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SOME PROPERTIES OF GERMANIUM-SILICON ALLOY SEMICONDUCTORS

RADIO CORPORATION OF AMERICA

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Some Properties of Germanium-Silicon Alloy Semiconductors

Approved

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Introduction

An important parameter in a semiconductor transistor material is the forbidden band gap, i.e., the minimum energy needed to release a hole-electron pair. For example, transistors made of silicon operate at considerably higher temperatures than do those which are made of germanium because of the larger band gap of silicon; however, silicon has lower charge carrier mobilities. Crystalline alloys of germanium and silicon have shown promise in that they have intermediate properties between those of their two constituents. Transistors made of such alloys may be operated at higher temperature than those made of germanium, and yet have higher carrier mobilities than those made of silicon.

This bulletin presents newly measured physical data on a variety of germanium-silicon alloys. It is shown that the properties vary continuously between the two extremes, and that only a modest addition of silicon to germanium is needed to raise the band gap appreciably.

Preparation of homogeneous alloys of germanium-silicon has been reported by Stöhr and Klemm[1] and Wang and Alexander[2]. RCA Laboratories prepared a series of germanium-silicon alloys by a process of homogenization at high temperatures and has determined composition, density, lattice constant and forbidden band gap. All alloys were homogeneous within the precision of the X-ray measurements. Absolute values of composition of the material were determined by analyzing for germanium polarographically. This method of analysis, with silicon as the sole chemical impurity, is believed to be accurate to better than ±1 per cent. Forbidden band gaps were determined optically, on samples normalized to 0.020-inch thickness. The band gap was taken as the energy corresponding to the value of the absorption which is exhibited by germanium at its accepted band gap (0.72 e.v.). At this point the absorption coefficient was 22.7 cm^{-1}. All absorption curves had slopes which were similar to that of pure germanium*.

In Table I is summarized the data obtained on these alloys. Fig. 1 shows the variation of lattice constant with composition and agrees within experimental error with that obtained by Stöhr and Klemm[1]. Lattice constant measurements indicate that one should observe a non-linear variation of density with composition due to the small volume difference between germanium and silicon. However, these measurements of density and composition are not sufficiently sensitive to detect this. Consequently, a plot of density versus composition (Fig. 2) is linear within experimental error. This indicates that density is adequate for determining composition

[1] Herbert Stöhr and Wilhelm Klemm, "Two-Component Systems with Germanium", *Zeit. für Anor. und Allg. Chem.*, 241, 4, (305-424) 1939.

[2] C. C. Wang and B. H. Alexander, "Properties of Germanium-Silicon Alloys", A.I.M.M.E., Symposium on Semiconductors, Feb. 15-18, 1954, New York, New York.

*The slopes of those curves obtained on polycrystalline specimens differed slightly from the single crystalline specimens. However, sufficient information on polycrystalline samples was obtained to indicate that the general appearance of the curve shown in Fig. 3 would not change appreciably if all the data had been obtained on single crystalline specimens.

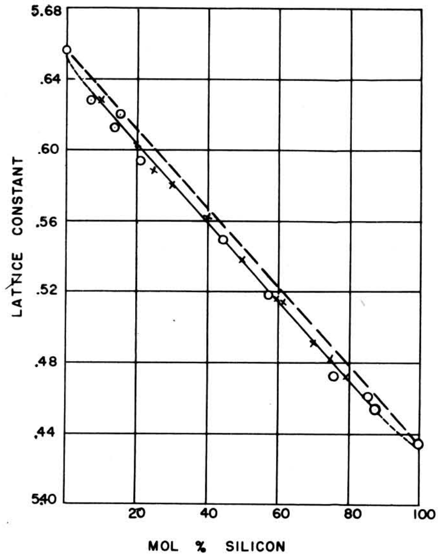

Fig. 1 - Variation of lattice constant with mol per cent silicon.

X = Values given by Stöhr and Klemm corrected to the more modern values of lattice constant for pure Ge and Si.

O = Values of lattice constant measured and reported herein.

of homogeneous material, within a few per cent. In Fig. 3 is plotted band gap versus composition. As can be seen, a marked change in slope occurs at approximately 10-mol per cent silicon. The alloys containing less than 12-mol

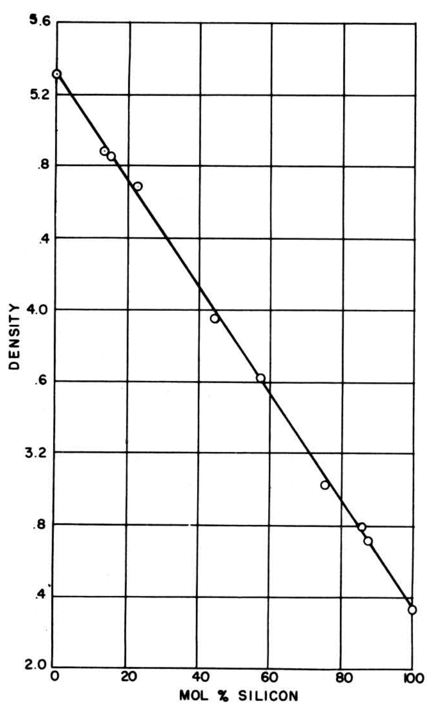

Fig. 2 - Variation of density (gms/cm^3) with composition.

Table I

Data on Germanium-Silicon Alloys

Designation	Density	Lattice Constant	Mol % Silicon	Forbidden Band Gap (e.v.)
GS-23	2.80	5.461	85.8	1.15
GS-25	2.72	5.454	87.4	1.16
GS-26	3.03	5.473	75.7	1.13
GS-29	3.62	5.518	57.5	1.08
GS-30	3.95	5.549	44.3	1.05
GS-31	4.86	5.620	15.0	0.94
GS-34	4.89	5.613	13.5	0.93
GS-37	4.70	5.593	22.9	0.94
D-40-G	--	5.626	7.0	0.91
D-28	--	--	3.0*	0.83
200-S	--	--	0.2*	0.73
Ge	5.323	5.657	--	0.72
Si	2.328	5.434	--	1.20

*determined Spectrographically

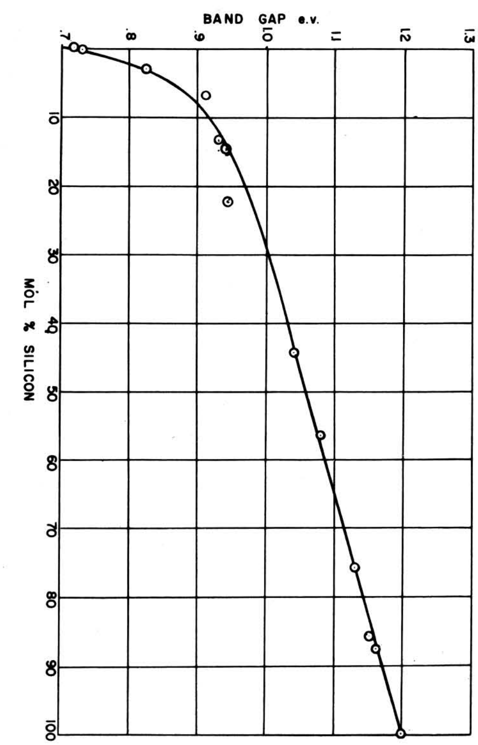

Fig. 3 - Variation of energy gap with mol per cent silicon.

per cent silicon were single crystal specimens while those containing more than 12-mol per cent were polycrystalline.

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