

## INTRODUCTION TO MIXED METAL CLAY



Hadar Jacobson

This presentation is an introduction to firing mixed metal clay. It provides an insight into the sintering process as well as the different sintering temperatures of different metals. It explains how to fire a mixed metal piece in light of these different temperatures. Additionally, it shows what can happen when clays are fired at temperatures that are too high or too low, and gives some suggestions on how these effects can be avoided or remedied.

## The Sintering Process



Sintering occurs when a powdered material coalesces into a solid, porous mass through heating, without liquefying (melting).

These ice balls represent particles of metal powder.

As the temperature rises they stick together and can be held in the air without falling apart.

If the temperature rises to the melting point of ice, the ice balls will become water.

As an illustration, a solid, porous mass made up of ice balls is used to symbolize the state of metal particles in the sintering process.

## The Sintering Process



“The Sintering Bracelet” – each tile represents a stage in the sintering process.

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Here is a bracelet I created. I call it “The Sintering Bracelet” – not only because it has undergone sintering, but also because it graphically depicts the sintering process.

# The Sintering Process



1

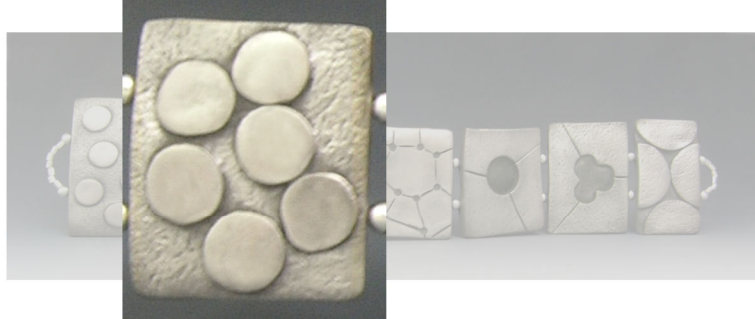
Loose particles of metal in the container. Spaces between them are filled with binder and air.

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In the first tile from the left, the circles represent the particles of the metal powder clay in the package. The spaces between them are filled with binder and air.

## The Sintering Process



2

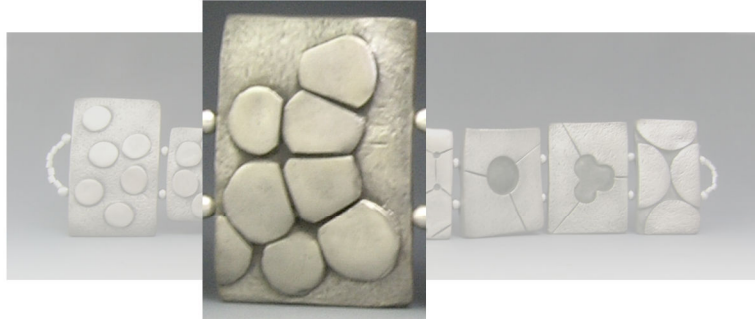
Binder has burned. Particles increase in density, becoming closer together.

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In the second tile from the left, the binder has burned. The particles increase in density, getting closer to each other.

## The Sintering Process



3

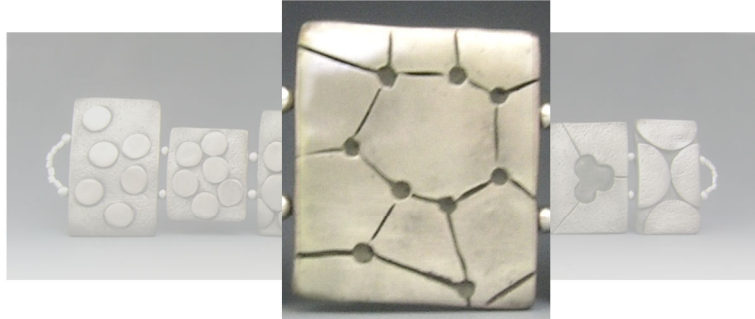
Particles densify, lose their spherical shape, and partially fuse into one another.

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In the third tile from the left, the particles lose their spherical shape and partially fuse into each other.

## The Sintering Process



4

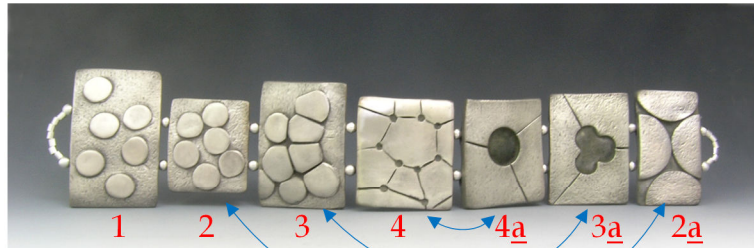
Particles are as close together as possible (maximum shrinkage) without reaching melting point; there are spherical pores between them.

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In the fourth tile (the middle one), the metal is fully sintered. The particles are as close as they can be to each other without reaching the melting point of the metal, and there are spherical pores between them.

# The Sintering Process



The last three tiles are enlargements of tiles 2, 3, and 4. They show how the shape of the pores changes as the temperature rises.

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The rest of the tiles show how the spaces between the particles change their shape. Starting from the right side of the bracelet:

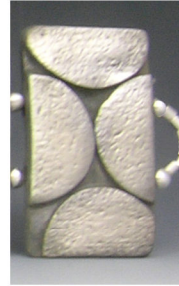
- The first tile from the right shows the shape of one pore between four spherical particles that hardly touch each other.
- The second tile from the right shows the shape of the pore after the particles have fused a little.
- The third tile from the right shows the spherical shape of the pore when the metal is fully sintered, as in the center tile.



## The Sintering Process



2



2a

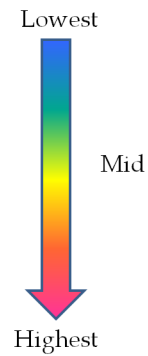
The mass of ice seems to represent tiles 2 and 2a of The Sintering Bracelet.

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The solid, porous mass of ice represents tiles 2 and 2a of the bracelet. In tile 2, the binder has burned. The particles increase in density, getting closer to each other. In the “close-up” version in 2a, we see the shape of one pore between four spherical particles that hardly touch each other.

## Different Metals Sinter at Different Temperatures



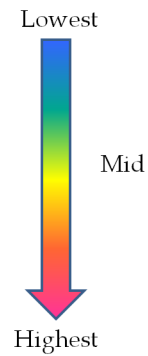
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When working with mixed metals, it is important to remember that each metal has its own sintering temperature.

## Different Metals Sinter at Different Temperatures

- White Bronze



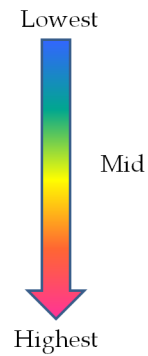
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White Bronze sinters at a lower temperature than other metals.

## Different Metals Sinter at Different Temperatures

- White Bronze
- Bronze



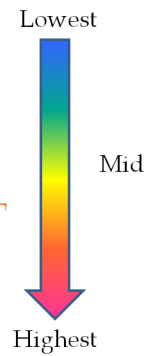
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Bronze sinters at a higher temperature than White Bronze.

## Different Metals Sinter at Different Temperatures

- White Bronze
- Bronze
- Copper, Rose Bronze, Steels, and Bronze XT



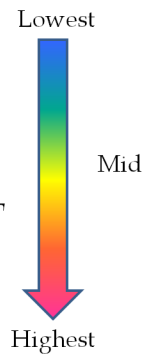
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The sintering temperature of copper, Rose Bronze, and steels is even higher.

## Different Metals Sinter at Different Temperatures

- White Bronze
- Bronze
- Copper, Rose Bronze, Steels, and Bronze XT



As we see, each metal has its own optimal firing temperature. But...

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Each metal has its own optimal firing temperature. But when working with a mixed metal piece, this raises a crucial question:

If each clay has its own  
optimal firing  
temperature, how do  
we fire a **mixed  
metal piece?**

The firing temperature  
of mixed metals  
is determined by the  
**lowest-firing** clay  
in the mix.

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Here is the answer: When firing a mixed metal piece, the optimal firing temperature is determined by the **lowest-firing** clay in the mix. The next slide illustrates this point for specific types of metal combinations.



## Firing Temperature – Mixed Metals

Determined by the **lowest-firing** clay in the mix

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The following list illustrates this point for various metal combinations.

## Firing Temperature – Mixed Metals

Determined by the **lowest-firing** clay in the mix

- Any mix that contains **White Bronze** must be fired at the **lowest** firing temperature
- Any mix that contains **Bronze** (but no White Bronze) must be fired at **mid** firing temperature
- **Copper, Rose Bronze, Steel, and Bronze XT** can be fired at the **highest** firing temperature

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The specific temperatures and schedules can be found in the **Instruction Manual for Hadar's Clay™**, which can be downloaded from my blog ([hadarjacobson.com/blog](http://hadarjacobson.com/blog)).

What happens to lower-firing clays  
when fired at higher temperature?

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It's critical to fire a mixed metal piece at its optimal temperature – not too high and not too low – to avoid undesirable results.

The next few slides show possible results that can occur when lower-firing clays are fired at higher temperatures. Later on we'll look at the opposite type of scenario – higher-firing clays are fired at lower temperatures.

After that, we'll see how these results can be avoided or remedied.

## What happens to lower-firing clays when fired at higher temperature?

**Example #1.** Firing a mix containing White Bronze above lowest firing temperature will cause the White Bronze to melt.

- These mixed pieces containing White Bronze were fired above optimal temp for WB.
- White Bronze melted, leaving empty spaces; smeared over the other metals, disguising their original color.



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Here is the first example of what can happen when lower-firing clays are fired at a higher temperature.

When firing a piece containing White Bronze, firing above the lowest firing temperature will cause the White Bronze to melt. The pieces in the picture are made of mixed metals and were fired too high. The White Bronze melted, which left empty spaces on the piece. The molten White Bronze smeared over the other metals, making it impossible to see their original color.

## What happens to lower-firing clays when fired at higher temperature?

**Example #2.** Firing a mix containing Bronze (but no WB) above mid firing temp will cause the Bronze to swell and/or alloy with copper.

- These mixed pieces containing Bronze were fired above optimal temp for Bronze.
- Piece on left curved; bronze smeared over copper, obscuring it.
- Pieces on right show swelling of bronze, some alloying.



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Here is the second example of what can happen when lower-firing clays are fired at a higher temperature.

When firing a piece containing Bronze (but no White Bronze), firing above mid firing temperature will cause the Bronze to swell and alloy with copper. The pieces of copper and bronze in these pictures were fired too high. The piece on the left became curved, and the bronze smeared over the copper. In the picture on the right, we can see some swelling in the bronze, as well as some alloying.

What happens to lower-firing clays when fired at proper temperature?



This is what a mix of copper and bronze looks like when it has been correctly fired at mid firing temperature.

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In contrast with the undesirable results shown in the previous slides, here is what a mix of copper and bronze looks like when it has been correctly fired at mid firing temperature. The metals are sintered and the contrast between them is sharp and clear. No melting, no smearing, no swelling, no curving.

What happens to higher-firing clays  
when fired at lower temperature?

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In the previous slides, we saw what can happen when lower-firing clays are fired at higher temperatures. Now let's look at the opposite type of scenario – what can occur when higher-firing clays are fired at lower temperatures.

What happens to higher-firing clays when fired at lower temperature?

**Result #1.** They may not sinter at all.



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The first possible result is that the pieces may not sinter at all. There's nothing that can be done to remedy this, but don't cry: there are steps you can take to avoid this tragic result, as we'll see later.



What happens to higher-firing clays when fired at lower temperature?

**Result #2.** They may not fully sinter.



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The second possible result when higher-firing clays are fired too low is that they may sinter, but only partially.

## What happens to higher-firing clays when fired at lower temperature?

**Result #3.** They may sinter but not reach their full density.



Copper did not shrink as much as bronze. As a result, the bronze pulled away.

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A third possibility is that they may sinter, but without reaching their full density. In other words, they do not shrink as much as they could.

What happens to higher-firing clays when fired at lower temperature?

**Result #4.** They may sinter fully.



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And the fourth possibility is that the pieces will sinter properly.

What happens to higher-firing clays when fired at lower temperature?

**Result #4.** They may sinter fully.



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Here are some more pieces in which high-firing clays were fired at mid temp, but the pieces sintered fully.

What is the remedy when higher-firing clays fired at lower temperature do not sinter properly, or at all?

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The following slides will show us how we can remedy these results, or at least try to avoid them.

## Higher-firing clays fired at lower temperature: Remedies

**Result #1.** They did not sinter at all.



- Most likely to occur when **large amounts** or **big chunks** of higher-firing clay are combined with lower-firing clays.
- Unfortunately, no remedy once it happens, but it can be avoided:
- To avoid this result, fire the high-firing clay first, then add low-firing clay and re-fire.
- The following slides show some examples.

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The first unfortunate result of firing high-firing clays at too low a temperature, was that they did not sinter at all and crumbled to pieces. This is most likely to happen when large amounts or big chunks of higher-firing clay are combined with lower-firing clays.

Unfortunately, there's nothing that can be done once this has happened. The good news is that there are things we can do to keep this from happening in the first place. Fire the high-firing clay first at its optimal firing temperature, then add the low-firing clay and re-fire at the lower temperature.

The following slides show some examples.

## Higher-firing clays fired at lower temperature: Remedies

Example A: Steel and White Bronze



1. Steel fired first at highest firing temperature



2. White Bronze added and re-fired at lowest firing temperature

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In this example, the steel was fired first at the highest firing temperature, and sintered properly. Then, White Bronze was added and re-fired at the lowest firing temperature.

## Higher-firing clays fired at lower temperature: Remedies

**Example B: Steel and Bronze**



1. Steel fired first at highest firing temperature



2. Bronze added and re-fired at mid firing temperature



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In this second example, the steel was fired first at the highest firing temperature, and sintered properly. Then, bronze was added and re-fired at the mid firing temperature.



## Higher-firing clays fired at lower temperature: Remedies

### Example C: Steel and Mixed Metal



1. Steel fired first at highest firing temperature



2. Mix of copper, bronze, and steel added and re-fired at mid firing temperature

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In this example, the steel was fired first at the highest firing temperature, and sintered properly. Then, a mix of copper, bronze, and steel was added and re-fired at the mid firing temperature.

## Higher-firing clays fired at lower temperature: Remedies

### Example C: Steel and Mixed Metal

#### Question:

The spinner contains steel, which was fired lower than its optimal temperature. Why did it work?



Take a guess! The answer is in the next slide.

## Higher-firing clays fired at lower temperature: Remedies

### Example C: Steel and Mixed Metal

#### Question:

The spinner contains steel, which was fired lower than its optimal temperature. Why did it work?



#### Answer:

Only a very small amount of steel was used.

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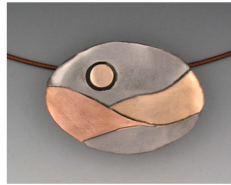
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If the spinner had contained a larger amount of steel, it might not have sintered properly.

## But then what about these pieces?

**Question:**

These pieces contain a considerable amount of steel but were fired only once. How is this possible?



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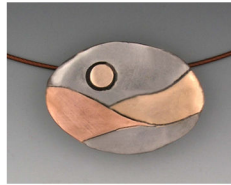
But wait: Look at these pieces.

They contain a considerable amount of steel, but they were fired only once. How is this possible?

## But then what about these pieces?

**Question:**

These pieces contain a considerable amount of steel but were fired only once. How is this possible?



**Answer:**

These are not high-firing clays fired at a lower temp. This new bronze type, Bronze XT, can be fired at highest temp.



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The answer is that this is not a case of high-firing clays being fired at a lower temperature.

The bronze you see in these pieces is a new type of bronze, called Bronze XT, which can be fired at the highest temperature.

## Higher-firing clays fired at lower temperature: Remedies

Example D: Copper/Bronze and White Bronze



1. First firing at mid temperature



2. Second firing at lowest temperature

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Here is another example. The copper and bronze were fired first at mid firing temperature, and sintered properly. Then, White Bronze was added and re-fired at the lowest firing temperature.

## Higher-firing clays fired at lower temperature: Remedies

### Example E: Copper/Bronze and White Bronze



Commercial ring (cast)



One firing at lowest temperature.  
Copper sintered because it was used  
in small amounts.

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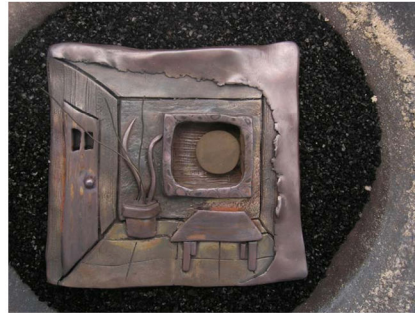
In this case, which uses a commercial ring case, the piece was fired once at the lowest temperature. As in the earlier example we saw, with the steel in the spinner, the copper in this example fired successfully because it was used in small amounts.

## Higher-firing clays fired at lower temperature: Remedies

### Example F: Mixed Metal and White Bronze



1. First firing at mid temperature.  
Copper did not reach full shrinkage  
but is still strong enough.



2. Piece fired; white bronze added

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In this last example, the first firing was done at mid temperature. The copper did not reach its maximum density, but was still strong enough because of the bronze content. White Bronze was added, and as you will see in the next slide, the piece was re-fired at the lowest firing temperature.



## Higher-firing clays fired at lower temperature: Remedies



3. Piece re-fired at lowest firing temperature

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Here you see the piece after being re-fired at the lowest firing temperature.

## **Higher-firing clays fired at lower temperature: Remedies**

**Result #2.** Partial sintering.

When can you fire high-firing and low-firing clays together in a single firing?

- Small quantities of high-firing clays
- No big chunk of high-firing clays

## Higher-firing clays fired at lower temperature: Remedies

White Bronze and copper: It may work the first time.



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Here are some examples of White Bronze and copper that were fired together at the firing temperature of White Bronze. The copper still sintered properly, even though the firing temperature was low.

## **Higher-firing clays fired at lower temperature: Remedies**

Or: The high-firing clay may not sinter all the way.



These earrings with a thin copper back were fired with White Bronze at lowest temperature. The copper part did not fully sinter.

**How do we fix this?**

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But in other cases, the high-firing clay may not sinter all the way, as we see here. The copper part did not fully sinter. What can we do to fix this?

## Higher-firing clays fired at lower temperature: Remedies

**Re-firing** usually solves the problem.



When re-firing,  
in most cases:

- No repair required
- No pre-firing required

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Usually, we can remedy this situation simply by re-firing. When re-firing, there is usually no need for any repair or pre-firing.

## Higher-firing clays fired at lower temperature: Remedies

**Result #3.** Sintering, but not to full density (maximum shrinkage).

The high-firing clays may sinter, but will not shrink enough. As a result, the metals will separate and show cracks. These can be filled and re-fired.



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On the left is the third possible unsatisfactory result of firing higher-firing clays at lower temperatures: they may sinter, but not to full density. In other words, they do not reach their maximum shrinkage. This can cause the metals to separate and crack. In these cases, the cracks can be filled and the pieces can be re-fired.

## Higher-firing clays fired at lower temperature: Remedies



Or: A surface that was perfectly flush before firing will be bumpy after firing, due to the different shrinkage rates of the clays.



If this happens, sand the surface flush using a coarse sanding band.

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Another possibility when the higher-firing clay does not reach full shrinkage, is that a surface that was flush before firing will become bumpy after firing, due to the different shrinkage rates of the clays.

If this happens, you can sand the piece flush again using a coarse sanding band.

## QUESTIONS AND DISCUSSION

