SYNTHESIS AND MECHANICAL CHARACTERISTICS OF THE INTERMETALLIC COMPOUND Nd_3Al

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In the manufacture of permanent magnets of the Nd–Fe–B system, the necessity of melting the Nd_3Al master alloy for performing liquid-phase sintering and increasing the coercive force in these magnets arises.

The authors made an attempt to prepare magnets by the so-called "two-phase" technology. The $Nd_2Fe_{14}B$ monophase alloy and a low-melting-point addition, namely, the Nd_3Al intermetallic alloy, are melted individually, which makes it possible to perform sintering at a lower temperature and protect neodymium from oxidation. The Nd_3Al alloy can be stored for many years under normal conditions without changes in the chemical and the phase composition. However, we failed to grind the melted alloy to a required granulometric composition because of its increased ductility, which gave reasons for investigating the mechanical properties of the Nd_3Al intermetallic compound.

According to the Nd–Al binary diagram [1], the Nd_3Al composition was chosen, and a mixture was prepared. As starting materials, we used NM-1 metallic neodymium (TU-48-4-205-72) and aluminum (99.999%). An ingot of the alloy was obtained in an argon-arc furnace. To study the structural state and phase composition, the methods of X-ray structural analysis, scanning electron microscopy (SEM) with electron probe microanalysis of the chemical composition of the phase components, and optical microscopy were used. Strength characteristics ($\sigma_{ult.b}$ and $\sigma_{y.b.}$), plasticity characteristics, and Young's modulus were determined in three-point bending tests. The fracture toughness (K_{Ic}) was investigated in bending tests of specimens with an induced crack. The obtained data are presented in the table.

The performed X-ray structural analysis showed that the obtained alloy consists of several phases: the Nd_3Al intermetallic compound and oxide phases Nd_2O_2 and $NdAlO_3$. The main phase is Nd_3Al, and the content of the secondary phases is at most 3%.

Table
Mechanical properties of the Nd_3Al intermetallic compound

Ultimate strength $\sigma_{ult.b}$, MPa	540
Yield strength $\sigma_{y.b}$, MPa	440
Fracture toughness K_{Ic}, MPa·m$^{1/2}$	7.8
Young's modulus E, GPa	52
Microhardness HV, GPa	1.35
Plasticity before fracture δ, %	0.5

The investigation of the structure of the alloy by the SEM method showed (figure) that, along grain boundaries of Nd_3Al, phases saturated by oxygen, are located. This is confirmed by the distribution of elements in the characteristic oxygen radiation obtained in the electron probe microanalysis.

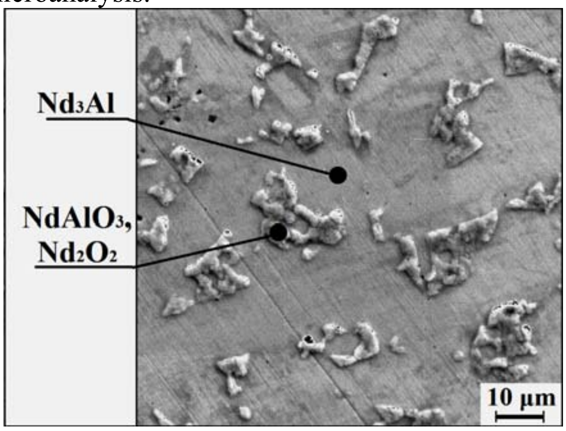

Fig. SEM image of the structure of the Nd_3Al alloy obtained from the surface of a specimen

From the results of the investigation (table) it was established that the Nd_3Al alloy has a high value of the fracture toughness and some plasticity, which distinguishes it among other intermetallic compounds.

1. Constitutional Diagrams of Binary Metallic Systems: A Handbook in 3 volumes: Vol. 1 /Ed. by N.P. Lyakishev. Moscow: Mashinostroenie, 1996, 992 p.