Superconductivity and Pressure-released Metallic State in Single Crystal Germanium to 23 GPa

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Introduction

It has been known for 3 decades that for high pressure structure at room temperature, Ge has a diamond-type structure (GeI), and at 10GPa the GeI structure undergoes a transition to the white tin (β-Sn or GeII) structure. When pressures higher than 12GPa are released, the GeII structure does not return to the GeI structure, but forms a metastable, high density structure (GeIII), this structure was known as semiconducting so far[1]. Here we report systematic high pressure electrical properties of Ge single crystals using a conventional four terminal method with a diamond anvil cell (DAC)[2] measured the pressure up to 23 GPa.

Experimental

The diamond anvils had a top surface diameter of 560 μm, and Inconel 625 was used as the metal gasket. A mixture of fluorinert (3M) 1:1 of FC-70 and FC-72 was used for the pressure medium. The pressure was determined by the standard ruby fluorescence method at room temperature. The temperature dependent magnetoresistance was measured in the NHMFL Cell 6 magnet system.

Results and Discussion

The sample resistivity is too high to be measured in the lower pressure region, and near the transition pressure the resistivity decreases 6 orders of magnitude. At 10.7 GPa the sample resistance becomes measureable, and fully metallic. The room temperature resistivity slowly decreases with increasing pressure up to 23 GPa, after which the pressure was decreased to 10.1 GPa, where the temperature dependence of resistivity exhibited a superconducting transition at 5.3 K. At 9.2 GPa the resistance has an abrupt drop around 6.2 K, but this drop is obviously different from superconducting transition. The drop rate became smaller with decreasing pressure (see Fig. 1). We suggest that there are coexist two different structures in this pressure region. During the process of pressure release, we find that for pressures lower than 6.9 GPa, germanium transforms to a new phase that remains metallic for temperatures down to 4.2 K.

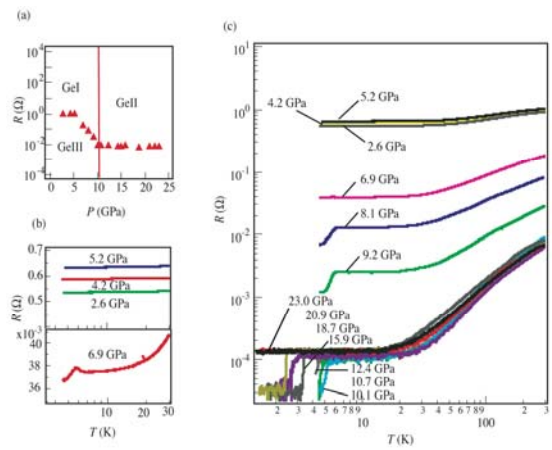

Fig.1. The temperature and pressure dependence of the resistance of single crystal Ge. (a) Room temperature resistance vs. pressure. (b) Temperature dependent resistance after depressurization. (c) Temperature dependent resistance for pressurized and depressurized conditions.

Conclusions

We performed systematic electrical properties single crystal of Ge under high pressure up to 23 GPa. The phase diagrams of *R-T* and T_c-*P* were also investigated to high pressure, and we have characterized the high pressure superconducting state of Ge vs. temperature and magnetic field, and confirm it to be a bulk, Type-I superconductor. We found for the first time a stable metallic state that appears from pressure release from very high pressure.

Acknowledgements

We would like to thank Dr. S. Tozer of NHMFL, for use of the ruby fluorescence system. This work was supported in part by NSF DMR-0602859 and performed at the National High Magnetic Field Laboratory, which is supported by NSF Cooperative Agreement No. DMR-0654118, by the State of Florida, and by the DOE.

References

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