Physical-mechanical Properties of Ni-Doped Boron

G. Darsavelidze, O. Tsagareishvili, D. Gabunia, Z. Zoidze & L. Gabunia
F. Tavadze Institute of Metallurgy, Georgian Academy of Sciences, 380071, Tbilisi, Georgia

ABSTRACT. Temperature dependence of interval friction and shear mudulus of boron-nickel alloys at 1Hz torsional oscillation in the temperature range from 300 to 1000 K has been investigated. In alloys with nickel content from Ï.0 to 2.5% in the temperature range 450-500 K activation energy decreases from 1.25 to 0.8 eV and frequency factor changes from $5x1O^{n}$ to $lxlO^{12}$ sec'[1]. The origin of (he maximum is explained by twin boundary migration in (100) plane. An additional maximum has been found in alloys with nickel content > 2 5% at 650 K with activation energy equal to 1.8eV and frequency factor about 10^{14} sec"[1]. It is presumed that the variations of activation parameters of basic relaxation maximum of internal friction in nickel alloyed boron is caused by changes of electron contributions into migration activation energy of twin dislocations.

1. INTRODUCTION

In covalent crystals mobility of structural defect is determined to a large extent internal stresses and electrically active alloying elements (Iendrich and Haasen, 1988). The least investigated among such crystals, from the point of view of dislocation dynamics, is ß-rhombohedral boron (below referred to as ß-boron). Its structure is characterized by a large number of deformation twins and stacking faults (McKelvy, Smith and Fynng, 1982). In complex lattice structure *$-boron* variations of bound length, coordination number, dimensions and shapes of lattice holes where atoms of alloying elements can be inserted are enchountered. Consequently electrical activity of solute atoms, nature of their influence on nucleation and migration of various structural defects can change depending on their valence and lattice position- As certain alloying dements have a strong effect on lattice parameters ß-boron (Lundstrom, 1986), it is natural to expect ranges in crystallographic and activation characteristics of defects in alloyed boron.

It has been established (Gabunia and Tsomaia, 1974, Arifov, Panteleeva and Kantov, 1974) that nickel in boron not only affects electrical and physical properties, but also changes the conductivity type. In this respect it is interesting to investigate the influence of nickel on electrical, physical and structural sensitive properties of ß-boron.

In this paper results of reseach of electrical and physical properties, as well as temperature dependence of internal friction of nickel alloyed ß-*boron* are presented. The aim of this investigation was to find connection between changes of structural sensitive properties of ß-boron and on concentration and electrical activity of alloying elements.

2 METHOD AND MATERIAL

Samples have been obtained tiirough melting of corresponding mixtures in boron nitride crucibles in a resistance furnace. The obtained samples had polycrystallme structure with irregular distribution of deformation twins and stacking faults in (100) plane. Boron alloys, containing 0.8... to 2.5 at % nickel, have been investigated. Electrical and physical properties of samples at room temperature have been investigated by fourprobe method in constant magnetic field. Temperature dependence of interval friction and shear modulus have been studied at 1Hz torsional oscillaüons It was shown (Table 1) that alloys containing up to 2 5 at % of nickel at room temperature are characterized by hole conductivity Hole concentration varied from 10^{17} to 1O" cm \ their mobility changed in 10 25 cm^2V'"sec ' range Conductivity type inversion takes place *in* alloys containing more than 2 5 at % nickel In such alloys concentration of electron earners changes from 10^{19} to 10 cm , while mobility decreases from 5 to 2 5 cm^2V 'sec ' Annealing m vacuum for 5h at 1000 K has no significant effect on electrical and physical properties of boron alloys containing up to 2 5 at% Ni

In unalloyed boron at IHz torsional oscillation frequency intensive relaxation maximum has been found at about 530 K, accompanied by the shear modulus defect (=0 5) (Fig 1) At 570 K a non relaxation maximum of internal friction has been observed Above 600 K dynamic shear modulus is fully restored, that contradicts the behaviour of standard linear body" (Nowick and Berry, 1972)

Internal friction maximum at about 530 K is characterized by activation energy of 1 25eV (as determined by its temperature shift with frequency) and frequency factor of $5x10^{13}$sec ' There was found no internal fncùon maximum at 570K m the studied alloys of B Ni system (Fig 2) Temperature and activation characteristics of relaxation process at 530 K decrease as concentration of nickel increases (Table 2) In alloys with electron conductivity broad relaxation maximum was observed at about 650 K with intensity = 0 05 ind modulus defect = 015 Relaxation process is characterized by activation energy 1 8eV and frequency factor $1x10^{-4}$sec ' Activation charactenstics do not depend on nickel content in the range of studied alloy concentrations

Table 1 Electrophysical characteristics of Ni-doped boron

Material	Conduction type	Charge earners concentration cm^3	Mobility of charge cames, cm V" sec '
B	P	5 10^{16}	12
B+0 8at%Ni	P	**no^{17}**	20
B+l 7at%Ni	P	3-10^{18}	25
B+2 5at%Ni	n	2 10^{20}	5

Table 2 Physical-mechanical charactenstics of Ni-doped boron

Matenal	Maximum temperature, K	Acuvaaon energy, eV	Frequency factor, sec '	Shear modulus, GPa
B	530	125	$5*I0^{13}$	175
B+0,8at%Ni	510	1 10	$1*10^{13}$	185
B+ 1 7at%Ni	490	105	$5*10^{12}$	190
B+2 5at%Ni	475 650	0 80 180	$1*10^{12}$ $1*I0^{W}$	200

Retaxation maximum intensity increases with the growth of deformation amplitudes while the maximum shifts by 10-20K to lower temperatures These changes in alloys are similar to those m bec metals and germanium crystals in which internal friction maximum connected with dislocations are observed (1) It is supposed, that intensive maximum at 530 K is connected with migration of twin boundaries by nucleation and expansion of twinning dislocation loops on (100) planes changes maximum at 650 K, found in alloys with n - type conductivity, might be connected with reversible of stacking width Taking into account results of our research (Darsavehdze and Tsagareishvili, 1986) and specific pecuiianties of dislocation migrations in alloyed semiconductors (Belıavskı, Dannski and Shalimov, 1982) we can interpret our results in the following way at low stresses (-10^5 G) activation energy of coherent twin boundary migration includes the energy of twin dislocation loop nucleation, migration energy of kinks along the twinning plane and, interaction energy of kinks with anchoring solutes Nickel forms oxides, mtndes and carbides, that lower caneenttatian of solute atoms around dislocations Another explanation can be connected with electrically active solute atoms of nickel that can shift Fermi level near dislocations As a result, concentration of electrons and holes m dıslocaüon zones splitted by deformation fields of dislocation from the edges of volume zones (those of valence and conductivity) may change Redistribution of charge cames in dislocation field condibons, at the expense of electron contribution, the decrease of the nucleaüon energy of kinks of twin dislocations

Thus we may suppose, that die maximum of internal frıcüon at 530K is conditioned by nucleaüon and expansion of twinning dıslocaüon loops on (100) plane Mechanism, explaining maximum at 650K may be connected with reversible changing of stacking fault width in twining planes under the influence of oscillating stresses

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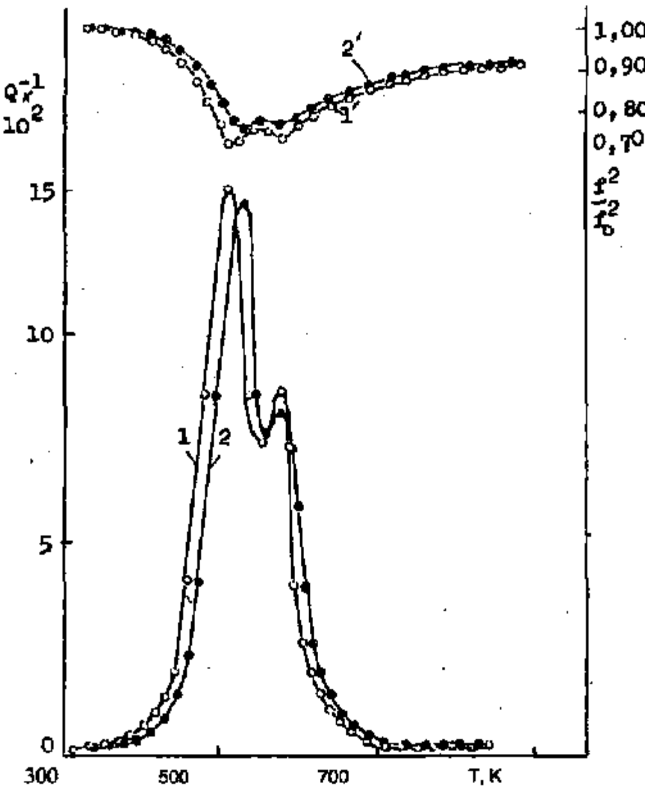

Rgure I. Imemal friction spcctrumfQ"[1]) and relative shear modulus (fVf_0^2) of polycrysialline **ß-boron.**

1,1* -Q'andfVtVat the frequency fo=lHz

2,2' - Q'and f^3/f_0^2at the frequency fo=5Hz

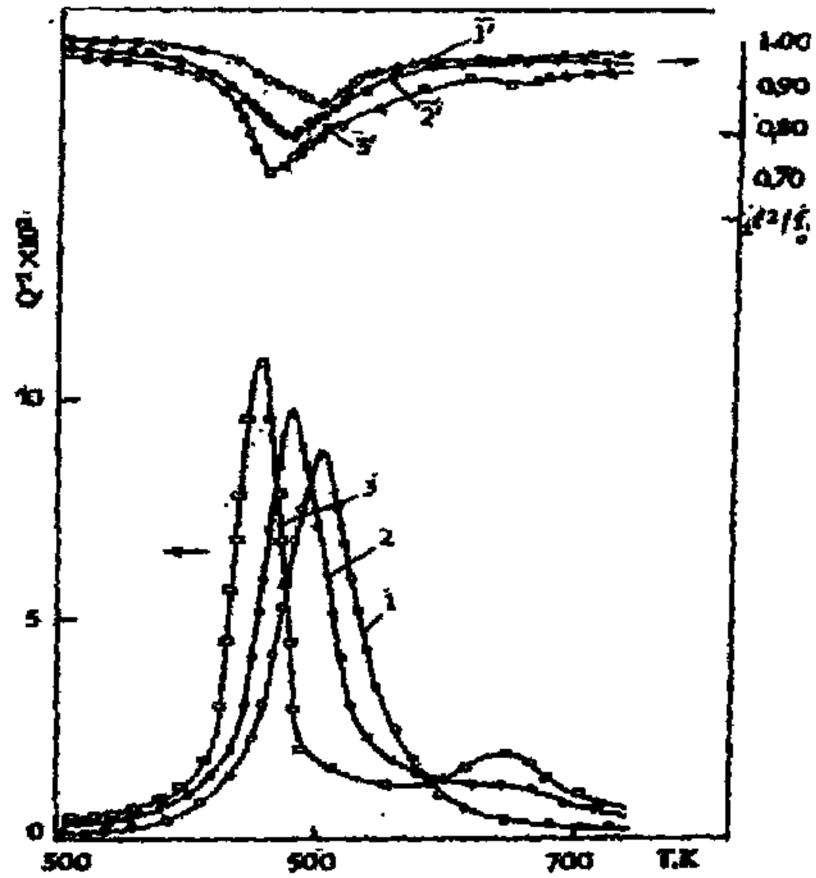

Figure 2 Internal friction spectrum(Q ') and relative shear modulus (f^/fo^3) of Ni-doped boron

1, r -Q 'and $f^2/f_0^2$of B+0 8aL%, Ni, ftf=lHz

2,2" Q 'and *Pftfof* B+1 7at %, Ni, fo=lHz

3,3' Q 'and f^2/^^{2} of B+2 5at %, Ni, fg=l 2Hz