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TRIZ-BASED TOOLS FOR KNOWLEDGE CREATION

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ABSTRACT

Effective tools and processes for creating scientific knowledge have been in development since the 1960s to address these scientific problems and situations, which require a creative approach:

- Discoveries of new events, effects and phenomena
- Integration and hybridization of knowledge and ideas from different areas
- Creation of a model or theory to explain a new event or phenomenon
- Planning and developing of experiments, effective measurement systems, methods for processing information, etc.
- Finding new applications for new effects

This paper offers manual (software-free) techniques for addressing the above issues, and includes three case studies illustrating the practical application of these techniques.

INTRODUCTION

Within R&D divisions of large organisations, effective tools and processes are necessary in order to create knowledge and innovations suitable for mass implementation. This issue has become critical in light of recent success in addressing the current crisis in innovation.[1] The following scientific problems and situations require a creative approach:

- Discoveries of new events, effects and phenomena
- Integration and hybridization of knowledge and ideas from different areas
- Creation of a model or theory to explain a new event or phenomenon
- Planning and developing of experiments, effective measurement systems, methods for processing information, etc.
- Finding new applications for new effects

The utilization of a TRIZ approach to science has its own history.[2] In 1960, TRIZ founder Genrich Altshuller distributed his paper entitled "How Scientific Discoveries Are Made," in which he formulated the basic approaches to developing methods for solving scientific problems.[3] In particular, he identified two classes of discoveries:

- Class 1 – The discovery of a new phenomenon or fact
- Class 2 – Finding an explanation for a new phenomenon or fact whose mechanism or nature is unclear

Based on an analysis of a limited number of discoveries of both types, Altshuller formulated around ten useful recommendations to help with class 1 discoveries, and eight recommendations for class 2 discoveries.

Later, the accomplished TRIZ specialist and educator Volyuslav Mitrofanov suggested a method for utilizing the Patterns and Lines of Evolution to discover new physical, chemical, and other effects.[4]

In this article, the authors introduce certain tools, techniques and algorithms that have been in development and successfully utilized since the mid-1980s.

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1 Boris Zlotin and Alla Zusman, "Directed Evolution of R&D Organizations," paper presented at TRIZCon 2002.

2 Boris Zlotin, et al., "TRIZ Beyond Technology." Proceedings from TRIZCon 2000 (Worcester, Mass.: The Altshuller Institute for TRIZ Studies, 2000).

3 Genrich Altshuller, "How Scientific Discoveries Are Made," manuscript (in Russian), 1960. Published later in Solving Scientific Problems (Kishinev: STC Progress in association with Kartya Moldovenyaska, 1991).

4 Volyuslav Mitrofanov, From Manufacturing Defect to Scientific Discovery (St. Petersburg: TRIZ Association of St. Petersburg, 1998).

TOOLS AND TECHNIQUES

1 Integration and hybridization of knowledge and ideas

It is well known that integration is one of the most effective methods of producing new theories from existing ideas (sometimes even opposite ideas). An example is the complementary principle introduced by the physicist Niels Bohr. To ensure the effective integration of ideas, a special hybridization methodology has been developed in TRIZ.[5]

Hybridization is a specific process for combining different systems for the purpose of building a new one. It is an important means by which both biological and scientific/ technological systems evolve. Regarding evolution as a permanent process of hybridization helps us to understand that evolution relates to a family of systems (the population of fighter planes, for example) rather than a specific system (the F-16 airplane). Very often this evolution presents itself as the exchange of features (solutions, designs, specific technologies and processes, etc.) between family members. The hybridization technique provides the following advantages:

- The possibility of advancing a system through incremental, easily-acceptable steps.
- The exchange of proven and readily-available solutions and subsystems between different systems, which accelerates evolution and increases the probability of successful implementation.

Besides the purely technological advantages, hybridization can be a strong psychological approach that provides:

- A new "big picture" of technology as a world of dynamic, flexible and prone-to-integration hybrids.
- The capability for easily (and without psychological pressure) "mentally disassembling" a complex system, then reassembling it in a different way.
- A reduction in psychological inertia that enables one to critically analyze his/her own system and compare it to competing systems, then attempting to hybridize.

2 Creating a model or theory to explain a new event or phenomenon

Both the solving of scientific problems and the generation of new scientific concepts are based on the same approach: *Problem Inversion*. The essence of Problem Inversion is simple: instead of asking "How can a certain phenomenon be explained?" one asks "How can this phenomenon be produced under the existing

5 Vladimir Gerasimov, Gafur Zainiev and Valery Prushinsky, "Hybridization of Alternative Systems," TRIZ in Progress (Ideation International Inc., 1999), 221-224.

conditions?" The problem therefore becomes a typical inventive problem and can be attacked using existing TRIZ tools.

Based on this approach, a method for building new scientific concepts has been developed. This method includes the following steps:

- Formulate the original problem
- Amplify the problem
- Invert the problem
- Search for creative "hints"
- Utilize resources
- Verify the obtained hypotheses

For a more detailed description, see Appendix 1.

3 Building new scientific concepts

In many situations, it is enough, for practical purposes, to obtain one or more explanatory mechanisms. At other times, a comprehensive new concept is needed. The following algorithm is recommended for developing concepts:

- Analyze an existing system
- Synthesize a new concept
- Verify the new hypothesis
- Further develop the new concept

This algorithm was applied by the authors to create concepts in the following areas:

- Organization theory6
- A "brain" for evolution (a concept related to the theory of biological evolution)7.

For a more detailed description, see Appendix 2.

4 Creating experiments

Experiments designed for the purpose of verification are often costly and time consuming. For such cases, TRIZ offers a knowledge base related to creative measurement and detection. (This knowledge base is based on certain Innovation Principles and Standard Solutions developed by Genrich Altshuller in the early 1960s and mid-1980s, respectively.) Today, a special module called *Developing and improving systems for measurement and control*, which contains over 50 Operators (recommendations) is available to support this type of activity.[8]

For selected recommendations, see Appendix 3.

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6 See certain elements of the theory in Boris Zlotin and Alla Zusman, Directed Evolution: Philosophy, Theory and Practice (Ideation International, 2001).

Appendices 8 and 9.

7 To be published.

8 The module is incorporated in the Innovation Workbench (IWB)® software.

5 Finding new applications for new events and effects and/or to prevent or eliminate harmful effects

Once the mechanism of a phenomenon is clear, the following can be considered:

- Finding a useful application for the phenomenon
- Amplifying the phenomenon
- Preventing undesired effects or eliminating their harmful consequences
- Creating a method for early detection of the phenomenon

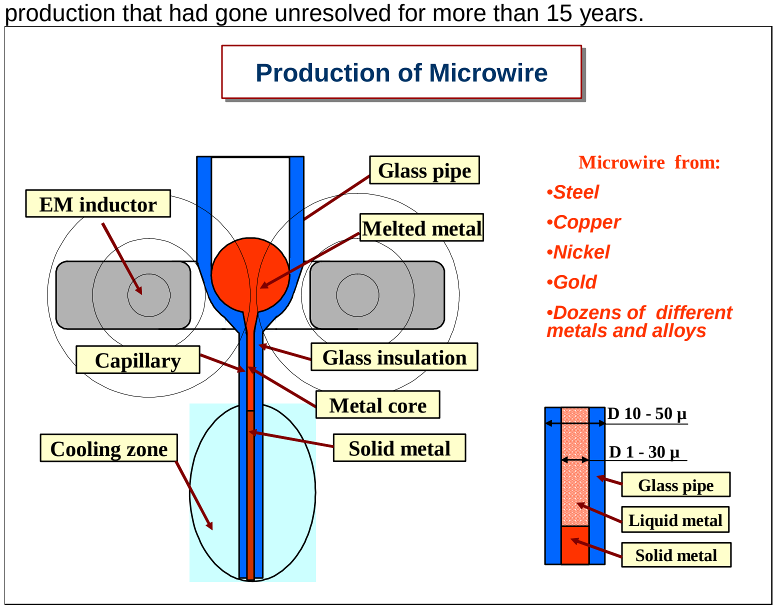
For more detail, see Appendix 4.

References

1. Altshuller, Genrich, Boris Zlotin, Alla Zusman and Vitaliy Philatov. *Searching for New Ideas: From Insight to Methodology*. Kishinev: Kartya Moldovenyaska Publishing House, 1989. (In Russian.)
2. Altshuller, Genrich. “How Scientific Discoveries Are Made.” Manuscript, 1960. (In Russian.) Later published in *Solving Scientific Problems*. Kishinev: STC Progress in association with Kartya Moldovenyaska, 1991.
3. Zlotin, Boris and Alla Zusman. *Solving Scientific Problems*. Kishinev: STC Progress in association with Kartya Moldovenyaska, 1991. (In Russian.)
4. Gerasimov, Vladimir, Gafur Zainiev, and Valery Prushinsky. “Hybridization of Alternative Systems,” *TRIZ in Progress*. Ideation International Inc, 1999.
5. Mitrofanov, Volyuslav. *From Manufacturing Defect to Scientific Discovery*. St. Petersburg: TRIZ Association of St. Petersburg, 1998.
6. *TRIZ in Progress*. Ideation International Inc, 1999.
7. Zlotin, Boris, et al. “TRIZ beyond Technology,” *Proceedings from TRIZCon 2000*. Worcester, Mass.: The Altshuller Institute for TRIZ Studies, 2000.
8. Zlotin, Boris and Alla Zusman. *Directed Evolution: Philosophy, Theory and Practice*. Ideation International, 2001.
9. Zlotin, Boris and Alla Zusman. “Directed Evolution of R&D organizations.” Paper presented at TRIZCon 2002.

CASE STUDY 1. PRODUCTION OF MICRO-WIRE

This case study, based on a problem solved in 1984 by our student, Anatoly Yoisher, represents the first scientific problem solved using the technique called *Create a model or theory to explain a new event or phenomenon* (Appendix 1)[9]. Mr. Yoisher applied the technique to a critical problem in the area of microwire production that had gone unresolved for more than 15 years.



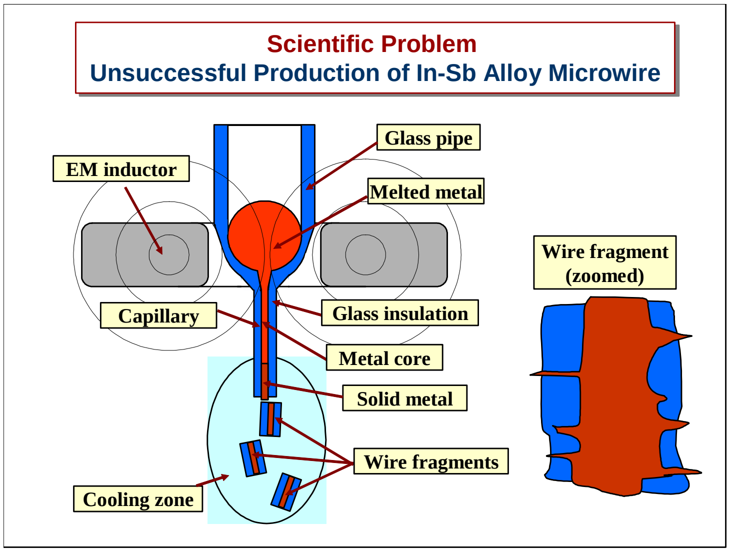
Microwire consists of a metal core encased in glass insulation. The production of microwire entails the following operations:

- A portion of the metal is placed in a thin glass pipe, which is then heated using microwaves. In the process of heating, the metal melts and the glass softens.
- A glass rod is touched to the softened glass at the end of the pipe. The glass sticks to the rod, which then pulls the glass onto a rotating drum.
- The rotating drum continues pulling and winding the glass capillary with the metal inside.

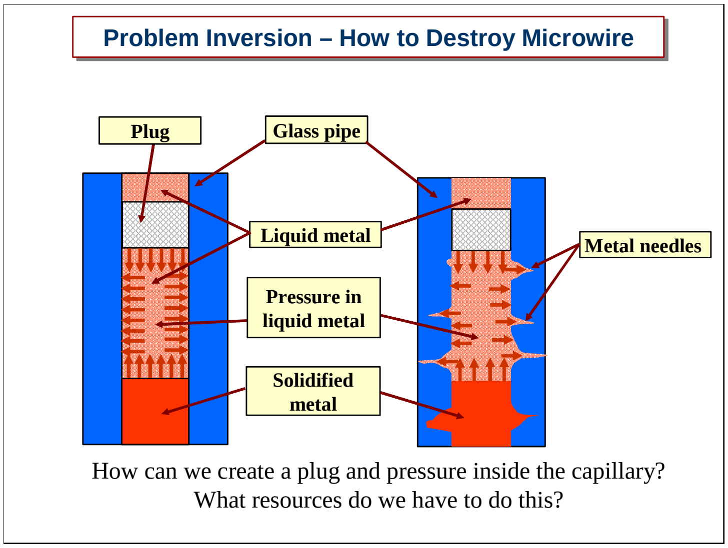
This method had been successfully used to produce microwire from over 50 various metals and alloys.

For 15 years, however, the company was unable to produce microwire from an important alloy: indium-antimony (In-Sb). For unknown reasons, the pulled microwire ruptured into small (0.5 mm) pieces. Under a microscope, these pieces looked as if they contained thin metal needles that pierced through the insulation.

9 Genrich Altshuller, Boris Zlotin, Alla Zusman and Vitaliy Philatov, Searching for New Ideas: From Insight to Methodology (Kishinev: Kartya Moldovenyaska Publishing House, 1989, in Russian): 124.

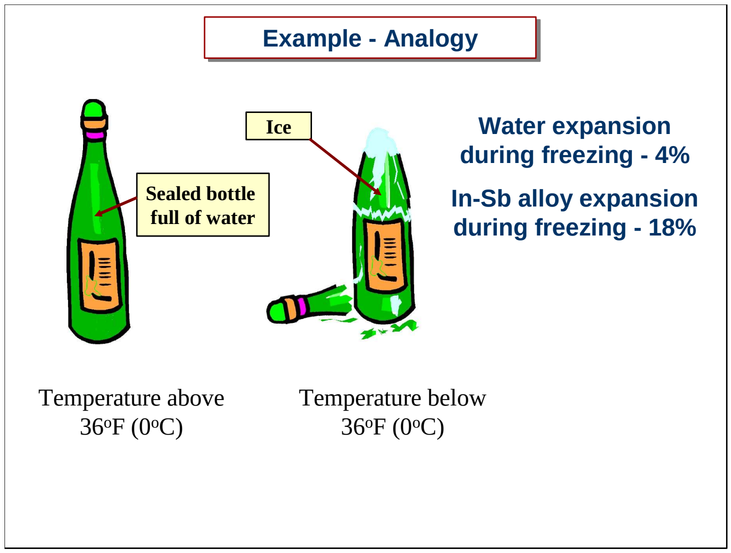


The In-Sb alloy differs from other metals in that its volume increases by 18% during solidification. It was suspected that this might be contributing to the problem, but it was unclear exactly how. By experimenting with various glass types and varying the microwave power and cooling modes, the length of the microwire pieces was increased to between 2.5 and 3 mm. But the minimum requirement was 250 mm (10”).



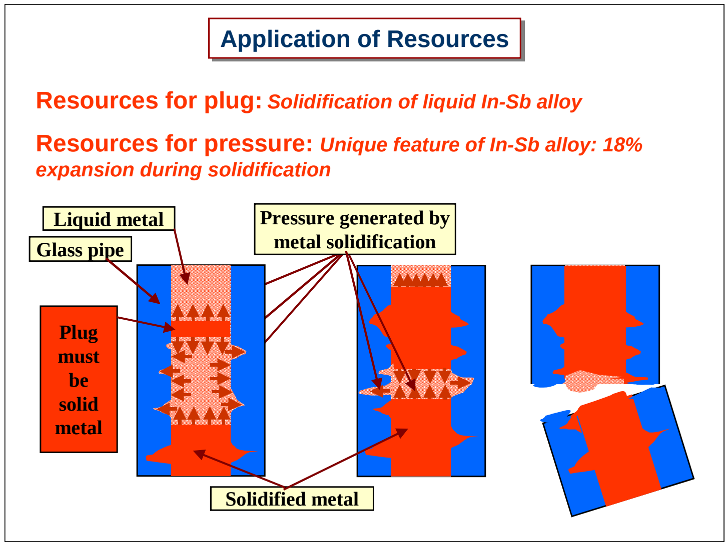
The problem was inverted: Instead of *“What is causing the destruction of the microwire?*” it became *“How can we intentionally destroy the microwire?”* And with that, Mr. Yoisher concluded that the best way to force the metal to pierce the glass was to plug the capillary and increase the internal pressure (using the plug as a piston, for example).

This seemed like a stupid idea, and Mr. Yoisher was about to give up. But he decided to take a look at the next step.



The next step recommended looking for analogies and creative “hints” in other areas of science, technology, or even everyday life. Mr. Yoisher quickly recalled a situation where he had left a sealed bottle on his balcony during the winter, and the bottle had ruptured.

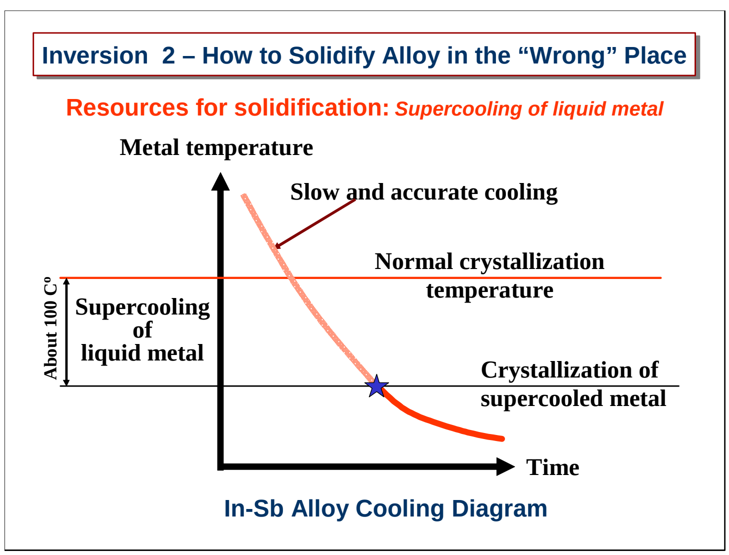
This analogy helped overcome the psychological barrier associated with his “stupid” idea.



The list of available resources was rather limited, consisting of the alloy (liquid and solid) inside the glass capillary, and the properties of the alloy, which included a unique feature: In-Sb expands by 18% during solidification.

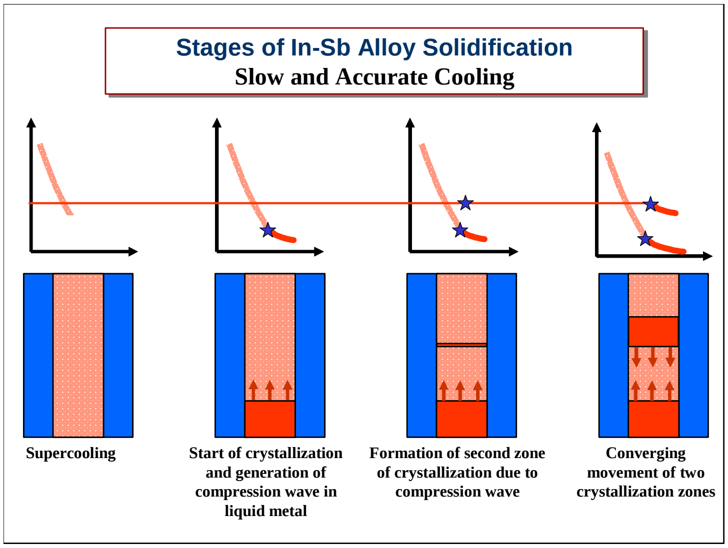
The easiest way to create a plug would be to use the solidified alloy.

The next inverted problem then became: *"How can the liquid metal be forced to solidify in at least two places, with liquid in between?"* An experienced scientist, Mr. Yoisher quickly realized that a well-known effect associated with the behavior of supercooled liquids could be utilized.

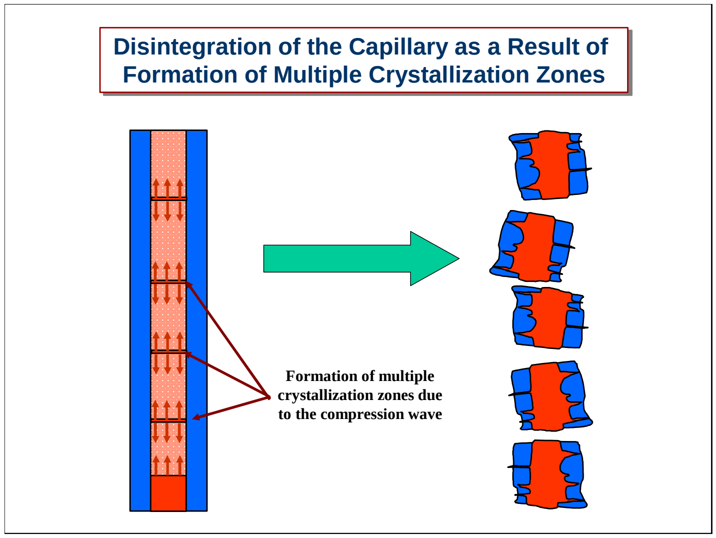


When a very pure liquid (i.e., lacking a crystallization seed) is slowly cooled, the liquid can remain in a liquid state under temperatures much lower than the usual crystallization temperature.

For example, when distilled water is cooled very slowly, it remains a liquid until 20°F (-10°C). At the same time, a supercooled liquid will instantly solidify when subjected to a very weak impact. Merely tapping a nail against a beaker of super-cooled distilled water is enough to turn the water into ice.

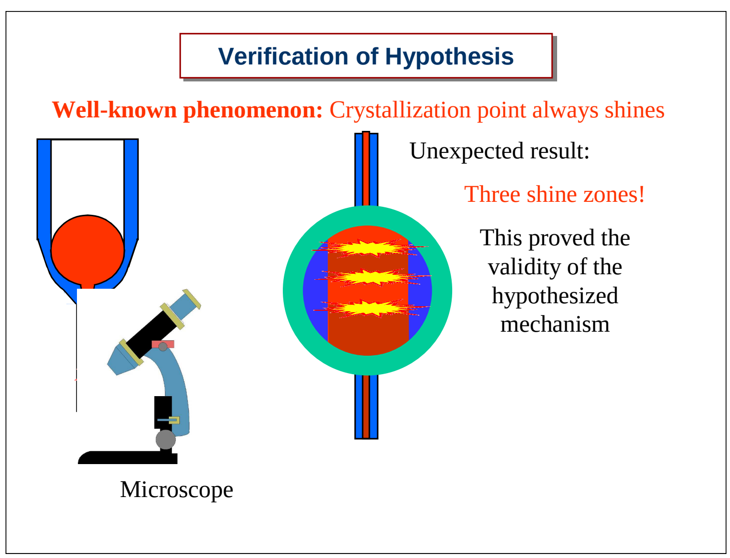


The following hypothesis was offered as an explanation for the capillary rupture: The liquid alloy in the capillary is supercooled to a temperature much lower than the crystallization point. At a certain moment the solidification starts in a certain zone. As the volume of the alloy increases, a pressure wave is created in the liquid metal. The compression wave creates a new crystallization zone at a certain distance from the first zone. The resulting crystallization fronts travel towards each other, compressing the liquid in between. Under this pressure the liquid metal pierces the glass, eventually breaking it as the two crystallization fronts converge.



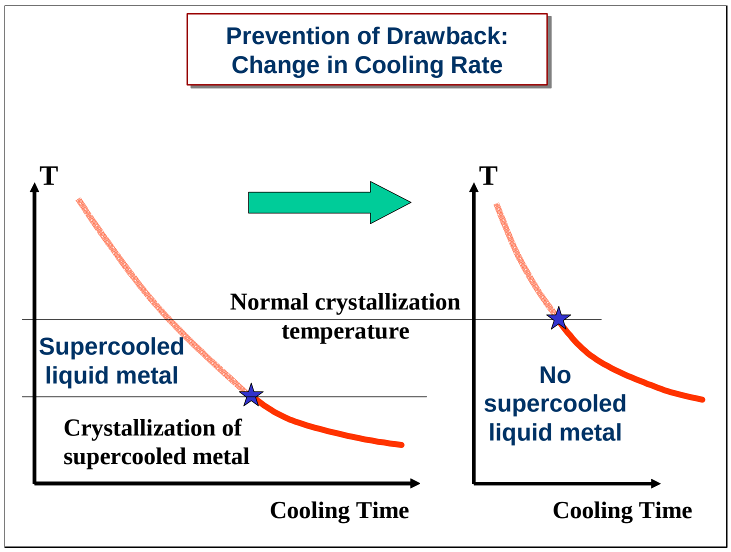
A compression wave can create more than one crystallization zone. And it is important to note that additional zones always appear at a certain distance, as additional latent heat is released in the crystallization zones, heating the alloy.

The emergence of multiple crystallization zones causes the microwire to rupture into small pieces. This explains why many years of experimentation produced a limited increase of the length of the alloy pieces, but could not completely resolve the situation.



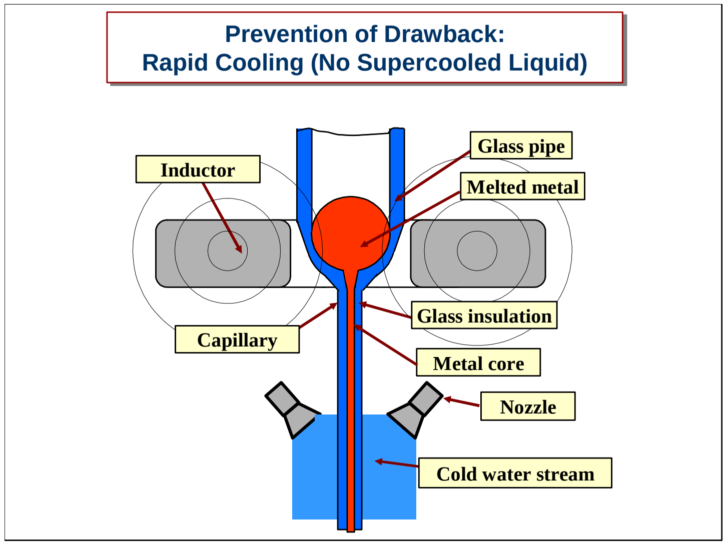
Mr. Yoisher was very interested in the newly-discovered mechanism, as supercool-ing was observed in other metals as well. It soon became clear how his hypothesis could be tested: according to specialists, crystallization creates a weak luminescent light. The first attempt to view the crystallization process under a microscope for different metals showed several such light spots.

However, metals (alloys) that did not significantly expand under solidification did not cause the capillary to rupture.



How could the knowledge of this newly-discovered mechanism be used to solve the problem with producing the In-Sb microwire?

Contrary to the existing practice, it seemed clear that the cooling stage should be carried out rapidly rather than gradually, in order to prevent the supercooled liquid effect. This idea seemed very strange, as it contradicted all existing production theories . . .



Mr. Yoisher spent several hours removing the complex device that provided gradual cooling, replacing it with two cold water streams directed onto the microwire. The first run with the new production method produced 15 meters of microwire (using all of the available alloy)!

But the main benefit of the solution (aside from a Ph.D. dissertation and the prospect for a new type of microwire) was that the revealed mechanism of supercooled liquids in a capillary provided a better understanding as to why microwires made from certain metals had unstable electrical and mechanical parameters. This new knowledge resulted in substantial increases in the quality of all types of microwire.