

FABRICATION OF Si-As-Te TERNARY AMORPHOUS SEMICONDUCTOR
IN THE MICROGRAVITY ENVIRONMENT

M-13

Yoshihiro Hamakawa
Osaka University
Toyonaka, Osaka 560, Japan

Outline of FMPT Experiment

Ternary chalcogenide Si-As-Te system is an interesting semiconductor from the aspect of both basic physics and technological applications. Since a Si-As-Te system consists of a IV-III-II hedral bonding network, it has a very large glass forming region with a wide physical constant controllability as shown in Figure 1. For example, its energy gap can be controlled in a range from 0.6 eV to 2.5 eV, which corresponds to the classical semiconductor Ge (0.66 eV), Si (1.10 eV), GaAs (1.43 eV), and GaP (2.25 eV). This fact indicates that it would be a suitable system to investigate the compositional dependence of the atomic and electronic properties in the random network of solids.

In spite of these significant advantages in the Si-As-Te amorphous system, a big barrier impeding the wide utilization of this material is the huge difficulty encountered in the material preparation which results from large differences in the weight density, melting point, and vapor pressure of individual elements used for the alloying composition.

The objective of the FMPT/M13 experiment is to fabricate homogeneous multi-component amorphous semiconductors in the microgravity environment of space, and to make a series of comparative characterizations of the amorphous structures and their basic physical constants on the materials prepared both in space and in normal terrestrial gravity.

On the basis of systematic investigations on the Si-As-Te amorphous semiconductor system in terrestrial experiments, a proposal to FMPT/M-13 project has been planned. Samples to be fabricated in this experiment were selected from the terrestrial experimental data for compositions $\text{Si}_x(\text{As}_3\text{Te}_3)_{1-x}$ in which x is varied from 0.25 to 0.75. In order to examine the valence electron controllability, a trial will be made of impurity doping with Mn and Ni elements of several atomic percent on $\text{Si}_9\text{As}_{14}\text{Te}_{21}$ glass, on which the electronic properties have been most intensively investigated.

The Si-As-Te samples already synthesized with Si, As, and Te mixture of designed atomic fractions are employed for the starting material. This procedure is likely to be essential to avoid the possible break down of material sealings due to a rapid increase in vapor pressure, particularly of decomposed As, upon an accidental extreme overheating. Ground powder samples are sealed three-fold with silica ampoules, and encapsulated in the Ta universal cartridge. They are heated to 1300 °C continuously for 1 hour using the CHF apparatus. After that, a rapid quenching is accomplished in the cooling chamber using He gas flow; from 1300 °C down to below 45 °C in less than 10 minutes. A systematic investigation will be carried out on the structure and electronic properties of Si-As-Te amorphous semiconductors thus fabricated, with particular emphasis placed on the differences between the space-fabricated semiconductors and those fabricated under the normal terrestrial gravity environment.

Expected Results

In modern civilization we are surrounded by electronic devices - telephones, television, desk calculators, video taperecorders, microwave ovens, business computers, etc. Electronics

have become an indispensable tool in today's life. The marvelous growth of semiconductor electronics in the past 35 years was made possible by the well-established single crystalline foundation of solid state physics.

Amorphous materials are solids in which the atomic sites are randomly arranged. They lack long-range ordering in their lattice networks. The amorphous semiconductor will someday have a similar impact on modern life as have the crystalline semiconductors. This material is provided with wide controllability of physical constants and of fractions of the composed elements, doped impurity and defect compensator atoms. These features are a result of a lack of long-range order in the atomic structure. Being free from the constraints of periodicity in the atomic array, amorphous semiconductors lend themselves to relatively low-cost fabrication of large-area and thin film electronic devices with a good mass producibility.

Among a wide variety of amorphous semiconductors, the Si-As-Te system offers us the greatest opportunity for carrying out systematic investigations on the compositional dependence of structural and electronic properties. On the other hand, from the technological standpoint, this material is expected to be applied to multi-layered heterojunction devices and also optoelectronic functional elements in a wide spectral region from near-infrared to visible light region. The issue for making the best use of these advantages is to fabricate homogeneous Si-As-Te alloy materials, which would be possible if they were synthesized in the microgravity environment of space. The FMPT/M-13 experiment has been planned on this background idea. The results from the FMPT experiment will contribute to the physics of disordered materials as well as to the development of new materials for semiconductor electronics.

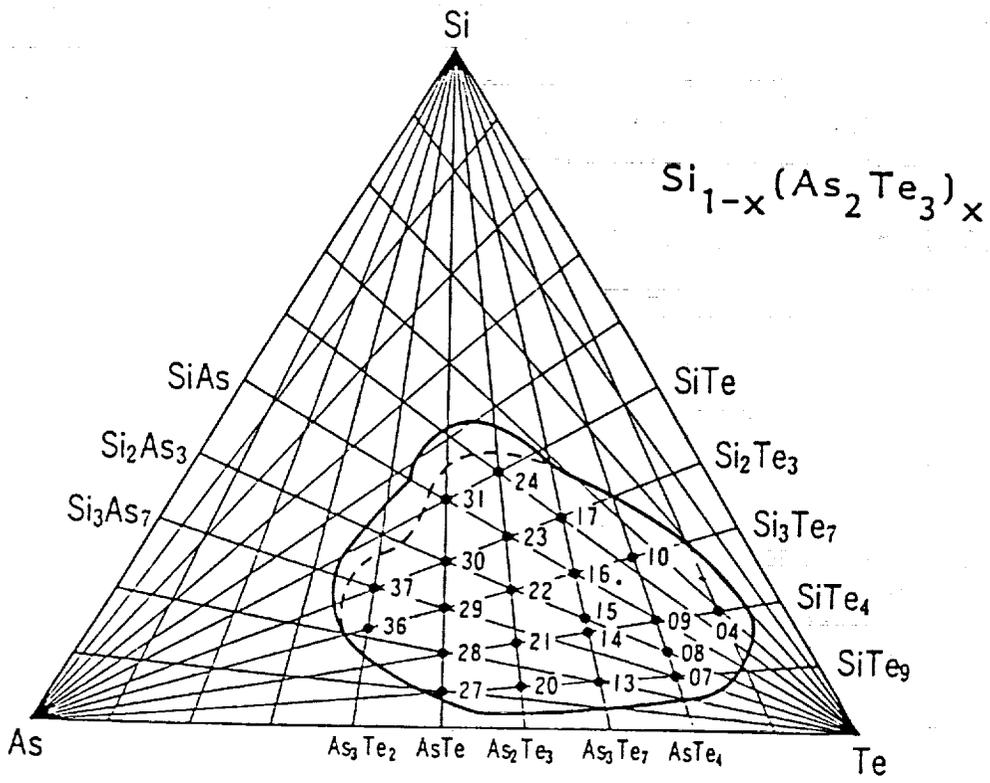


Figure 1. Glass forming region of Si-Te-Te system.