# Lab 9: Tin-Bismuth Phase Diagram

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Laboratory Performed: October 28th, 2021

***I pledge my honor that I have abided by the Stevens Honor System***

Bemin Shaker

Gwendolyn Marchi

Alexander Gaskins

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# Introduction

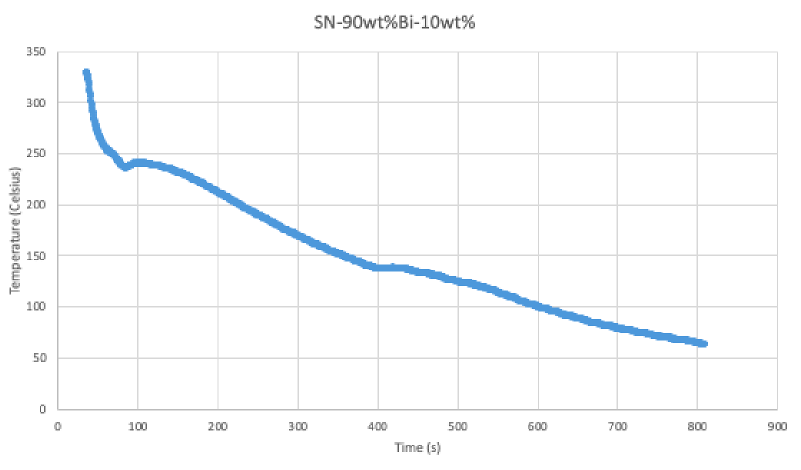
Objectives:
The goal of this lab was to produce cooling curves of the change in temperature of several alloys, as well as to use a microscope to describe the basic principles of their composition. Additionally, the phases of their compositions were determined by using various points on their respective phase diagrams.

Approach:
For the first portion of the lab, the main focus was to create a cooling curve of each of the tin-bismuth mixtures consisting of four different compositions. The mixtures provided by the TA include pure Sn, pure Bi, 43wt% Bi-57%wt Sn, and 18wt% Bi-82%wt Sn. Each sample was heated past their melting point. A small sample of each composition was placed into a glass tube with a thermometer. Then, the tube was lowered into the metal bath and the recording of the temperature was initiated. Once the temperature reaches 300℃, the glass tube was removed from the metal bath and was allowed to cool. The recording was stopped once the temperature dropped below 100℃. The data of the four curves was uploaded and the results were analyzed.

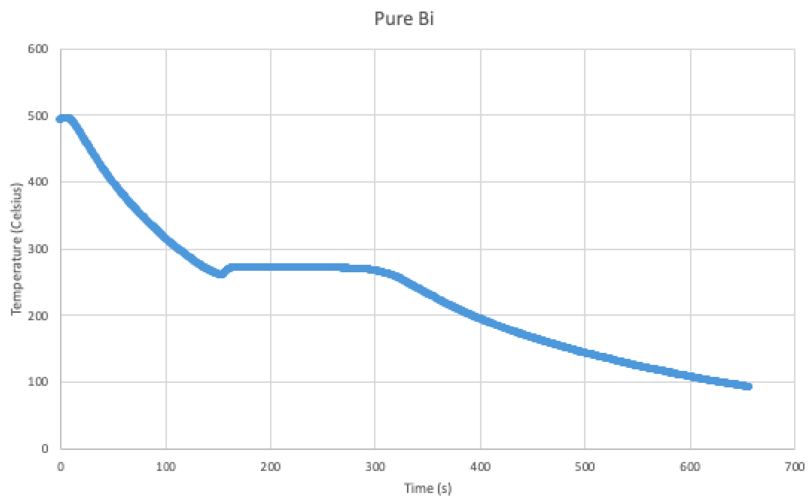
The main focus of the second portion of the lab was to perform observations of the microstructure of the bismuth-tin samples. Using a microscope connected to a laptop, screenshots were taken of each sample at appropriate magnifications. Utilizing the images, the team was able to identify the phases and phase mixtures as well as relate these microstructures to the cooling curves and at what points particular structures were present.

# Results

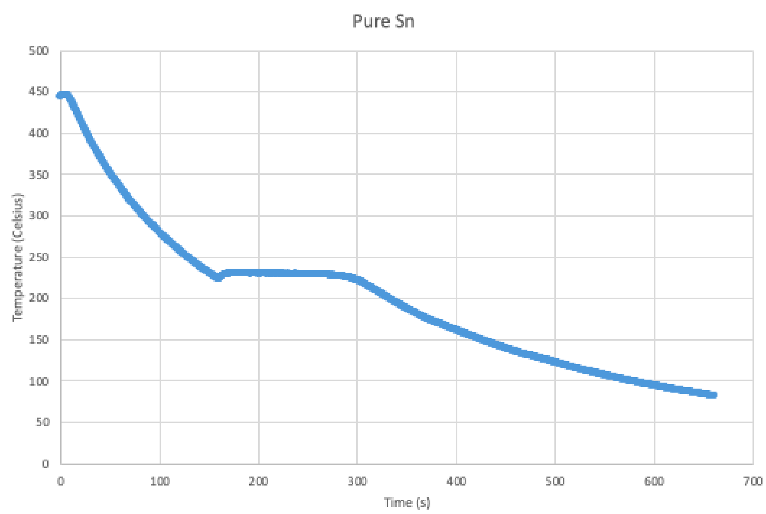
*Creation of a Cooling Curve*



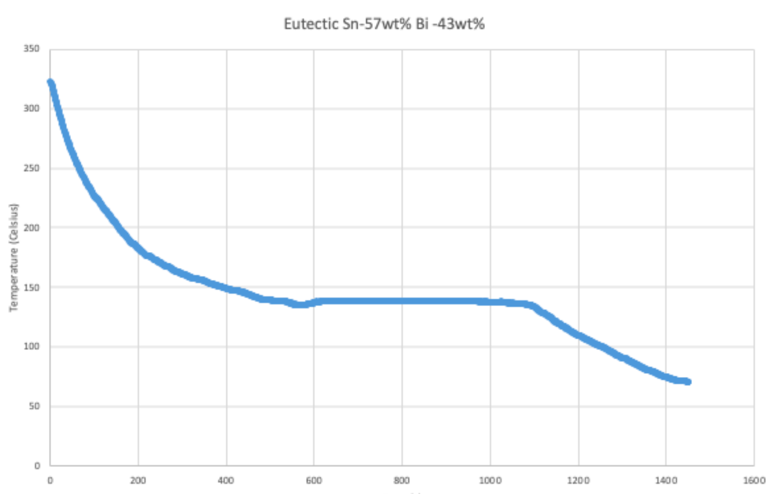

Inflection Point: T=240ºC, t=90s




Inflection Point: T=265ºC, t=150s



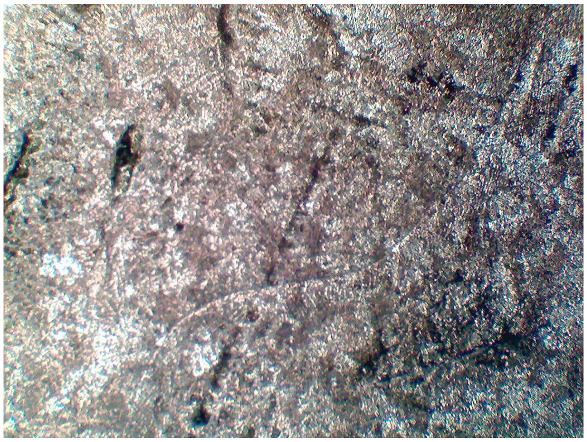

Inflection Point: T=225ºC, t=160s




Inflection Point: T=140ºC, t=580s

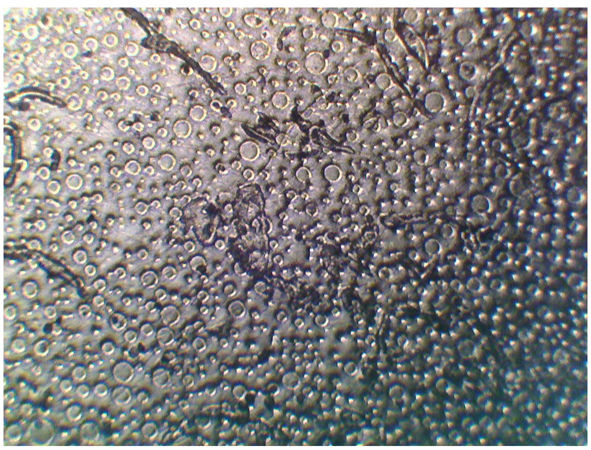
*Observation of Samples*

Bi18%-Sn82%



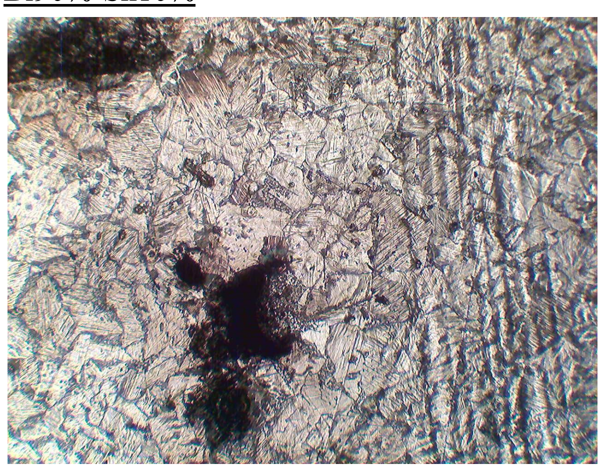
As seen by the abundance of eutectic layers, the sample is at a later stage in the cooling-curve, as the tin and bismuth have had more time to combine, as opposed to the primary layers of tin, that are lighter and precipitate before the eutectic layers.

Bi43%-Sn57%



This seems to be at an in-between phase, with a noticeable mixture of both layers. As seen from the somewhat evenly distributed tin and eutectic layers, this substance is at a middle area on the cooling curve, after some time has passed.

Bi90%-Sn10%



Most of the visible sections of the substance are a lighter color, indicating that it is at a stage in the cooling process where primarily tin was being precipitated, with minimal eutectic dispersion. It is most likely at an earlier stage in the cooling curve.

## Discussion and Conclusions

This lab was conducted with the purpose of comparing the properties of alloys as they undergo a change in temperature. This was done using multiple different tin (Sn) and bismuth (Bi) alloys that were first melted in a heated metal bath, and then cooled in a room temperature environment once the substance reached 300ºC. After being removed from the metal bath, a thermometer connected to a computer was used to record the change in temperature of the alloy as the substance cooled over time.

From the acquired observations, it was found that each graph exhibited similar results. The graphs presented an expected decrease in temperature over time, and as hypothesized, an inflection point represented a phase change of the alloy. This point indicates that a phase boundary exists, and once the alloy reaches the following corresponding phase (in the case of a cooling curve, it would be the freezing point of the substance), the alloy reaches a solid state. It continued to decrease in temperature at a noticeably slower rate for each alloy observed. After the inflection point, the curve experienced a temporary flattened state, as the latent heat of fusion must first be removed.

Depending on the purity of the tin alloy, the amount of time that it took to cool, as well as the temperature at which it experienced a phase change changed. For both pure tin and pure bismuth, the amount of time that passed before a phase change was reached was around 150 seconds, at a temperature of 225ºC for tin and 250ºC for bismuth. Compared to these values, the graph for Sn57%-Bi43% had an inflection point at (580, 140). This was a noticeable change, as the alloy took more than 3 times as long to reach a phase change, and at a lower temperature.

After analyzing the cooling curves of the alloys, a microscope was used to observe the difference in microstructure of these cooled alloys depending on their composition. The brighter tan areas seen on the alloy through the microscope at 100x represent areas of pure tin that precipitates from a liquid first, and the alternating dark and tan spots represent eutectic layers of tin and bismuth. Depending on the weight percent of the eutectic layers, the grain boundaries varied in shape and size.

## Broader Impacts

This lab demonstrates the variety of processes that are used to analyze and alter the phases of metals for real-world practices. A key example of this being used in real-world applications is with casting metals. Metal casting is defined as the process in which molten metal is poured into a mould that contains a hollow cavity of a desired geometrical shape and allowed to cool down to form a solidified part. This process requires metal to first be heated to a point of melting, and cooled in a specific environment. This process has been used by humans for over 6000 years to reshape metals, for purposes such as with weaponry (knives and swords), and in more modern times, for tools and metal parts, such as screws, hammers, hinges and machine components. It is much more efficient than reshaping and carving metals in most cases, and typically cheaper as well.

## Reference

"What Is Metal Casting? - Metal Casting Types - How Does Metal Casting Work." *Engineering Product Design*, 17 Dec. 2019, https://engineeringproductdesign.com/knowledge-base/metal-casting/.