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# PROPOSED SEARCH FOR SUPERCONDUCTIVITY IN THE SEMICONDUCTOR SiTe

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# ERRATA

## Erratum: Proposed search for superconductivity in the semiconductor SiTe [Phys. Rev. B 10, 870 (1974)]

Richard Dalven

The following reference was called to the author's attention too late to include in the published paper. L. G. Bailey [J. Phys. Chem. Solids 27, 1593 (1966)] has reported that the compound SiTe does not exist in the silicon-tellurium system. There is thus a discrepancy between the results of Bailey and those of Smirous *et al.* Until this question is definitely resolved, the results on possible superconductivity in SiTe, which were based on Smirous's published work, remain unchanged.

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# Proposed search for superconductivity in the semiconductor SiTe

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It is shown, based on experimental data in the literature, that silicon telluride is a semiconductor with an energy gap of approximately 0.47 eV at 0 °K. It is suggested that SiTe is likely to be a superconductor with a transition temperature higher than that of GeTe with the same carrier concentration.

The only known superconducting semiconductors[1] are SnTe, GeTe, and $SrTiO_3$. Since two of these are IV-VI semiconductors, it is interesting to investigate other group-IV tellurides as possible superconductors. The object of this article is to point out the existence of the semiconductor silicon telluride, to determine its energy gap from experimental data in the literature, and to suggest that SiTe will very possibly be a superconductor for values of the carrier concentration typical of those of the other group-IV tellurides.

The only paper published in the last twenty years on the electronic properties of SiTe is that of Šmirous *et al.*[2] These workers synthesized SiTe and determined that its crystal structure is *not* of the NaCl type. They also measured the electrical conductivity $\sigma$ of polycrystalline samples of SiTe as a function of temperature. In the temperature range from 210 to 430 °K, $d\sigma/dT$ was observed to be positive, and it was concluded that silicon telluride is a semiconductor. Measurement of the thermoelectric power indicated hole conductivity.

Given these experimental results, the following investigation may be made of the quantities appearing in the BCS equation[3] based on the BCS (single-square-well) model[4]:

$$T_c \propto T_D e^{-1/N(0)V} . \tag{1}$$

In Eq. (1), $T_c$ is the superconducting transition temperature, $T_D$ is the Debye temperature, $N(0)$ is the electronic density of states at the Fermi energy, and $V$ is the attractive electron-electron interaction. The aim of this paper is the qualitative comparison of probable values of $N(0)$ and $T_D$ for SiTe with values for SnTe and GeTe, both of which are known to be superconducting semiconductors.

To discuss the value of $N(0)$ for SiTe, we note that a parabolic-band model yields the relation

$$N(0) \propto m^* n^{1/3} , \tag{2}$$

where $m^*$ is the effective mass and $n$ is the carrier concentration. We may estimate the relative magnitude of $m^*$ for SiTe as follows. The experimental plot of $\ln\sigma$ as a function of $1/T$ given by Šmirous *et al.* has the shape characteristic of an intrinsic semiconductor, and these workers report it intrinsic above room temperature. Making the usual assumptions[5] concerning such data, the slope $d(\ln\sigma)/d(1/T)$ of the intrinsic line ($300 < T < 430$ °K) yields a value of the energy gap of SiTe at 0 °K of approximately 0.47 eV. Using the $f$-sum rule[6] and considering a band model including only the lowest conduction band and the highest valence band, it can be shown[7] that

$$m^*/(m \pm m^*) = (m/2|M|^2)E_G , \tag{3}$$

where $E_G$ is the minimum energy gap, $m$ is the free-electron mass, $M$ is the $f$-sum matrix element, and the plus and minus signs are appropriate for holes and electrons, respectively. If we assume[8] that the matrix element $M$ is the same for all members of the sequence SnTe, GeTe, and SiTe, then the fact that $E_G$ for SiTe is larger than $E_G$ for GeTe[9] or SnTe[9] implies that $m^*$ is larger for SiTe than for either GeTe or SnTe. Equation (2) then states that for a given carrier concentration $n$, the density of states $N(0)$ will be larger[10] for SiTe than for the other two group-IV tellurides. In addition, the Debye temperature $T_D$ would be expected to be larger for SiTe than for SnTe and GeTe because of the decrease in atomic mass upon going from tin to germanium to silicon.

Since $N(0)$ and $T_D$ may be expected to be larger for SiTe than for SnTe and GeTe, it is concluded, based on Eq. (1), that $T_c$ for silicon telluride should, for a given value of $n$, be larger than $T_c$ for SnTe and GeTe *if* the electron-electron interaction $V$ remains approximately constant within the sequence of group-IV tellurides. (From a more empirical point of view, it may be argued that since $T_c$ is larger[11] for GeTe than for SnTe for all values of carrier concentration, it is likely that $T_c$ for SiTe would be larger than for GeTe, all other things being equal.)

Even though the discussion given above is qualitative and several simplifying assumptions are made, it seems that the conclusion that silicon telluride is likely to be a superconducting semiconductor is a reasonable one. For this reason, and because of the very small number of super-

conducting semiconductors presently known, it is proposed that the preparation of samples of silicon telluride ($p$ type due to an excess of tellurium) be investigated experimentally with the aim of obtaining hole densities in the $10^{21}$ $cm^{-3}$ range. A search for superconductivity in such samples would be interesting, and, based on the discussion above, quite probably fruitful. If superconductivity *is* indeed observed in SiTe, a comparison of the results with those for SnTe and GeTe would be most interesting to interpret in terms of current theoretical models.[12]

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[1]M. L. Cohen, Phys. Rev. 134, A511 (1964).

[2]K. Šmirous, L. Štrourač, and J. Bednař, Czech. J. Phys. 7, 120 (1957).

[3]See, for example, C. Kittel, *Quantum Theory of Solids* (Wiley, New York, 1963), p. 163.

[4]M. L. Cohen, in *Superconductivity*, edited by R. D. Parks (Dekker, New York, 1969). See also Sec. IV B, p. 661 for a discussion of the applicability of the BCS model to degenerate semiconductors.

[5]See R. A. Smith, *Semiconductors* (Cambridge U. P., Cambridge, 1961), p. 320ff for a discussion of the determination of energy gaps of semiconductors from conductivity data.

[6]See, for example, Ref. 3, p. 186.

[7]R. Dalven, J. Phys. C 6, 671 (1973), and references therein.

[8]It appears that this assumption may be rather risky since the crystal structure of SiTe is known to be different from those of SnTe and GeTe, so the band structure of SiTe may also be significantly different.

[9]See F. Herman *et al.*, J. Phys. (Paris) 29, C4-62 (1968) for values and for references to the original work.

[10]In this connection, it should be noted [M. L. Cohen (private communication)] that SiTe may not have a many-valley band structure because its crystal structure is not cubic, thereby decreasing N(0).

[11]See Ref. 4, Fig. 15.

[12]See, for example, Ref. 4, for a review.

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