shows that the remanent magnetization, and thus the spontaneous magnetization (curve III) is indeed reversed at about 38°C.

When a rod of this material is magnetized and suspended torsion-free in a small magnetic field ($<H_c$), the turning of the rod over an angle of 180° on heating or cooling through the compensation temperature provides an illuminating demonstration of the existence of ferrimagnetism.

According to Néel's theory[2] this phenomenon could occur for spinels containing only one type of magnetic ions (e.g., Fe^{3+}), when a certain relation (reference 1, p. 151) holds between the distribution of the magnetic ions among the tetrahedral and octahedral positions and the ratios between the tetr.-oct., tetr.-tetr. and oct.-oct. (indirect) exchange interactions.

As these ratios are fixed by the angles Me–O–Me,[9] and the distances Me–O (Me = magnetic ion) according to unknown laws,[10] it seems likely that for one type of magnetic ion only this relation can be fulfilled for a very narrow range of ionic distributions only.

For a material containing two types of magnetic ions Me_i and Me_{ii} there are, in addition, differences between the interactions Me_i–Me_i, Me_i–Me_{ii} and Me_{ii}–Me_{ii}, so that here a corresponding relation may be more easily fulfilled.

X-ray investigation of the above series of solid solutions[11] shows *inter alia* that with increasing Cr-content a an increasing proportion of Li ions occupies the tetrahedral position. This accounts for the fact that the low temperature saturation magnetization of $Li_{0.5}Fe_{1.25}Cr_{1.25}O_4$ is unequal to zero, which value should have been expected for an arrangement $[Fe]^{tetr}[Li_{0.5}Fe_{0.25}Cr_{1.25}]^{oct}O_4$.

The magnetic investigation of the system $Li_{0.5}Fe_{2.5-a}Cr_aO_4$ will be reported upon in the near future.[12] An interesting behavior of the g factor as a function of temperature was found by van Wieringen.[13]

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[1] P. P. Ewald and C. Hermann, *Strukturberichte* (Akademische Verlagsgesellschaft, Leipzig, 1931), Vol. I, p. 350.

[2] L. Néel, Ann. phys. **3**, 137 (1948).

[3] *International Tables for X-ray Crystallography* (Kynoch Press, Birmingham, England, 1952), Vol. I, p. 340.

[4] E. W. Gorter, Nature **165**, 798 (1950); or Compt. rend. **230**, 192 (1950).

[5] L. Néel, Compt. rend. **230**, 190, 375 (1950).

[6] C. Guillaud *et al.*, Compt. rend. **229**, 1133 (1949); **230**, 1256, 1458 (1950); **232**, 944 (1951).

[7] Shull, Wollan, and Strauser, Phys. Rev. **81**, 483 (1951).

[8] For long-range order phenomena at the limiting compositions, see P. B. Braun, Nature **170**, 1123 (1952) and reference 10.

[9] P. W. Anderson, Phys. Rev. **79**, 350 (1950); E. W. Gorter, J. phys. et radium **12**, 237 (1951).

[10] R. S. Weiss, Ceramic Age **59**, 35 (1952), suggests an empirical formula for this relationship, which cannot, however, easily be tested because of the large possible error in the experimental oxygen parameter values. Theoretical background is still lacking.

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[12] E. W. Gorter and J. A. Schulkes, Physica (to be published).

[13] J. S. van Wieringen, Phys. Rev. **89**, 488 (1953).

Anomalous Behavior of the *g* Factor of LiFeCr Spinels as a Function of Temperature

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IN the preceding letter[1] ferromagnetic LiFeCr spinels are described with a curious $\sigma-T$ curve. For a certain range of values of a in the mixed crystal series $Li_{0.5}Fe_{2.5-a}Cr_aO_4$, the magnetization changes sign at a "compensation" temperature that depends on a. For $Li_{0.5}Fe_{1.25}Cr_{1.25}O_4$ ($a=1.25$), this compensation temperature is situated at 38°C. We measured the ferromagnetic resonance absorption of polycrystalline samples of $Li_{0.5}Fe_{1.25}Cr_{1.25}O_4$ at 3.1-cm wavelength as a function of temperature. The samples were placed near the bottom of a *TE*111 resonant cavity. The cavity could be heated up by a filament or cooled down by a stream of cooled air. Two spheres of $Li_{0.5}Fe_{1.25}Cr_{1.25}O_4$ of radii 0.5 and 0.2 mm, respectively, gave the same temperature dependence of g. Near the compensation temperature strong variations are found in the g factor (Fig. 1).

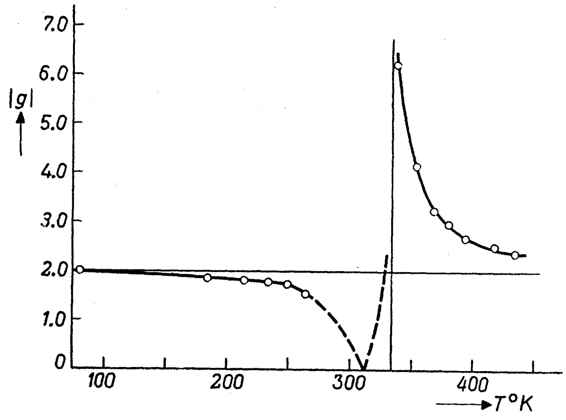

FIG. 1. g factor of $Li_{0.5}Cr_{1.25}Fe_{1.25}O_4$ as a function of temperature. Dashed curve: approximate extrapolation making use of Kittel's g-factor formula (1).

Between 263 and 337°K the resonance absorption was too weak to be observed. This is the temperature region where the magnetic moment is very small.[1] Hence the resonance peak may be expected to have a small height here. Its height is still further reduced, because the half-width increases in the same temperature region.

The general behavior of the g vs T curve can be understood from Kittel's formula[2] for the spectroscopic g factor

$$g=\frac{2mc}{e}\frac{M_{\mathrm{spin}}+M_{\mathrm{orbit}}}{J_{\mathrm{spin}}}. \tag{1}$$

Here M_{spin} and M_{orbit} are the mean spin and orbital magnetic moments, respectively, and J_{spin} is the mean spin angular momentum averaged over the two sublattices. The total magnetic moment, $M_{\mathrm{spin}}+M_{\mathrm{orbit}}$, is shown in Fig. 2 of the preceding letter.[1] It changes sign at 38°C; hence g should be zero there. From a comparison of Eq. (1) and Fig. 1 it follows that J_{spin} goes through zero at about 60°C.

A sphere (radius 0.2 mm) of $Li_{0.5}FeCr_{1.5}O_4$ ($a=1.5$) showed a similar resonance behavior.

The author wishes to thank Mr. Gorter and Mr. Schulkes who supplied the samples and Mr. Beljers and Mr. Van der Kint for their assistance during the measurements.

It is intended to publish a more detailed account in *Physica*.

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[1] E. W. Gorter and J. A. Schulkes, preceding letter, Phys. Rev. **89**, 487 (1953).

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Semiconducting Intermetallic Compounds

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THE development of solid state electronic devices has been handicapped by the very small number of semiconducting materials that have been found suitable for practical application in spite of extensive investigations of the properties of the elements and of compounds of the elements of group six of the periodic table. It seems, however, that the existence of a number of semiconductors with promising properties has been largely overlooked, namely, the semiconducting intermetallic compounds. It was pointed out by Mott and Jones[1] that intermetallic compounds with the fluorspar structure, such as Mg_2Sn, should be characterized by an unusually low conductivity, since the number of available states within the first Brillouin zone is just equal to the number of available valence electrons. This unusually low conductivity was first observed experimentally by Kurnakov and Stephanov.[2] More recently the semiconducting nature of Mg_2Sn

has been established by Robertson and Uhlig[3] who investigated the conductivity and thermoelectric power of the material.

A new series of such compounds is formed between the elements of the B subgroups of the third and fifth columns of the periodic table, such as InSb. These compounds crystallize in the zincblende structure with 4 molecules per unit cell.[4] The volume of the Brillouin zone determined by the [220] planes is $16/a^3$. Then, since the average atomic volume is $a^3/8$, there are available 4 electronic states per atom. The average number of valence electrons per atom in these compounds is 4; hence the materials would be expected to have low conductivities since the available states will just be filled.

The electrical properties of InSb, GaSb, and AlSb prepared in a state of reasonably high purity have been investigated in detail, with results to be presented later. Briefly, however, it has been found that these materials are semiconductors with properties strikingly similar to the elementary semiconductors of the fourth column of the periodic table but characterized by high charge carrier mobilities. The value for the electron mobility in InSb at room temperature is about 2.1×10^4 cm^2/volt sec. This value is in reasonable agreement with the value 2.5×10^4 cm^2/volt sec recently reported by Welker[5] for InSb. Rather high mobility values are also found in the other compounds. The energy gap increases as the size of the unit cell decreases, as is also found for the elements of the fourth column, the smallest value, *ca* 0.40 ev, being found for InSb.

It seems then that further investigation of other intermetallic compounds with filled zones should be very fruitful and may produce a considerable number of useful materials.

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[2] N. S. Kurnakov and N. J. Stephanov, Z. anorg. Chem. **46**, 171, 181 (1905).

[3] W. D. Robertson and H. H. Uhlig, Trans. Am. Inst. Mining Met. Engrs. **180**, 345 (1949).

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Observations of Dislocations in Lineage Boundaries in Germanium

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Burgers[1] proposed a dislocation model for the boundary between two crystals differing in orientation by a small rotation θ about an axis in the boundary. It consisted of a set of edge dislocations, parallel to the axis, of regular separation $D=b/\theta$, where b is the appropriate lattice translation vector. While some supporting evidence for this model has been offered, chiefly in the form of observations on etch pits in sub-grain boundaries,[2,3] a clear-cut correlation between D and θ has been lacking. We present here such a correlation, based on microscopic and x-ray studies of germanium single crystals.

The boundaries studied were selected from nearly perfect crystals grown from seeded melts in a horizontal boat,[4] the growth direction being ⟨100⟩. They were revealed by etching in a mixture of 5 parts HNO_3, 3 parts HF, 3 parts acetic acid, $\frac{1}{10}$ part Br_2. They tended to lie in (110) planes parallel to the growth direction and to maintain their general shape in successive cross sections, sometimes for distances of 5 cm or more. Examination of the boundaries at high magnification showed them to consist of regularly spaced, overlapping conical pits, as in Fig. 1, when viewed in planes transverse to the growth direction and to be invisible in planes parallel to the growth direction. These observations suggested that the boundaries consisted of edge dislocations parallel to the growth direction. This possibility was investigated by measuring the orientation difference between regions on either side of the boundary.

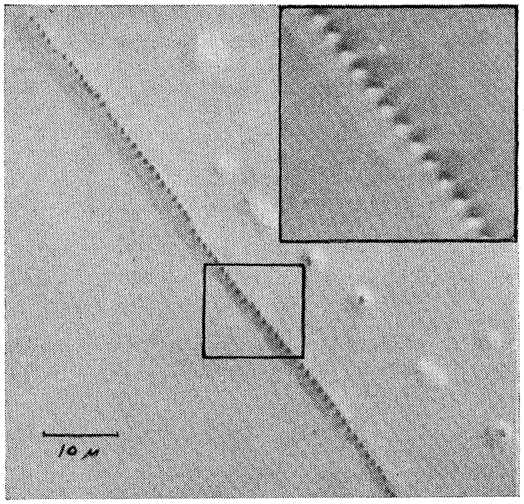

Fig. 1. Optical micrograph of lineage boundary in germanium single crystal, viewed in face transverse to growth direction. Lighting oblique.

To measure the orientation difference a boundary lying closely in a (110) plane was chosen and a cut was made exposing a (110) face normal to the boundary and parallel to the growth direction. A beam of copper K_α x-radiation was directed at the exposed face, and the intensity of the (220) reflection was measured with a Geiger tube. Curves of diffracted intensity *versus* angular position of the specimen were taken by rotating the specimen about the growth axis. Two curves were taken, one for each side of the boundary with the other side shielded from the x-rays, the difference in angular positions of the diffraction peaks being the angle θ in the above equation.

Table I. Calculated dislocation spacings and observed pit spacings.

Specimen No.	Orientation difference θ (sec)	D_{calc} (cm)	D_{obs} (cm)
128	17.5 ± 2.5	$(4.7\ \pm0.7)\times10^{-4}$	$(5.3\ \pm0.3)\times10^{-4}$
141	65.0 ± 2.5	$(1.3\ \pm0.1)\times10^{-4}$	$(1.3\ \pm0.1)\times10^{-4}$
144	85.0 ± 2.5	$(0.97\pm0.2)\times10^{-4}$	$(0.99\pm0.2)\times10^{-4}$

Good agreement was found between the separation D_{calc}, obtained from measured θ, and the separation between pits, D_{obs}, measured microscopically, for three boundaries from different crystals, as shown in Table I. Since both boundaries lay very nearly in a (110) plane, b was taken as one-half the face diagonal of the germanium unit cell, or 4.0A, a value arrived at from consideration of the geometry of the dislocation array.

Further information was obtained from x-ray diffraction photograms made by interposing a film between the specimen and the

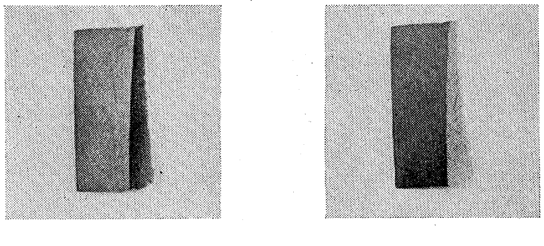

Fig. 2. X-ray diffraction photograms of specimen of Fig. 1 viewed in face parallel to growth direction and normal to lineage boundary, taken at positions differing by a rotation of 25 seconds about the growth axis.