Effect of high uniform pressure and residual stress on the superconductivity of alloys of the $V_3(Si_{1-x}Ge_x)$ system

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The dependence of the superconducting transition temperature T_c on pressure (p up to 30 kbars) and compressibility is studied in $V_3(Si_{1-x}Ge_x)$ alloys. In all alloys T_c depends on p linearly. The magnitude of dT_c/dp grows linearly with the Ge content. It changes from 4×10^{-5} degree/bar in V_3Si to 7×10^{-5} degree/bar in V_3Ge. It is shown that the sharp concentration dependence of T_c in $V_3(Si_{1-x}Ge_x)$ alloys does not correlate with the variation of the mean atomic volume of the alloys induced by Ge doping of the alloys. This is in contradiction to the predictions in[1,2] regarding the behavior of the alloys under pressure or on alteration of their composition. Inhomogeneous uniaxial stresses on powder samples results in a strong broadening of the temperature range in which the superconducting transition occurs. The magnitude of the temperature range varies in a regular manner with variation of the composition, maximal expansion being observed in the V_3Si alloy. Some peculiarities of the effect are considered.

Alloys with composition V_3X (where X is an element from subgroup IIIB or IVB) have been attracting particular attention because of the following exceedingly interesting physical properties: high critical parameters T_c and H_c of the transition to the superconducting state; an anomalous temperature dependence of the magnetic susceptibility, of the Knight shift, and of other constants; and the presence in them of a low-temperature structure transformation due to the loss of crystal lattice stability (see the review by Testardi[1]). In spite of the tremendous number of investigations devoted to these alloys, the great complexity of their electronic structure has made it impossible to solve completely the problem of the connection of T_c with the characteristics of their phonon spectrum and with such parameters of the electron structure as the density of the electronic states at the Fermi level or the magnitude of the electron-phonon interaction.

Recently Testardi[1,2] continued his study of the elastic properties of V_3X alloys in the anharmonic approximation. This approach has provided a better explanation of the cause of certain features of their physical properties. In particular, according to his analysis, the alloys should have a strong dependence of T_c on the lattice deformation:

$$T_c - T_c(\max) \approx -10^5 \varepsilon^2 \ {}^\circ\mathrm{K},$$

where $\epsilon = (c - a)/a$ in the case of tetragonal deformations (a and c are the lattice parameters), and $\epsilon = (a - a_p)/a_p$ for cubic deformations (hydrostatic compression), where a_p is the lattice parameter at which T_c has a maximum as a function of the volume (T_c(max)). This character of the dependence of T_c on the deformation should have led to a difference in the signs of dT_c/dp for V_3Si and V_3Ge, namely negative for V_3Si and positive for V_3Ge. Experiment has shown, however, [3] that $dT_c/dp > 0$ for both compounds.

Analyzing the properties of these compounds from a unified point of view, Testardi[1] reached the conclusion that "in many V_3X alloys the principal contribution of the X atoms is that they change the average atomic volume of the alloy. This is most clearly pronounced in the isoelectronic alloys V_3Si and V_3Ge, where the changes of T_c are due mainly to the change of the atomic volume..."$^{1)}$ (see[1], p. 80).

We deemed it of interest to investigate in greater detail the behavior of the alloys $V_3(Si_{1-x}Ge_x)$ under hydrostatic compression. Indeed, by comparing the changes of T_c due to the same decrease of the lattice parameter for both hydrostatic pressure and as a result of alloying, we can verify the extent to which Testardi's assumptions are satisfied[1,2]. For such a check it is necessary to measure the values of dT_c/dp and the compressibility in the same pressure (deformation) interval for alloys with different compositions. The first part of the paper is devoted to this question.

In alloys with A15 structure, particularly V_3Si, recently Matthias and co-workers[4] have observed that inhomogeneous residual stresses increase greatly the temperature interval in which the transition to the superconducting state takes place. These stresses were produced by uniaxial compression of powdered samples to 20 kbar. It was assumed[4] that the smearing of the transition and the formation of the second low-temperature step on the transition curve was due to a more extensive development of the martensitic transition in these alloys, under the influence of the stresses, than in the undeformed samples. In a later paper, however, McCarthy and Viswanathan[5] attempted to attribute this effect to peculiarities of the alternating-current measurements used in[4] to determine the transition curves of the powdered samples. Thus, the low-temperature part of the transition was attributed to partial screening of the sample volume by slip planes and other defects which are produced by the deformation. Since the degree of smearing of the transition in certain alloys depends on the value of their T_c, alloys of the system $V_3(Si_{1-x}Ge_x)$ are good objects for the establishment of the possible regularities, or at least correlations, between T_c and the degree of smearing. In addition, and this is probably most important, in alloys of composition close to V_3Si there is observed a martensitic transformation, to which the smearing of the transition is attributed in[4], whereas no such transformation is observed in alloys close to V_3Ge.

We have attempted at the same time to ascertain the differences between powdered-sample transition curves determined by different methods.

EXPERIMENTAL PART

We investigated alloys fused in an induction furnace in an argon atmosphere from pure vanadium (>99.9%), silicon (>99.99%), and germanium (>99.99%). After the melting, the ingots were annealed at 950° for 250 hours in an atmosphere of argon. The phase composition and the lattice parameters were determined by x-ray diffraction using powdered samples. All the alloys had a single-phase structure of type A15 after the heat treatment. The measured lattice parameters agreed with those cited by Pearson[6]. After tempering, we determined the superconducting transition temperatures of all the alloys. The transition temperatures were measured by an induction method in an alternating magnetic field with $H_{max} < 1$ Oe and frequency 37 Hz.

Let us stop to discuss more fully the details of the method. The gist of the method is to determine the temperature dependence of the inductance of measuring coils inside which the sample is placed. The T_c of the sample is usually assumed to be the temperature at which the inductance changes by 50%. In our setup, the coils were wound to form a differential transformer. A signal from a 37-Hz generator was applied to the coil, and the two secondary measuring coils, which were located inside the primary coil, were connected to buck each other. The sample was placed in one of the secondary coils. The coils together with the sample were placed in a thick-wall copper cylinder whose temperature could be regulated. The signal from the secondary coils was fed to a selective amplifier and then to a phase detector. In all measurements, the phase detector was tuned in synchronism with the generator. During the course of heating or cooling, the superconducting transition of the sample produces a change of its susceptibility and consequently a change in the detector signal V, which is proportional to the real part of the susceptibility, i.e., to the diamagnetic moment of the sample. If the field of the primary coil is weak in comparison with H_{c1} of the sample, then the detector signal is proportional at each fixed temperature V_T to the volume of the superconducting phase in the sample. The transition curve, represented by the coordinate $-(V_T - V_{20^\circ K})/V_{20^\circ K}$, is in essence a plot of the dependence of the diamagnetic moment on the temperature.

A test made by us with a sample having a superconducting transition that stretches over approximately 10° K (see below) has shown that both in the case of measurements of the temperature dependence of the diamagnetic moment in a static field 10 Oe (ballistic method) or 200 Oe (magnetic balance) and in the case of an induction method with an alternating field, the transition curves determined by all three methods and plotted in relative units fully agree with one another. It follows therefore that our transition curves reflect exactly the quantitative ratio of the superconducting volumes with different transition temperatures in the sample.

The change of the superconducting transition temperature T_c following application of a hydrostatic pressure up to 40 kbar, and the compressibility at room temperature, were measured with a special setup[7]. The high-pressure chamber had a construction of the "piston—cylinder" type. Samples in the form of cylinders of 2.5 mm diameter and 3—5 mm length were cut from the ingots by the electric-spark method. The pressure-transmitting medium was a thin (100 μ) layer of structureless graphite pressed in cigarette paper[8].

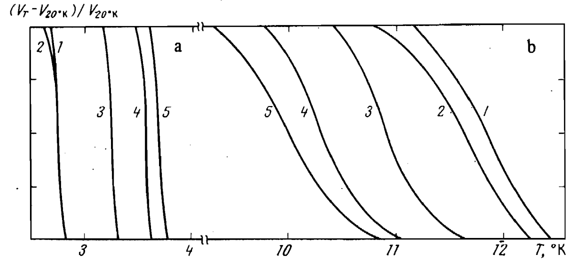

FIG. 1. Superconducting transition curves of a tin "manometer" (a) and of a $V_3(Si_{0.75}Ge_{0.25})$ sample (b) under the following pressures (kbar): 1—24.4, 2—24.4, 3—10.4, 4—3.2, 5—0.

The superconducting transition under pressure was registered likewise by an induction method. The samples were loaded in the press to pressures ~ 30 kbar at 300° K, and the press was then cooled to helium temperatures and T_c was measured as a function of the pressure in the chamber. The relative change of the temperature was determined in this case with an error less than ±0.05° K, while the error in the pressure did not exceed ±2 kbar. The pressure calibration in the chamber at 300° K was based on the BiI—BiII—BiIII transitions, and the $T_c(p)$ dependence was determined from data on the value of T_c of pure tin, samples of which were placed in the chamber together with the $V_3(Si_{1-x}Ge_x)$ samples.

The measurement of $T_c(p)$ were performed on samples with compositions $V_3(Si_{0.95}Ge_{0.05})$, $V_3(Si_{0.75}Ge_{0.25})$ and $V_3(Si_{0.35}Ge_{0.65})$. Figure 1 shows by way of example the transition curves of the alloy $V_3(Si_{0.75}Ge_{0.25})$ at different pressures, and for comparison the transition curves of a tin sample that served as a manometer.

It should be noted that alloys of the system $V_3(Si_{1-x}Ge_x)$ turned out to be very sensitive to that pressure inhomogeneity which was produced in our chamber, where the pressure-transmitting medium was a solid. As seen from Fig. 1, the transition curves of the samples under pressure were smeared over 1—2° K. Since the inhomogeneous stresses never change the temperature of the start of the transition in these alloys (see below), and this temperature changes only under pressure, we have decided to assess the effect of the pressure by determining the temperature of the start of the transition. With this procedure, the pressure effect is revealed, in our opinion, in its purest form. Were we to assess this effect by the temperatures of the middle of the transition, as is customarily done, then a much larger scatter of the data would be observed at approximately the same results. The results that follow will therefore pertain to the influence of the pressure on $T_{c_{in}}$.

The compressibility was measured at 300° K by recording the displacements of the piston after lowering the samples to 30 kbar in the high-pressure chambers. We determine the compressibilities of the alloys $V_3(Si_{0.95}Ge_{0.05})$, $V_3(Si_{0.75}Ge_{0.25})$ and $V_3(Si_{0.5}Ge_{0.5})$. The error in the compressibility was quite large but did not exceed ±50%.

To determine the influence of the composition on the temperature interval in which the transition to the superconducting state takes place as a result of the inhomogeneous residual pressures, the samples were

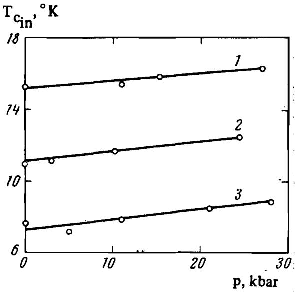

FIG. 2

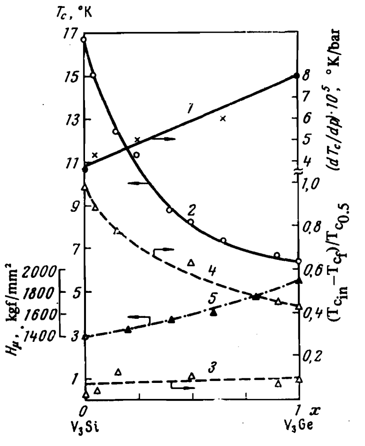

FIG. 3

FIG. 2. Dependence of the temperature of the start of the superconducting transtion $T_{c.\,in}$ on the pressure for the following alloys: 1—$V_3(Si_{0.95}Ge_{0.05})$, 2—$V_3(Si_{0.75}Ge_{0.25})$, 3—$V_3(Si_{0.35}Ge_{0.65})$.

FIG. 3. Dependence of certain properties on the composition of the $V_3(Si_{1-x}Ge_x)$ alloys: curve 1—dT_c/dp; 2—T_c, 3, 4—values of $(T_{c_{in}}-T_{cf})/T_{c_{0.5}}$(see the text), 5—microhardness H_μ. Curves 1, 2, 3, 5 pertain to samples in the initial annealed state; curve 4 pertains to powdered samples after loading to 20 kbar; ●—data of [3]: ▲—[9].

subjected to a treatment similar to that used in[4]. Pieces of the ingots were crushed and ground into a powder in an agate mortar, and then the powder was wrapped in a lavsan polyester film and placed in a chamber of the "piston—cylinder" type, while the sample was compressed, the load on the piston being raised to 20 kbar. The load was then removed. The produced pellet was extracted from the chamber and the superconducting transition in the pellet was determined by an induction method. In addition, the intensity of the (321) line of the powders processed in this manner was measured with an x-ray diffractometer in order to estimate the residual lattice deformation.

RESULTS AND DISCUSSION

A. Influence of Hydrostatic Pressure on T_c of $V_3(Si_{1-x}Ge_x)$ Alloys

Figure 2 shows plots of the temperature of the start of the transition against the pressure, for the investigated alloys, while Fig. 3 (curve 1) shows the dependence of the quantity dT_c/dp on the composition, plotted in accordance with our data and the data of Smith[3]. We see that the agreement with Smith's results[3] is satisfactory, in spite of the fact that the latter were determined by a method in which the hydrostatic pressure was kept more homogeneous. We see that $dT_c/dp > 0$ for all the alloys, and dT_c/dp itself increases approximately linearly with increasing Ge concentration in the alloys.

According to our measurements, the volume compressibility of the alloys $V_3(Si_{0.35}Ge_{0.65})$, $V_3(Si_{0.75}Ge_{0.25})$ and $V_3(Si_{0.95}Ge_{0.05})$ is low and lies in the range $(0.4-0.8)\times 10^{-6}$ bar^{-1}. From the data of Testardi (see[1], Table IV) on the elastic moduli C_{11} and C_{12} in the cubic phase, we can easily calculate the compressibilities of V_3Si and V_3Ge at 300° K. They are equal to 0.568×10^{-6} and 0.587×10^{-6} bar^{-1} respectively. Thus, the compressibilities of the alloys of the system $V_3(Si_{1-x}Ge_x)$ are close in value.

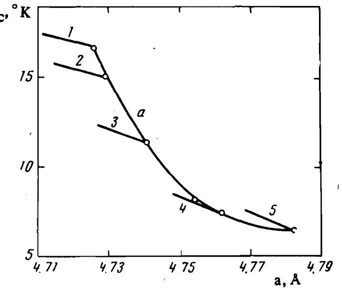

FIG. 4. Dependence of T_2 on the lattice parameters for $V_3(Si_{1-x}Ge_x)$ with different degrees of alloying (curve a) and under hydrostatic compression (straight-line segments, see the table).

Values of $\partial T_c/\partial a$ for certain $V_3(Si_{1-x}Ge_x)$, obtained from data on the compressibility and on the elastic moduli [1], and from data on the dependence of T_c on the lattice parameter a

Composition	Number of curve, Fig. 4	$\partial T_c/\partial a$, deg/A	
		at p = 1 atm	at the given composition
V_3Si	1	4.4	0.48 [1]
$V_3(Si_{0,95}Ge_{0,05})$	2	3.7	0.52
$V_3(Si_{0,75}Ge_{0,25})$	3	2,9	0.65
$V_3(Si_{0,35}Ge_{0,65})$	4	0.9	0.71
V_3Ge	5	0.091	0.8 [1]

The results of the measurements of the compressibility by different methods, under pressure and with the aid of an ultrasonic technique, are in satisfactory agreement. This is a very important fact, since Testardi[1] (p. 82), attempted to attribute the observed discrepancies between Smith's data[3] on dT_c/dp of V_3Si and his predicted[1] behavior of V_3Si under pressure to the fact that the compressibility used for the calculations was taken from results of ultrasonic experiments in which the deformations are small ($\sim 10^{-6}$). At large hydrostatic pressures, when the deformations reach $\sim 10^{-3}$, the compressibility might differ appreciably. We see that this is not observed in the experiment. Since we know that the bulk moduli in these alloys vary little when the temperature changes from 300 to 4.2° K (< 1%), we can take the compressibility at 4.2° K to be equal to the compressibility at 300° K.

It is important that the compressibility does not depend on the pressure in the pressure interval 10—30 kbar, where the volume effects due to the impacting of the high pressure cell no longer affect the results. It follows from this fact that when the alloys are compressed to 30 kbar the crystal-lattice parameter a decreases linearly with increasing pressure. We recall that the pressure dependence of T_c is nearly linear for all $V_3(Si_{1-x}Ge_x)$ alloys.

The data obtained enables us to compare quite simply the changes of T_c resulting from equal changes of the lattice parameters both in the case of alloying, i.e., when silicon is replaced by germanium, and in the case of hydrostatic compression at a fixed composition. This comparison can be made by setting in correspondence the values of $\partial T_c/\partial a$ determined at p = const or x = const, where x is the atomic fraction of Ge. The values of $(\partial T_c/\partial a)_{p=\mathrm{const}}$ were determined graphically from the plot of T_c against the lattice parameter (see Fig. 4), and $(\partial T_c/\partial a)_{x=\mathrm{const}}$ were calculated from the data on the compressibility and on dT_c/dp. These values are listed in the table for five alloys. The straight lines in Fig. 4 show the sections of plots of $T_c = f(a)$ for the five alloys. These straight lines show clearly how T_c of different alloys vary with decreasing lattice parameters under hydrostatic compressure. As seen from the data, there is a considerable discrepancy between the values of $\partial T_c/\partial a$, especially for alloys close in composition to V_3Si. This indicates quite obviously that one atomic volume cannot be a decisive factor in the value of T_c.

Since the atomic weights of silicon and germanium differ noticeably, the substitution in the sublattice X of one element by another must of necessity cause a change in the average phonon frequency $\langle\overline{\omega}_{ph}\rangle$ and in the Debye temperature. Therefore, when calculating the expected value of T_c in V_3X compounds, both for the case of alloying and for lattice deformation, it is necessary to take into account primarily the character of the changes occurring in the phonon spectrum and in the band structure. A rather successful attempt at such estimates of T_c was undertaken by Hopfield[9], who made rather simple assumptions concerning the form of the phonon spectrum. Unfortunately, the lack of the correct experimental data on the structure of the elastic and electronic spectra of $V_3(Si_{1-x}Ge_x)$ alloys and on the character of the variation of these spectra with changing lattice deformation does not make it possible to predict correctly the variation of T_c of different alloys under pressure.

B. Effect of Residual Stresses on the Superconducting Transitions of $V_3(Si_{1-x}Ge_x)$ Alloys

As already mentioned, to investigate the influence of the composition on the width of the temperature interval in which the transition takes place, all the alloys were subjected to identical treatment, after which residual stresses appeared in the powders. X-ray photography has shown that the residual deformation of the lattice is approximately the same for all alloys, and the relative distortion of the lattice parameter was $(a_0 - a)/a \sim 1 \times 10^{-8}$, where a_0 is the lattice parameter in the initial state and a is the parameter after the treatment. Since the bulk moduli for V_3Si and V_3Ge are 1.76×10^6 and 1.7×10^6 bar for the alloys V_3Si and V_3Ge, this yields residual stresses not exceeding 2 kbar.

Figure 5 shows the transition curves of a number of alloys in the initial state (Fig. 5a) and after application of pressure of 20 kbar (Fig. 5b). It is seen from the curve that after strong compression under non-hydrostatic conditions there is observed a considerable "smearing" of the transitions, as already observed by Matthias et al. for V_3Si[4]. The V_3Si transition curve determined by us practically coincides with the curve obtained in[4].

The degree of smearing of the transition can be quantitatively estimated by introducing the quantity

$$Q = (T_{c_{in}} - T_{c_f}) / T_{c\,0,5}.$$

where $P_{c_{in}}$ and T_{c_f} are the temperatures of the start and of the end of the transition, and $T_{c_{0.5}}$ is the temperature at which the signal of the amplifier changes by 50%. Figure 3 (curves 3 and 4) show plots of Q against the composition for both structural states of the alloy. Before we proceed to consider the characteristic features of the observed picture, we recall (see above) that the transition curves on Figs. 5a and 5b show that part of the sample volume goes over at the given temperature into the superconducting state, and that the shape of the curve is not connected with the screening of part of the volume of the sample by various types of defects, as was assumed by McCarthy and Viswanathan. The obtained data show that the following phenomena appear in $V_3(Si_{1-x}Ge_x)$ alloys after identical treatment (compression to 20 kbar).

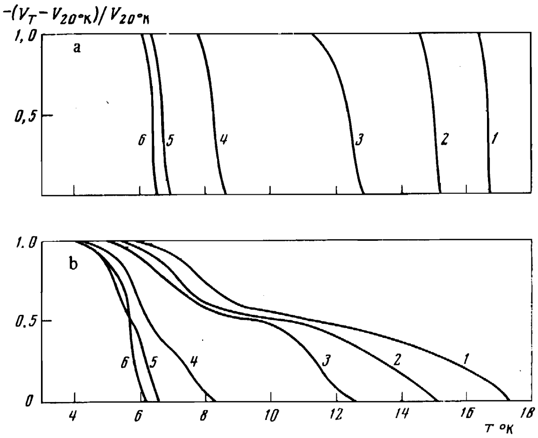

FIG. 5. Superconducting-transition curves of $V_3(Si_{1-x}Ge_x)$ alloys in the initial annealed state (a) and after loading to 20 kbar (b). The alloy compositions are: 1—V_3Si; 2—$V_3(Si_{0.95}Ge_{0.05})$; 3—$V_3(Si_{0.85}Ge_{0.15})$; 4—$V_3(Si_{0.5}Ge_{0.5})$; 5—$V_3(Si_{0.1}(Ge_{0.9})$; 6—V_3Ge.

1) Residual deformations $\sim 1 \times 10^{-3}$ and stresses not larger than 2 kbar are produced.

2) The transition curves smear out and a distinct second step appears on them; the height of this step is approximately the same for all alloys. The second low-temperature step corresponds to a transformation of ~50% of the volume. This step fails to appear only in the case of a V_3Ge alloy, in which there is no martensitic transformation.

3) The temperatures $T_{c_{in}}$ of the start of the transition remain practically unchanged, for all alloys, in comparison with $T_{c_{in}}$ in the initial state, i.e., T_c of part of the volume always remains close to the initial value. The transition itself shifts only towards lower temperatures. This shift is larger the closer the composition of the alloy to V_3Si.

4) Whereas in the initial state $Q \approx 0.1$ and close to one another, after compression Q increases by 4—10 times, while the plot of Q against the composition is very similar to the plot of T_c against the composition. In both cases, when the composition is varied from V_3Si to V_3Ge, the values of T_e and Q decrease, by an approximate factor ~2.5.

5) Just like T_c, the value of Q is maximal for alloys that have minimal values of the quantities characterizing the strength of the interatomic bond in the alloy lattice in the initial state, such as$^{2)}$ Θ_D and the microhardness H_μ (see curve 5 in Fig. 3, which was plotted on the basis of the data of[10])$^{3)}$.

When attempting to explain the causes of the observed effect, we must forgo immediately the point of view that it is due to the presence of static deformations and alloy lattice distortions in the sample. Indeed, the maximum decrease of the transition temperature of at least part of the volume of the samples, owing to the residual deformation, cannot exceed ± 0.2° K, since the residual stresses are < 2 kbar, and $dT_c/dp = (4-7) \times 10^{-2}$ °K/kbar. Even if we assume a quadratic variation of T_c with deformation[1], ΔT_c still should not exceed ± 1° K. In addition, as seen from the behavior of these alloys under pressure, the larger sensitivity to the action of stresses should be possessed by V_3Ge, and not by V_3Si. Even here, however, the opposite is observed: Q of V_3Si is much larger than that of V_3Ge. All this indicates that the residual stresses affect the behavior of T_c indirectly. Nor is the effect due to the small dimensions of the powder particles on which the transition temperature was measured. A control annealing of deformed V_3Si at 750° for two hours led to the vanishing of the second step, and its transition curve assumed the same form as in the initial state. Obviously, after such a short annealing time there could be no sintering of the powder and enlargement of the particles, and only the residual stresses could be relieved.

The most probable cause of the observed effects is the development of a martensitic transition in the alloys V_3Si, Nb-Al-Ge, Nb_3Sn, and others under the influence of residual stresses (an idea advanced by Matthias et al.[4]). The connection of the magnitude of the smearing of the transition with the value of T_c or with the probability of the occurrence of a martensitic transformation is obvious. The details of the behavior of the alloys are quite similar to those encountered in ordinary martensitic transformations. It is known, for example, that stresses or plastic deformation in the initial state raise the martensitic point T_M in many martensitic alloys, by the same token increasing, at the same measurement temperature, the amount of the produced martensitic phase. The martensitic process is hardly ever completed, and some fraction of the initial phase always remains in the samples. The martensitic point itself depends strongly on the composition. If we assume in the analysis of the transitions in the $V_3(Si_{1-x}Ge_x)$ alloys, as is done in[4], that the high-temperature step pertains to the transition of the initial cubic phase to the superconducting state, and the low temperature step pertains to the tetragonal martensitic phase, and the ratio of the heights of the steps is equal to the ratio of the volumes of the phases in the sample, then a fair analogy is observed with the ordinary martensitic transformation. Thus, a certain amount of material with initial T_c remains in all samples after compression and cooling to a temperature lower than T_M. The temperature intervals in which the first and second transitions take place remains constant with increasing residual stresses (all that changes is the ratio of the steps, i.e., the volumes of the phases). The degree of smearing Q and other quantities vary in regular fashion with the composition.

Unfortunately, this explanation can be regarded as only one of the possible variants, until precise x-ray diffraction investigations of the samples are made in different structure states at helium temperatures. Thus, it would be necessary to investigate the influence of the composition and of the stresses on the value of T_M, to develop a procedure for an exact quantitative analysis of the ratio of the volumes and tetragonal phases in the samples, etc. The simplest way to start the solution of this problem is not with alloys of the type V_3Si or Nb_3Sn, where the difference in the lattice parameters of the two phases is very small, but in system of the V-Ru type, where the volume effect in the martensitic transformation reaches ~1%[11]. But here, too, difficulties can arise because the low-temperature phase transitions in different systems may turn out to be of different order.

In conclusion, we are deeply grateful to V. F. Degtyareva for determining the lattice parameters of the alloys, to Yu. S. Karimov and A. V. Zvarykina for measuring the temperature dependence of the magnetic moment with the ballistic setup and with the balance, and to V. N. Kodes for supplying the alloys. We are grateful to L. P. Gor'kov for interest in the work and for supplying Testardi's preprint[1].

[1)] As is well known, the value of T_c of V_3Si and V_3Ge are ~17.0 and 6.4°K, and the respective average atomic volumes are 13.1 and 14.0 $Å^3$/atom. The $V_3(Si_{1-x}Ge_x)$ alloys have intermediate values of T_c and of the atomic volumes.

[2)] As is well known, the Debye temperature $\Theta_D = 330°K$ for V_3Si and 405°K for V_3Ge.

[3)] A similar picture was observed by us in the single-phase Nb-Al-G alloys with A15 structure. In their case, the largest T_c and Q are likewise possessed by alloys with minimal H_μ. In addition, we observed in these alloys that the smearing of the transition has the following interesting feature: when the pressure is increased from 2 to 20 kbar, the temperature interval $(T_{c\,in}-T_{cf})$ remains unchanged, all that changes is the ratio of the heights of the steps on the curve. Outwardly, the picture is the same as if the content of the low-temperature phase were to increase if the stresses were to increase to a definite value.

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