Preparation and characterization of Ge and Co doped V_3Si superconductors

Matt Baldwin[1]; Ravhi Kumar[2]; Selva Vennila[2] and Andrew Cornelius[2]
[1]University of Puget Sound, Tacoma WA 98416
[2]HiPSEC, Department of Physics and Astronomy, University of Nevada Las Vegas, NV 89154

ABSTRACT

V_3Si is an A15 superconductor. Germanium doping on the silicon site and cobalt doping on the vanadium site were performed to determine the effects of chemical substitutions on lattice parameters. Cobalt doping yielded an amorphous phase upon arc melting, whereas germanium doping yielded a cubic phase with a lattice parameter proportional to dopant mole percent. In future work, T_c will be found for doped samples to determine how these substitutions affect superconduction transition temperatures.

CONTACT

Matt Baldwin
Email: mkbaldwin@ups.edu

INTRODUCTION

The A15 compound V_3Si shows relatively high superconducting transition temperature around 16 K. Although it has a cubic structure at room temperature, it undergoes a phase transition to tetragonal slightly above its transition temperature [1]. In this project, we have synthesized new doping compositions in V_3Si and explored how chemical substitutions in V_3Si by the substitution Co and Ge at Si site (a type-II superconductor) affect the lattice parameters.

Materials and Methods

The V-Si system A15 phase forms congruently from the melt at 1935°C. Its homogeneity interval presents a maximum at 1800°C where it is stable between 19 and 25 at.% silicon. The T_c increases linearly while reaching the stoichiometric composition so the maximum critical temperature (~17.1 K) is achieved with the 25 at.% of silicon. The phase diagram of V-Si system is presented in Fig.1

Cobalt doping on the vanadium site:

Elemental cobalt, Vanadium, and silicon were weighed, ground, and pressed into 1 gram pellets with the stoichiometric ratios of V_3Si, $V_{2.5}Co_{0.5}Si$, V_2Co_1Si, $V_{1.5}Co_{1.5}Si$, and Co_3Si, where silicon was added in 20% molar excess. Pellets were then melted in an arc furnace for about 60 seconds, flipping samples several times to ensure homogenous melting. Afterwards, the nuggets were ground, then analyzed using a Bruker discover x-ray diffraction system operating with a Mo target.

Germanium doping on the silicon site:

Elemental germanium, vanadium, and silicon were weighed, ground, and pressed into 1 gram pellets with the stoichiometric ratios of $V_3Si_{0.95}Ge_{0.05}$, $V_3Si_{0.9}Ge_{0.1}$, and $V_3Si_{0.75}Ge_{0.25}$, where silicon was added in 20% molar excess. Pellets were then melted in an arc furnace for about 60 seconds, flipping samples several times to ensure homogenous melting. Afterwards, the nuggets were ground, then analyzed with x-ray diffraction. Peaks were fitted and the structural parameters were obtained using *Jade* software.

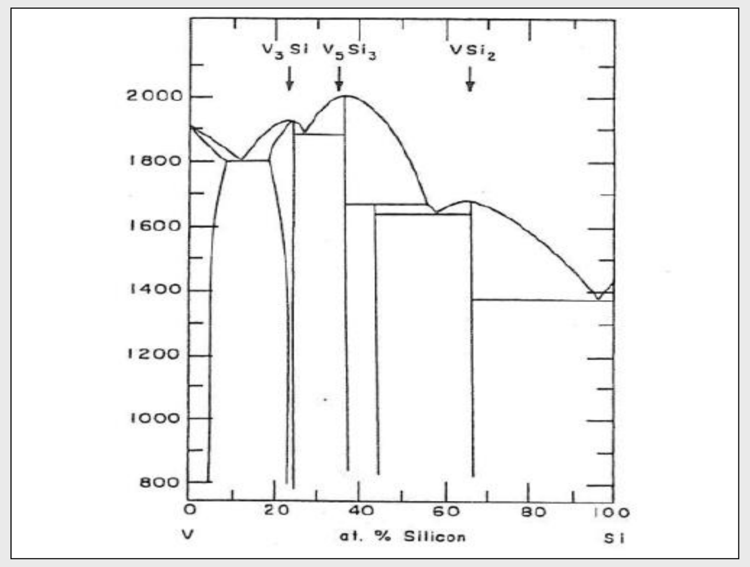

Fig.1 Phase diagram of V-Si system [2]

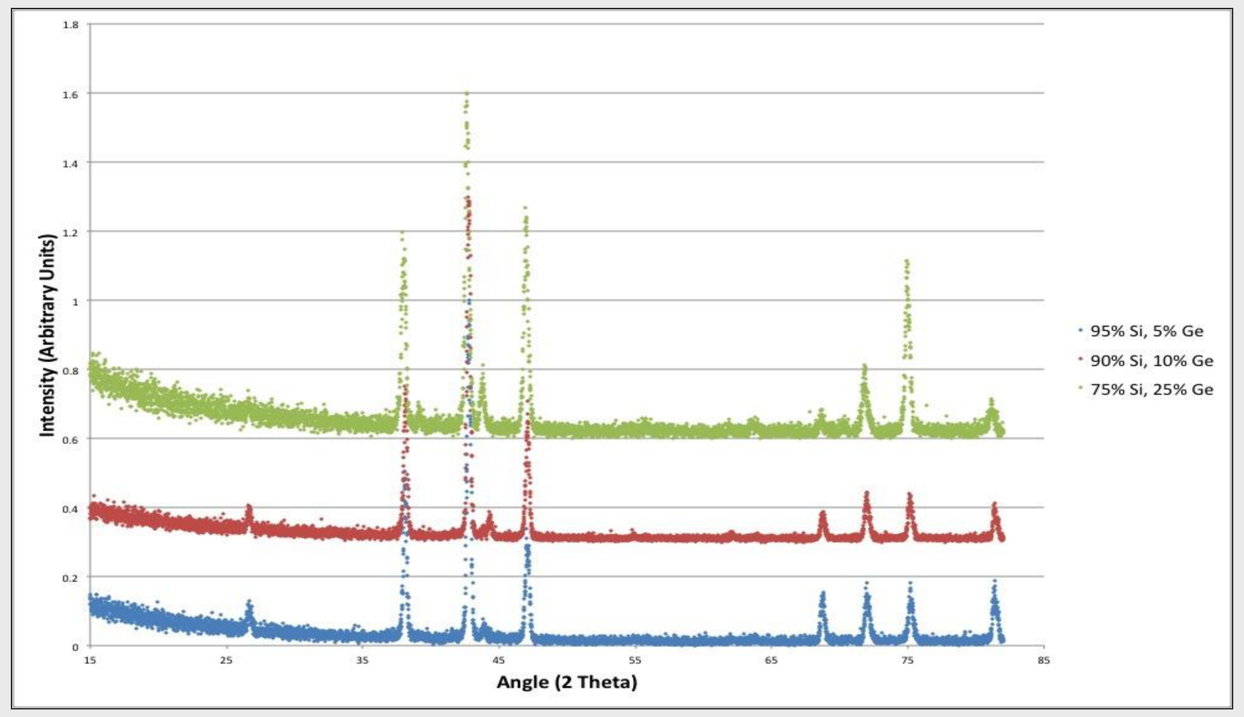

Fig.2 Diffraction patterns obtained for various Ge doping concentrations in V_3Si

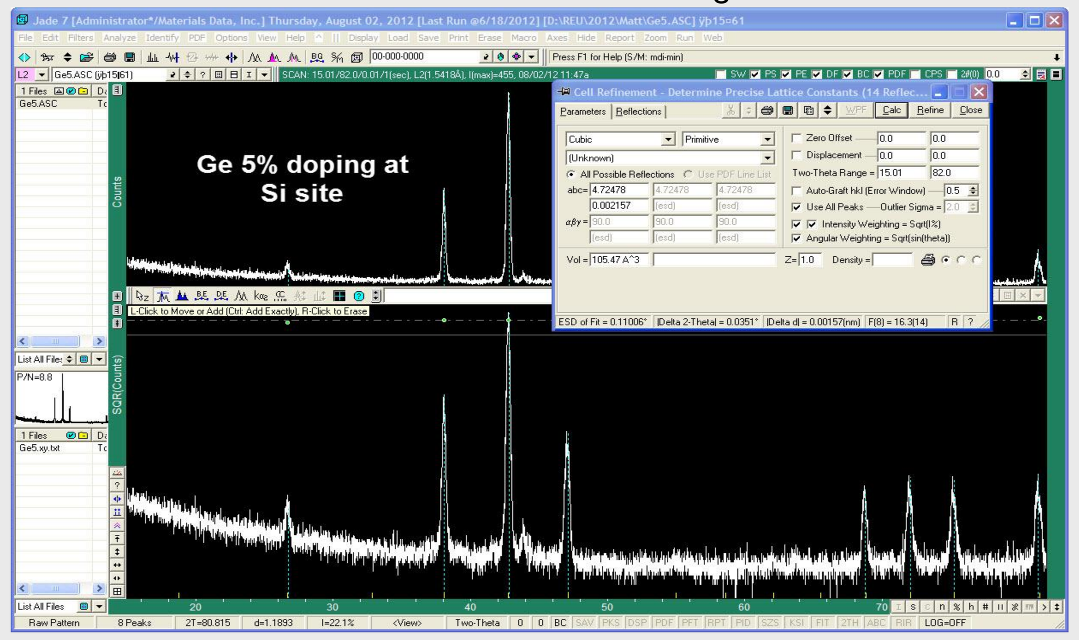

Fig.3 Peaks and lattice constants were found on the Jade software program

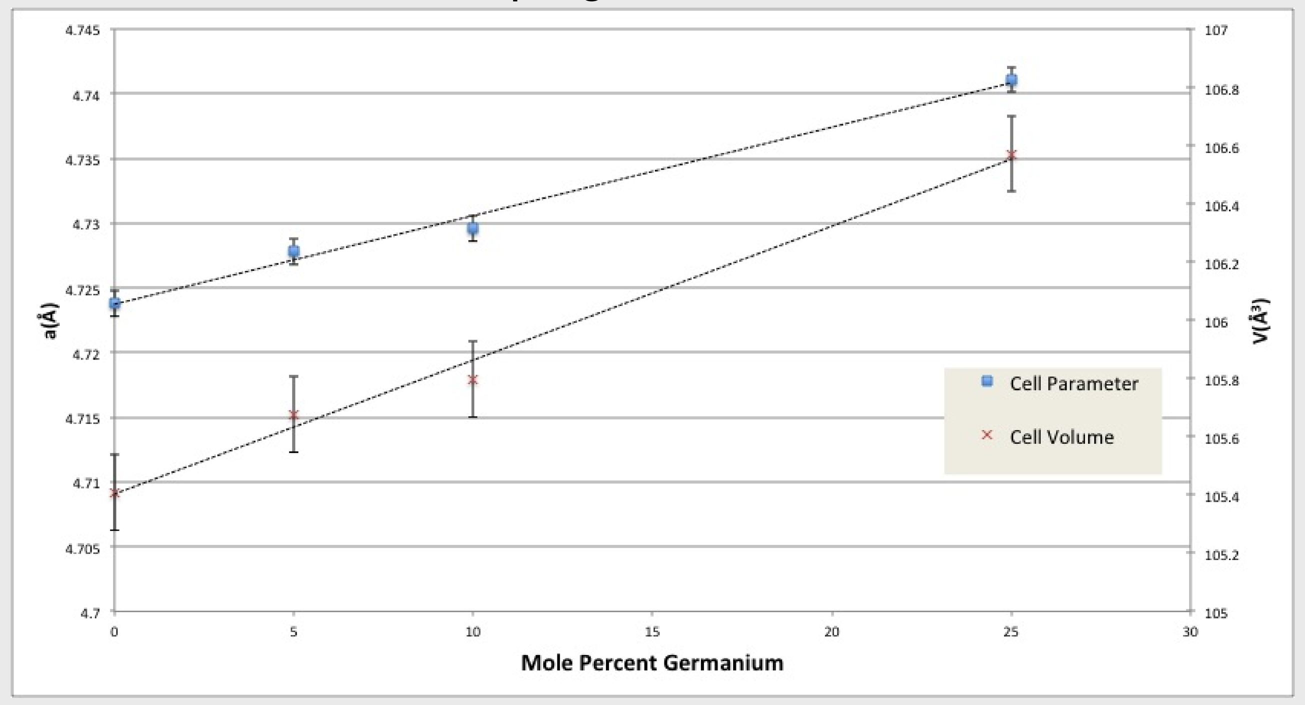

Fig.4 Variation of lattice parameter *a* and volume as a function of increasing germanium doping in V_3Si

RESULTS

Cobalt doped samples:
X-ray diffraction patterns indicated an amorphous phase in all samples which was primarily broad background with a few small, but insignificant peaks.

Germanium doped samples:
Samples showed parent V_3Si XRD patterns, indicating a cubic crystal structure [3], shown in Figure 2. Peak angles varied with dopant concentration, indicating slightly different unit cell spacing. Upon analysis, lattice parameter *a* increased proportionally to germanium concentration.

DISCUSSION

The increase in lattice parameter with Ge doping is expected since germanium is larger than silicon. A phase change was not expected because germanium and silicon have similar valence shell electron configurations.

Superconductivity will be tested down to 10K to determine the effects on transition temperature. This will be done in a physical property measurement system (PPMS) by performing AC magnetic susceptibility. Measurements.

CONCLUSIONS

Single phase germanium doped V_3Si were successfully synthesized using arc melting. Cobalt doped V_3Si yielded an amorphous phase when arc melted.

REFERENCES

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