Critical magnetic fields of superconducting compounds based on Nb_3Ge obtained at high pressures and temperatures

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Measurements were made of the initial section of the plot of the upper critical magnetic field H_{c_2} of compounds based on Nb_3Ge and produced at high pressures and temperatures. The maximum value of the critical magnetic field at zero temperature is estimated on the basis of these measurements.

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Nb_3Ge film has the largest critical transition temperature, 23.2 K, of all the superconducting binary compounds.[1] Bulk Nb_3Ge produced in the standard manner has a relatively low transition temperature, from 6 to 7 K, but the method of ultrafast quenching has enabled Matthias to obtain materials in which the transition begins at 17 K and has a width 10°.[2] The report that the transition temperature T_c of bulk Nb_3Ge was raised to 22 K by ultrafast quenching was not confirmed subsequently.[3]

Under conditions of high pressures and temperatures, Nb_3Ge with structure of A-15 type was first synthesized from the elements by Legger and Hall, but its superconducting properties were not measured.[4] A rise in the temperature of the superconducting transition to 13 K was observed by Blaugher after quenching molten Nb_3Ge under pressure.[4]

The Nb_3Ge synthesized by us from the elements under high pressures up to 90 kbar and at temperatures up to 2000 °C has revealed an appreciable increase of T_c; the superconducting transition started at a temperature 22.3 K. A noticeable increase of T_c was observed also in the case when molten Nb_3Ge was worked at high pressures and temperatures, and particularly when elemental germanium was added to it.[5] According to an x-ray local microanalysis, the composition of the Nb_3Ge with the maximum T_c after working at high pressure is close to stoichiometric, while the region of existence of an Nb_3Ge compound with A-15 structure is limited on the Nb-Ge phase diagram to approximately 18 at.% of germanium. Further investigations have shown that slight additions of gallium to the Nb_3Ge compound make it much easier to obtain near-stoichiometric Nb_3Ge with sufficiently high superconducting transition temperature, by lowering the required treatment pressure and temperature to 40–50 kbar and 600–800 °C.

TABLE I. Superconducting characteristics of compounds based on Nb_3Ge and worked at l
pressures and temperatures.

Sample	Working regime, P in kbar and T in °C.	T_c, K	$[dH_{c_2}/dT]_{T_c}$, kOeK^{-1}	H_{c_2}(O), kOe
1	——	6.2 ± 0.1	13.3	57 ± 3
2	70,1400	19.4 ± 0.1	17.6	235 ± 7
3	90,2000	15.7 ± 0.2	10.5	115 ± 20
4	70,1200	15.7 ± 0.2	16.0	170 ± 10

1. Initial Nb_3Ge alloy prepared by induction melting in a suspended state. The succeeding sam were quenched at high pressures and temperatures indicated in the second column of Table

2. Initial alloy, pressed powder.

3. Mixture of initial powdered alloy with elemental germanium in a weight ratio 3:1.

4. Mixture of initial powdered Nb_3Ge with 5 at.% gallium added.

It was of interest to measure the initial sections of the $H_{c_2}(T)$ curves of the upper crit magnetic field in samples obtained under high-pressure conditions. We chose for the measurem samples with narrowest transitions. The measurements were performed with a mutual-induc bridge at 33 Hz, and the amplitude of the modulating field did not exceed 0.5 Oe. Magnetic fi up to 70 kOe were produced with a superconducting solenoid. The sample temperature determined simultaneously with a germanium resistance thermometer having a very weak f dependence of the resistance, and with a gold (0.02 at.% Fe)—copper thermocouple with cor tions introduced for the influence of the magnetic field. The superconducting transition temp ture was determined from the start of the transition. For each sample, we obtained a famil superconducting transition curves with the temperature sweep effected automatically at low ve ity at various fixed values of the magnetic field H. From the experimental H and T_c points determined by least squares the initial slope of the plot of the dependence of the upper critical fi on the temperature $[dH_{c_2}/dT]_{T_c}$. Measurements of the upper critical field of many niobi compounds have shown that for these compounds the Pauli paramagnetism of the normal stat suppressed by strong spin-orbit scattering.[7] In this case the upper critical field $H_{c_2}(0)$ at z temperature can be calculated by a formula proposed by Hake[8]:

$$H_{c_2}(0) = -0.693T_c[dH_{c_2}(T)/dT]_{T_c}.$$

Table I lists the values of T_c, dH_{c_2}/dT and $H_{c_2}(0)$ for the initial Nb_3Ge obtained by induct melting in the suspended state, and for a number of samples heated at high pressure. The treatm at high temperatures and pressures leads to an increase of the superconducting-transition temp ture and of the upper critical field. It should be noted, however, that the measured values of H_c are lower than those of typical superconductors with A-15 structure having approximately same transition temperature. It is not excluded that this circumstance is connected with peculiarity of the state of the samples after quenching under pressure.

[1]J.R. Gavaler, M.A. Janocko, and C.K. Jones, J. Appl. Phys. **43**, 7, 3009 (1974).
[2]B.T. Matthias, T.H. Geballe, R.H. Willens, E. Corenzwit, and G.T. Hull, Phys. Rev. **139A**, 1 (1965).

[. Mikhaĭlov, I.V. Voronova, O.A. Lavrova, E.V. Mel'nikov, and M.N. Smirnova, Pis'ma Zh.
p. Teor. Fiz. **19**, 510 (1974) [JETP Lett. **19**, 271 (1974)].
I. Leger and H.T. Hall, J. Less Common Metals **34**, 17 (1974).
'. Blaugher, IEEE Transactions on Magnetics **13**, 821 (1977).
Vereshagin, E.M. Savitskiĭ, V.V. Evdokimova, V.I. Novokshonov, and V.G. Petrenko, Pis'ma
Eksp. Teor. Fiz. **24**, 218 (1976) [JETP Lett. **24**, 193 (1976)].
Dew-Hughes, Cryogenics **15**, 435 (1975).