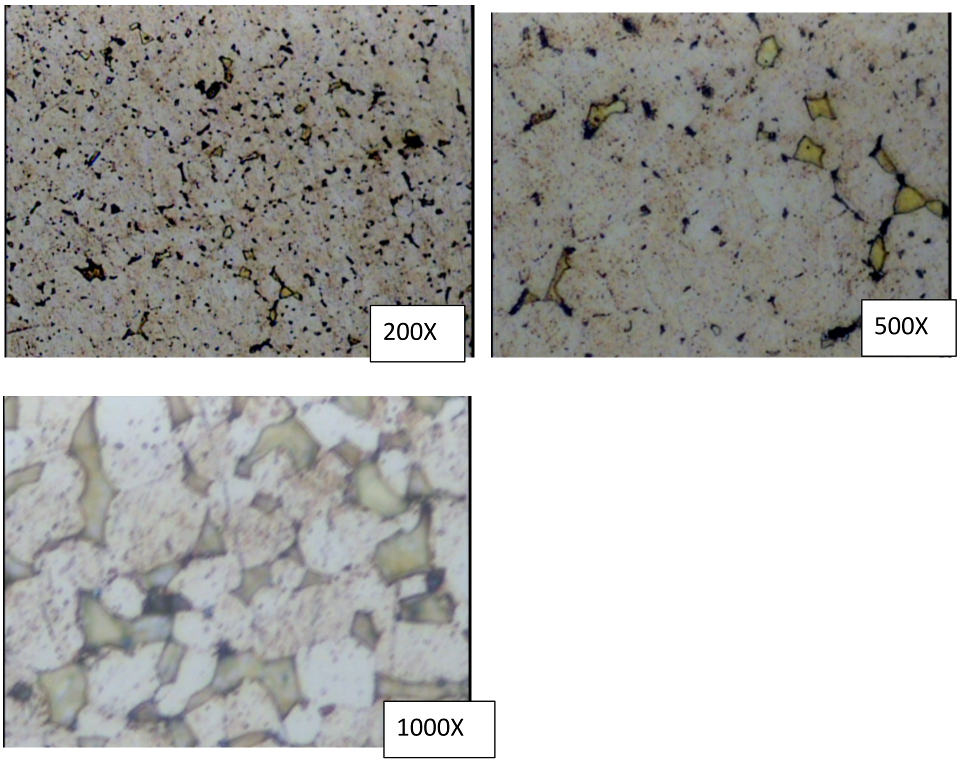

圖1: F材腐蝕後的顯微組織

(2) Material H:

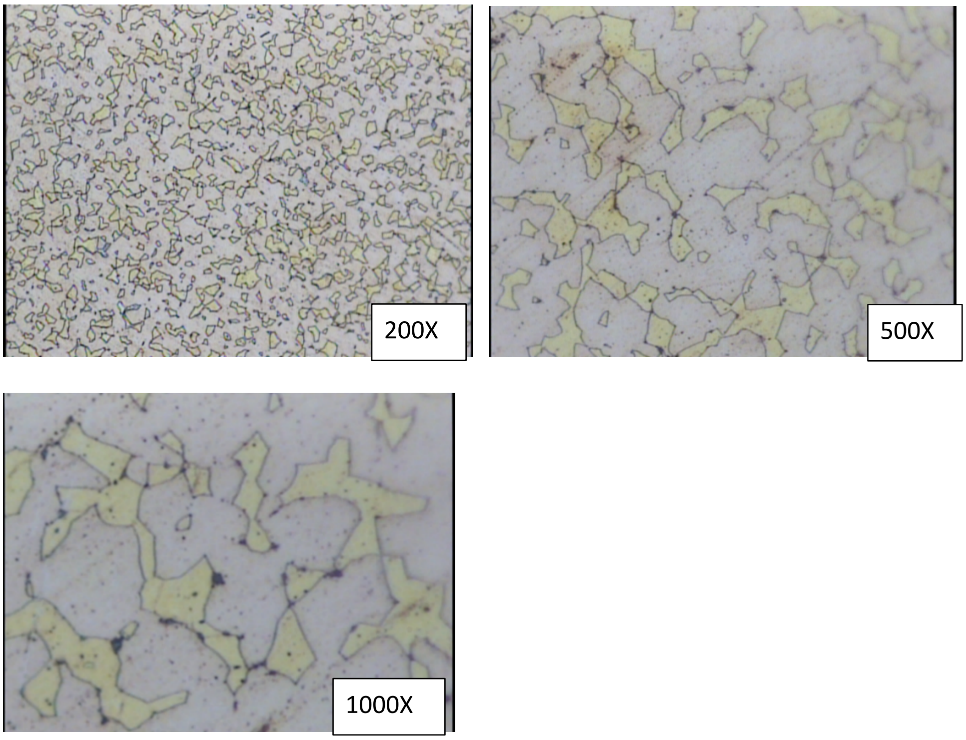

圖2: H材腐蝕後的顯微組織

(3) Material H600:

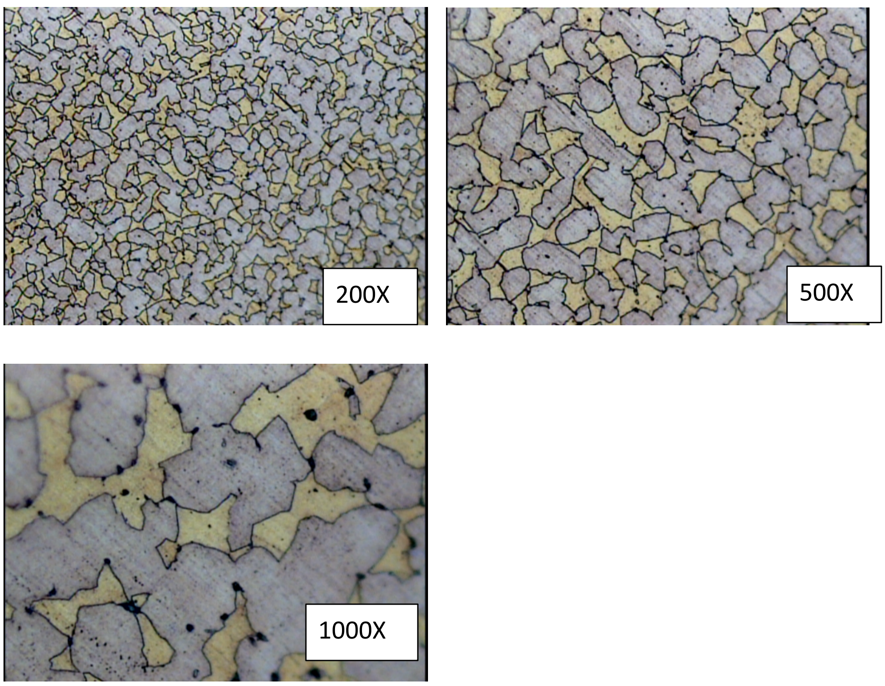

圖3: H600材腐蝕後的顯微組織

(4) Material H700:

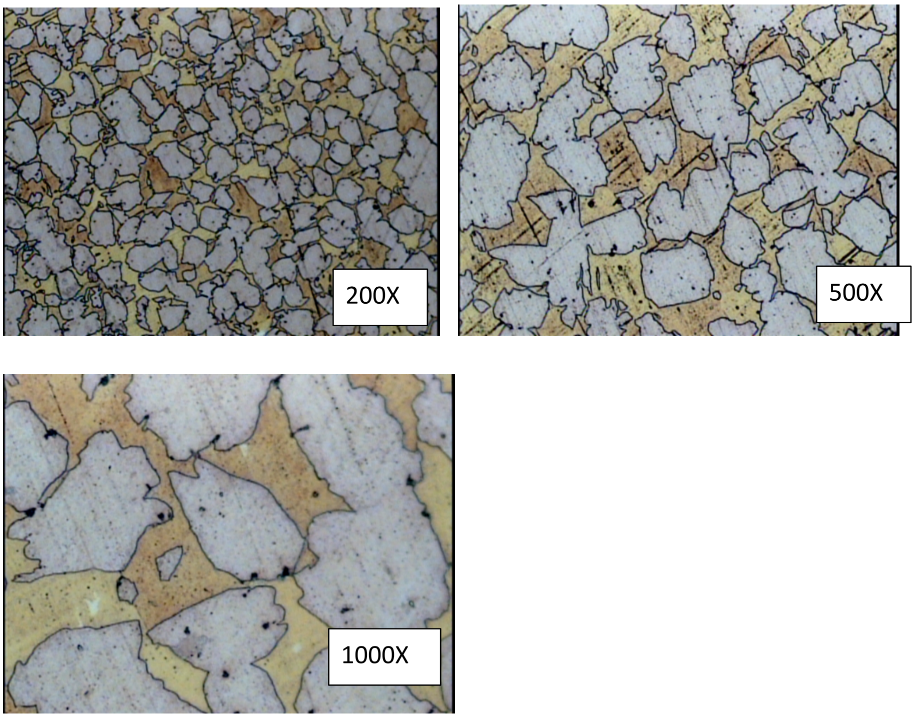

圖4: H700材腐蝕後的顯微組織

After corroded for a certain amount of time, under OM, we can see that the matrix is the mother phase, which is copper. And the big chunks of yellow are zinc, and the little black dots forming on the grain boundaries of zinc are lead. We can see that the zinc and lead part in material F are not consolidated compared to material H. Hence, we can predict that the heat treatment makes material H more homogenized than material F.

經過腐蝕一段時間後，在光學顯微鏡之下，可以看見母相為銅，大塊黃色的區塊為鋅，而在鋅的晶界析出的黑色小點為鉛。圖1中的鋅與鉛析出區塊的分布較鬆散、無規律，而圖2的分布明顯均勻許多，可以推測從F材轉變為H材經過的熱處理使此合金均質化的現象。而從圖1、圖2、圖3、到圖4的轉變，可以發現其晶粒（鋅）愈來愈大，且預均勻分布在母相（銅）中。

3. Electrical property

F	6.8×10^4 (S/cm)
H	8.8×10^4 (S/cm)
H600	7.6×10^4 (S/cm)

H700	$1.0x10^5$ (S/cm)

表二：電性量測--導電率

We use 4-point probe to test the conductivity of the samples that have not been under corrosion. Based on the chart above, as the temperature of the heat treatment goes higher, conductivity of the alloys are better. However, since the conductivity of Cu-Pb-Zn alloy is too excellent, the results shown using the 4-point probe fluctuate too much, hence lower the preciseness of the statistics. The statistics are for reference only.

用四點探針偵測未經腐蝕過的試片的導電性，如表二來看，熱處理的溫度愈高，導電率愈大。但是因為此銅鋅鉛合金材料的導電性太強，所以用四點探針測時，數值跳躍太快，可能會有偵測上的誤差，所以此數據為參考用。

4. Corrosion resistance

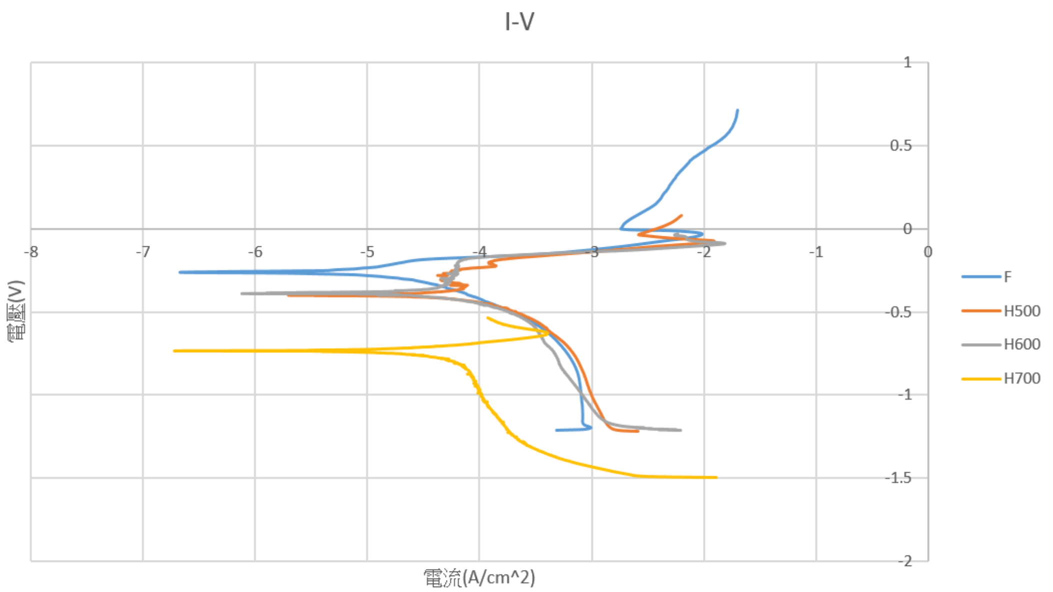

圖5: 耐腐蝕性量測--極化曲線

We use the corroded samples to test the corrosion resistance under the condition of sea water (3.5 wt%). Based on the picture above, as the temperature of heat treatment goes higher, corrosion potential gets lower, which means worse corrosion resistance; in terms of corrosion current, as the temperature of heat treatment goes higher, corrosion current gets higher, which means the corrosion rate is faster.

取已腐蝕的試片測耐腐蝕性，如圖5的極化曲線來看，熱處理的溫度愈高，腐蝕電位有愈來愈低的趨勢，表示材料愈不耐腐蝕；而從腐蝕電流來看，熱處理的溫度愈高，腐蝕電流愈高，表示腐蝕速度愈快。

● CONCLUSION & REVIEW

From the independent study that I have conducted for half a year, I have organized these conclusions regarding the heat-treated structural characteristics and electrochemical properties of Cu-Pb-Zn alloy:

1. From the structural characteristics under OM, it can be concluded that as the heat-treated temperature gets higher, the second phase, Zn, will grow from the matrix, Cu, and become larger. Heat treatment also has the ability to eliminate residual stress in the materials, thus making them more homogenized, while creating near perfect isometric crystals.
2. From the hardness test, it can be concluded that as the heat-treated temperature gets higher, the materials gets softer. With the results of the structural characteristics under OM, we can speculate that the growth of Zn is the reason why the materials gets softer. As they get softer, it will be more suitable for cutting, while avoiding unnecessary chips.
3. From electrical properties and corrosion resistance, it can be concluded that as the heat-treated temperature gets higher, the conductivity of the materials gets better, while corrosion resistance gets worse. With the results of the structural characteristics under OM, we are able to speculate that it is the growth of Zn that makes the resistance worse since Zn is more prone to corrosion than Cu, and that the growth of Zn leads to a higher percentage of Zn.

Suggestions:

Under the guidance of my teacher and senior, I have gained a lot of insights:

I still remember vividly that I walked into the lab the first time, I was still a novice at everything. It's the first time that I tried to complete an experiment alone, and could not even name most of the equipment in the lab. Gradually, I started to get familiar with the lab. I started to know how to conduct each step. I would like to thank my senior, Lin Yi Fan, for his help. I have many steps that I don't understand, whether it is the methods for equipment or understandings of theories, he is always willing to teach me. Every step of the experiment is an opportunity for me to learn. Besides the statistics of each data, there is also a link between the data and why it should be conducted this way. I found that I have grown from an ignorant student to an individual that is able to deal with a problem independently. This is the largest goal I have achieved in the past six months.

Of course, there are some aspects that needs improvement. Because of my other courses, I find it difficult for me to put too much time on the experiment. It is a pity because I may lose the opportunity to learn more experimental skills, for example, XRD measurement, tensile test, etc., and there is no way to get a perfect experiment. But I through the past six months of learning, I have an in-depth understanding of Cu-Zn-Pb alloy from the existing data, and I believe that this is an important condition to be a material student. And I also hope to present a essay with sufficient content and value for your reference.

從本次的專題實驗來討論銅鋅鉛合金的熱處理組織特性與電化學性質研究來看，可得到結論如下:

1. 從OM的顯微組織觀察，可以發現熱處理的溫度愈高，第二相晶粒「鋅」會從母相「銅」中成長，而愈來愈大；而熱處理

可以消除殘餘應力，使晶粒愈來愈均勻分布，進而產生趨近完美的等軸晶。

2. 從硬度觀察結果來看，可以發現熱處理的溫度愈高，硬度逐漸下降，並配合組織觀察結果來看，可推測鋅晶粒的成長使得材料愈軟，愈適合切削而較不會產生捲屑。
3. 從電性與抗腐蝕能力來看，可以發現熱處理的溫度愈高，材料的導電率愈佳，而耐腐蝕性愈差。配合組織觀察結果，可以推測因鋅比銅容易被腐蝕，而鋅晶粒的成長使鋅的比例愈來愈高，造成耐腐蝕性的下降。

建議:

從這半年來的專題實驗，老師的教導與學長的帶領下，我得到了許多收穫以及心得：

從第一天踏入實驗室，我還是一位大三新手，初次嘗試自己一人獨力完成一個實驗，甚至連很多實驗器材都無法叫出名稱。慢慢地，我開始熟悉這間實驗室，我開始知道每個步驟該如何進行，這邊我要感謝林益帆學長的幫忙，我有很多不懂的地方，不論是器材使用或是理論上的理解，學長都願意教我。而每個階段實驗的進行，都是我學習的機會，除了各個數據的量測外，還有數據之間的連結跟為什麼要如此操作，我發現我從一個懵懵懂懂的學生，到有辦法獨立處理一個問題，這是我這半年來得到最大的收穫。

當然，也有一些需要改進的地方，因為還有其他課程的關係，沒辦法投注太多的時間在專題上面，是我覺得可惜的一件事，因為我可能失去學到更多實驗技巧的機會，例如：XRD測量、拉伸測試等等，沒辦法得到一個非常完善的實驗，但是我從現有手中的數據，我對銅鋅鉛合金材料有個深入的了解，這是身為一個材料人所需要的條件，也希望可以呈現一個內容充足、有參考價值的論文，以供大家參照。

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