APS 110 Chemistry report

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"Brass Instruments: why are we made of Brass?"
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Materials play a huge role in constructing musical instruments. Without the proper selection of materials, an instrument would be unable to function or perform poorly in terms of its sound-producing capabilities and reliability in long term usage. In brass instruments especially, the material used must retain a lot of special properties in order for them to be properly built. As shown in figure 1 below, brass instruments come in many forms, and they tend to have intricate, complicated, and unique shapes. To achieve these precise shapes, malleable and very machinable material is needed. It should, perhaps, also be durable enough to withstand the tear and wear that musicians could inflict on their instruments [1]. As many could probably guess by now, the perfect material to construct brass instruments is, indeed, the metal alloy that is composed of copper and zinc named Brass. In this chemistry report, many of brasses' wonderful properties that make them the perfect material for building instruments will be addressed and explained.

Figure 1. A picture of a standard student Tuba [2]. Looking at different parts of this Tuba really gives people a sense of how intricate brass instruments could look.

Brass, being the wonderful metal alloy that it is, is widely used for decorative, mechanical, electrical, and architectural purposes [3]. Some brass made objects include household decorative such as antique candle holders, sculptures, trophies, and plaques [3]. It is also commonly found in sockets and switches of home electrical systems [3]. It is widely used in many things due to its malleability, machinability, durability, electrical and thermal properties, and resistance to corrosion. It is also an incredibly flexible material. The "flexible" here points to the fact that its properties could be changed by the varying ratios of Zinc and Copper used to make the alloy [3]. This grants it an amazing characteristic to be combined and customized for different usages [4]. Those properties are, again, why brass is also applied to the manufacturing of brass instruments.

For Brass instrument construction, the Brasses' malleability is hugely relevant if intricate and complicated shapes need to be achieved. The alloy's malleability is a property granted by how its atoms are bonded together. Since Brass is a metallic substance composed of Zinc and Copper atoms, its "bulk of metal atoms [5]" are grouped together through metallic bonding. Very different from non-metals and how each atom is strictly bonded to another through covalent bonding, the metal atoms in metallic substances are held together by a "sea of electrons [6]." This is also why metals are malleable, whereas ionic compounds are brittle [5]. This "sea of electrons" refers to the loosely held valence electrons that are allowed to move freely while the nuclei are held in their lattice positions [6]. Metals having very high boiling and melting points also suggest that metallic bonding is quite strong [5]. In figure 2 below, the blue-coloured regions represent the delocalized, free-moving electrons, while the "positive red spheres" are the ion cores (each as a unit contains the nucleus and core electrons together). This microscopic level structure explains many of Brasses' and metals' properties including malleability. Looking at the

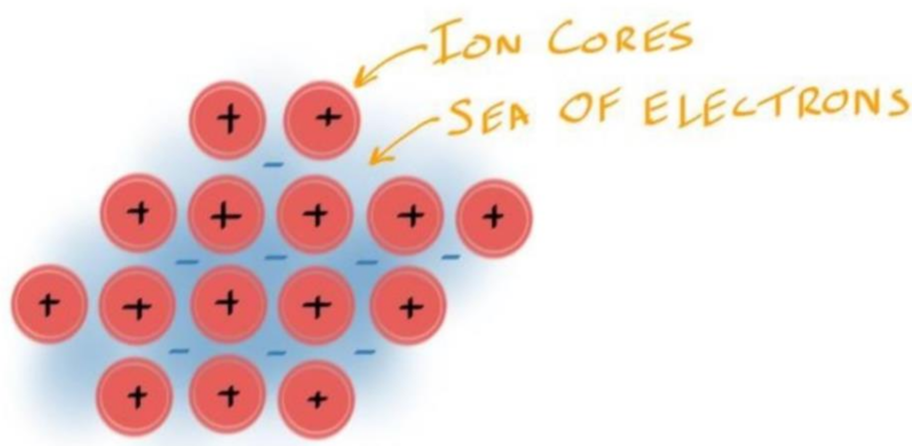

Figure 2." A cartoon depiction of a slice through a metal showing the sea-of-electrons bonding together the ion cores in a lattice [6]."

diagram below in figure 3, many can infer exactly how a metal's malleability is achieved. In this diagram, the atoms are grouped into planes to help think of the mechanism of movement when forces are applied. In reality, these forces could be produced by methods such as hammering. When sufficient forces (during deformation) are provided, the plane of atoms would slide past one another because they are always held together by the sea of electrons [6]. It would also help to think of the electrons surrounding the ion cores as a cushion for when the metallic substance is being deformed through various means [5]. This would mean that even when a piece brass is plastically deformed and its protons are rearranged into new equilibrium positions, the whole piece remains intact.

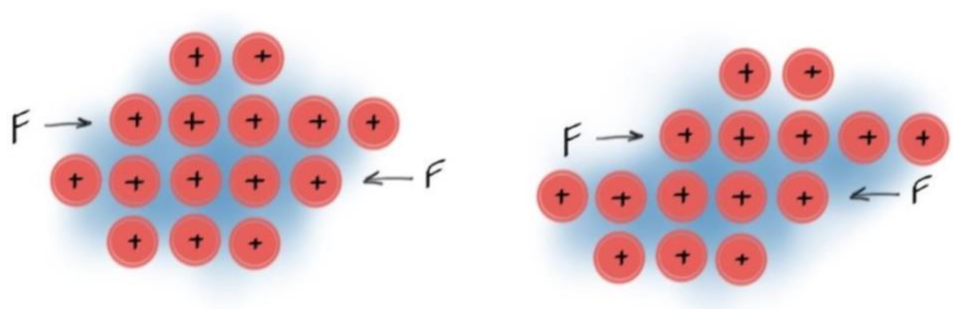

Figure 3. This cartoon depiction shows the forces interacting with the atomic planes and causing one to slide over the other [6].

Furthermore, this model of "sea of electrons" also conveniently explains the electrical and thermal conductivity property that brass possesses. The electrons moving freely within the positive lattice formed by the protons of the metals carry negative charges. When an electric voltage is applied to a piece of a conductor such as brass itself, the electrons will be prompted to move, forming an electron flow [7] (as can be seen in figure 4). Similarly, metals are also capable of conducting heat through the movement of electrons. When provided with heat energy, the electrons vibrate at a higher rate and gain more mobility to move around quickly, passing on the energy faster [7]. Though not explicitly mentioned through academic research, this heat-conducting property of brass could also potentially enhance the instrument's performance because it could make warming up more effortless for both the musician and the instrument. In this case, warming up the instrument could prevent or protect it from stress and strain during usage [8].

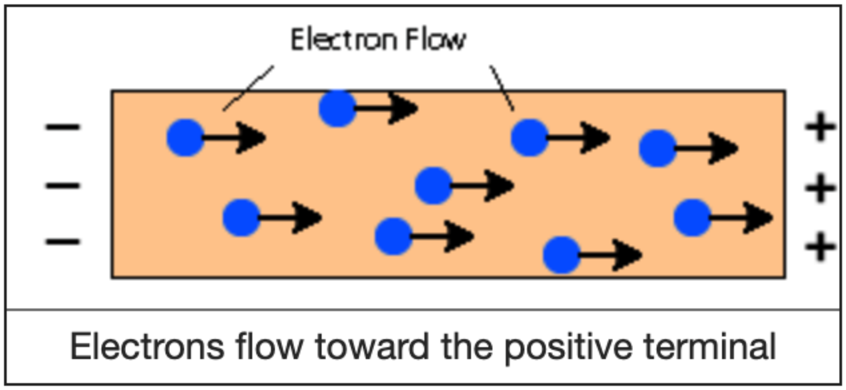

Figure 4. This diagram shows the flow of electrons from the negative terminal to the positive terminal of a conducting material [7]

Brass also has excellent machinability. Unlike ceramic materials and their poor machinability, as Professor Ramsay briefly mentioned in chapter three, “Behaviour That’s Not Elastic [6],” brass, on the other hand, is very machinable. This is because brass, being a metallic substance, is not brittle and does not immediately shatter during machining operations [6]. Instead, brass, thanks to its high copper content, behaves similarly to metals and has a high plastic strain to fracture [6]. Furthermore, the “addition of certain alloying elements [9]” could also significantly increase the machinability of Brass [9]. Lead is an excellent example of this as 1% to 3% of lead contents added to brass could significantly reduce the tool wear during cutting [9]. In the musical instrument industry, brass that is commonly used to build instruments is found to contain about 2% to 3 % of lead [10]. Leaded brass has lead particles primarily located in its grain boundaries [11]. In those grain boundaries, lead creates a lubricating effect, greatly reducing friction and heat, thus reducing tool wear [12]. This is all possible due to lead’s lower melting point of 328 degrees Celsius compared to that of brass, which allows it to be become “a semi-liquid film [9]” during cutting; this leads to an adhesion effect on the cutting tool surface [9]. Being machinable is crucial to the making of an instrument, and brass does the job perfectly.

A brass instrument should also stand the test of time and over usage. Since most wind instruments operate with many moving parts and repetitive motion, a durable material that is resilient to repetitive usage is required [2] — brass, again, does the job adequately. Like mentioned previously, brass is an alloy composed of Zinc and Copper. It inherited its malleability of metals from copper and is made a lot stronger than pure copper with the addition of zinc atoms [13]. Since metals plastically deform in a “step-wise breaking and reforming of bonds” known as dislocation [6], by interfering with the movement of dislocations to make it more difficult to move can strengthen a metal [6]. In this case, brass is a lot stronger than copper due to that a zero-dimensional imperfection is introduced in the form of a substitutional impurity to resist the movement of dislocations. Zinc, in this case, is a slightly larger substitutional impurity added to copper and it creates a strain in the lattice (as seen in figure 5 of the larger substitutional atom). This strain field, then disrupts movement of dislocation nearby the impurity [6], and the observed result is that the metal is strengthened.

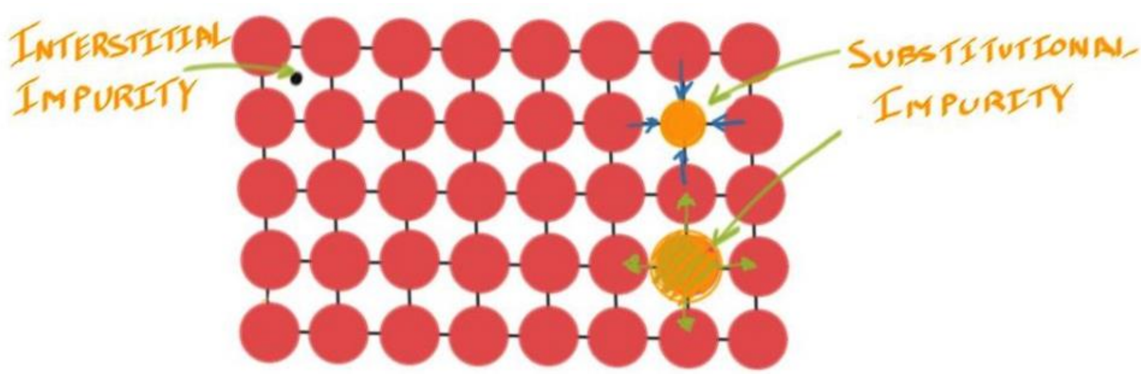

Figure 5. This cartoon depiction shows the substitutional and interstitial impurity that is added to a metal sample. The arrows also indicated the strain fields that is created by both the substitutional and interstitial impurity atoms [6].

Moreover, by increasing the numbers of dislocation can also lead to higher strength in metals. This could be done by many industrial methods such “rolling or pulling” a piece of metal through a die [6]. This type of strengthening is known as cold work as it is performed on metals at temperatures below their recrystallization point [14]. Two dimensional impurities in the form of grain boundaries also strengthen metals. This is because at points where crystals make contact with each other, the dislocation will have trouble moving through the atomic planes due to their random orientations (as can be seen in figure 6) [6]. Intuitively, by reducing the grain size in metals will create more obstruction for dislocation movement, and thus will increase the strength of metals even more. Below in figure 7 a grain reduction of brass through cold working is shown. It can be seen that with more percentage of coldwork, the finer the grains on the material seems. Lastly, three dimensional imperfections are introduced in brass having two phases alpha and beta, containing about 32% to 39% percent of zinc content [16]. Similar to grain boundaries, it is hard for dislocations to move through another phase, and thus is also a strengthening factor in brass.

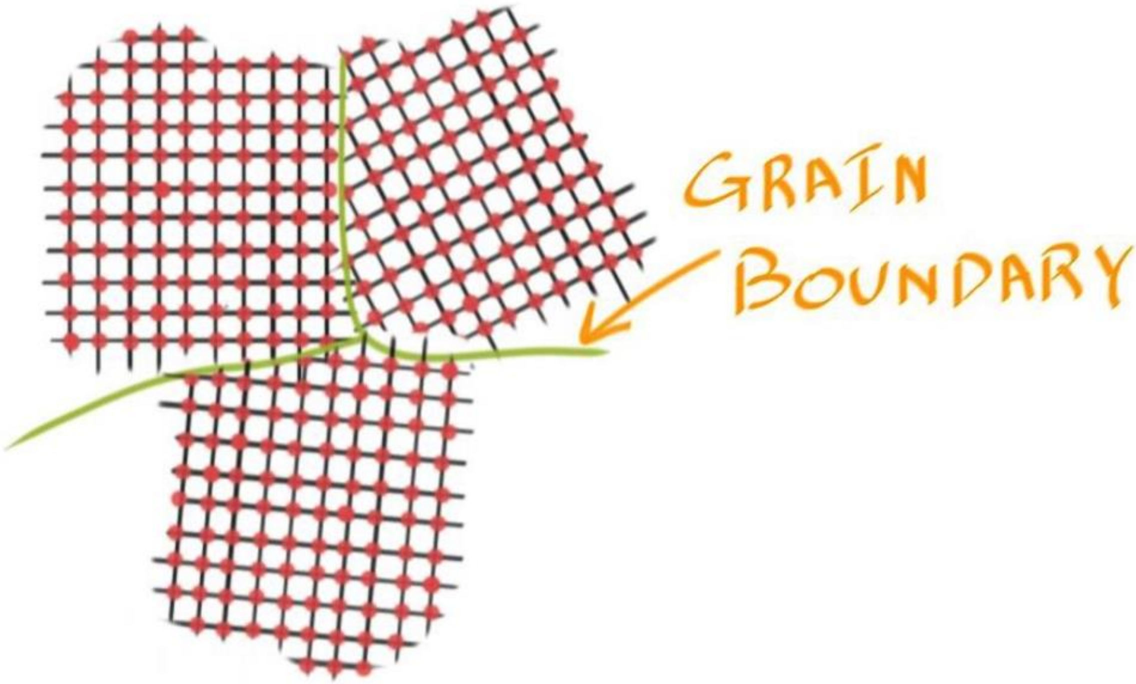

Figure 6. This figure shows three atomic planes and their grain boundaries indicated by the green line [6]

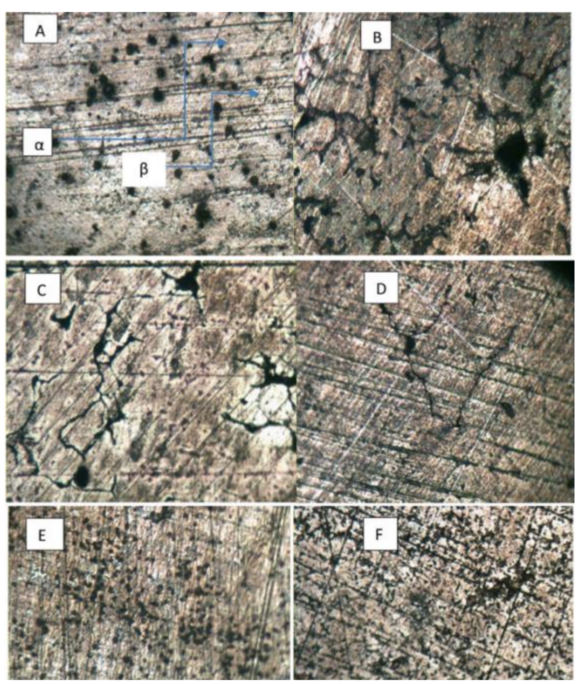

Figure 7. This is a picture taken at the grain level of a brass that was cold rolled. From mini pictures labelled from A to F, the grains of this piece of brass is observed to become finer (reduced in size) due to the percentage of cold roll that was applied. [15]

The last amazing property of brass is its resistance to corrosion. Since brass instruments are known to collect moisture and condensation during playing [17], using a material that is easily susceptible to corrosion is definitely not ideal. Brass itself is actually composed of two materials that are both very resistant to corrosion [18]. Adding zinc and copper together only made this material even more resistant to corrosion. Moreover, Nickel plating is also commonly added to brass instruments to make them even more rust resistant [19]. The nickel acts as a sacrificial coating [20] and protects the inner brass material from corrosion.

In conclusion, brass is a fantastic material composed of copper and zinc. Its many properties, such as malleability, machinability, durability, and corrosion resistance, make it the perfect material for constructing brass instruments. Over the years, brass instruments made of other materials such as plastic competed with the traditionally made instruments. While these plastic instruments excelled in terms of their ergonomics, lightweight, cost and durability [21], they came nowhere near the traditionally brass based instruments in terms of the sound [22] and elegance. Finally, no other material can compare to brass when it comes to building instruments and ensuring their sound-producing capabilities; it rightfully secures its spot as the most suitable material used to make brass instruments.

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