Demystifying The Metal Clay Firing Process.

What is Sintering?

A Google search reveals the following "Sintering is also called 'frittage,'
It is the process of forming a solid mass of material through heat and pressure without melting to the point of liquefaction. This process involves the atoms in materials diffusing across the particle boundaries and fusing together into one piece."

In the metal clay context, sintering is the bonding or fusing of loose metal particles, a process which occurs below their known melting point. The term sintering also applies to ceramics. A helpful ice cube metaphor (with thanks and courtesy of metal clay aficionado, pioneer and guru, Hadar Jacobsen) in understanding the sintering process. Ice melts at 0°C. The temperature in a freezer is well below 0°C. If the freezer temperature was raised (without reaching the ice melting point) the ice cubes would begin sticking together until a point where they could be picked up as a solid unit. Much like sintering with metal clay particles, melting ice cubes don't touch each other at every point of their surface. There are spaces in between and the whole mass is porous. If metal clay is fired above its melting point, it becomes liquid, flows into and fills the spaces.

The metal clay sintering process consists of 2 main phases:
1) Removal of the binder
2) Compaction of the particles.

Removal of the Binder
The purpose of the binder in metal clay is to give the metal powder the malleability and consistency of clay, so it can be shaped or pressed it into moulds. For the clay to metamorphosize into pure metal, all of the binder needs to be removed before the sintering process can begin. If any binder remains, whatever is left will prevents the metal particles from sticking/adhering to each other successfully and full sintering and strength will not be achievable.

Compaction of the particles. After the binder is removed, the metal particles will begin to bond closer and closer together. As the temperature rises, the contact areas increase and the metal particles compact. If the particles don't reach melting point and turn into liquid, they cannot flow and entirely fill the spaces between them.

What is a successful firing? The precious metal clays such as pure silver and gold are fired exposed to air. They don't react with the oxygen in the air, and the surrounding oxygen ensures the complete removal and burnout of any binder. Firing .999 fine silver clay is simple and straight forward in comparison to the base metal clays which is why we recommend starting out with fine silver metal clay.

Base metal clays such as copper and bronze behave very differently to fine silver metal clay. When they are fired exposed to air, they react with the oxygen and create oxides. Oxides are a third material which, much like the residue of the binder, prevent base metal clay particles from bonding. Pure copper can be fired exposed to air for a very short time before it oxidizes internally. Longer or repeated exposure to heat and air will enhance the oxidation and eventually the copper will weaken and disintegrate. Bronze, White Bronze, Sunny Bronze and others as well and the Metal Clay steels cannot be successfully fired exposed to air. If they are, a large chunk of them will come off, taking with it any texture or detail. This is why base metals are fired buried in activated carbon, namely coconut shell based Activated Carbon. Activated Carbon reduces the amount of oxygen in the kiln and inhibits this oxidisation reaction. Gold granulation is also done in much the same way because it involves the use of copper. The activated carbon creates what is known as a "reducing atmosphere" by burning and while burning, it consumes the oxygen present within the kiln chamber. However, there is a complication. Most organic binders used in metal clays need some oxygen in order to burn off completely. If there is not enough oxygen (because it has been reduced by the activated carbon) the binders in the various clays, will not burn off completely. If the binder is not completely removed, there can be no proper sintering. In a perverse way, activated carbon is both a blessing and a curse. It is critical and enables sintering and but it also interferes with removal of the binder.

The solution: If we can burn off the binder before the carbon catches fire, we increase our chances of successful sintering. Using the most popular jewellery kilns, it is expected that binder burns at around 538°C in a brick kiln or 593°C in a muffle kiln. At this temperature the carbon does not burn. Some brands of clay have more binder in them than others and may need to stay at this temperature longer in order for the binder to burn off completely. No matter which brand of clay is being used, it is always a good idea to hold at this burn off temperature between 30 minutes and 2:00 hours before going on to the recommended goal temperature. Larger, thicker pieces have a lot more binder to burn off than thinner, smaller pieces so holding this temperature will always be beneficial because holding at this temperature will not affect any thin or small pieces present in the batch. After completing this important step, the firing should then be stopped. Allow pieces to cool to room temperature and then ramp to the recommended sintering temperature. It's important to check that the carbon is not on fire during the first phase by opening the kiln at the end of the cycle. If the carbon is on fire, lower the temperature the next firing.

Combining Clays. If fired over 800°C (brick kiln) or 843°C (muffle kiln) when combining and firing higher firing and lower firing clays together will result in the bronze blistering or warping.

White Bronze will swell, warp or melt at above 677°C (brick kiln) or 718°C (muffle kiln). Copper clay reaches full density at much higher temperatures. However, when combined with other clays in small amounts all of these clays can sinter at the lower temperatures but they won't reach their maximum density and strength. Although they are only partly sintered, the Bronze and White Bronze still give strength to the fired piece. If larger amounts of copper clay are combined with low-fire clays, the copper should be fired first. The other clays can then be added to the fired copper and the piece fired again at the lower clay temperatures.