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VACUUM UNIT FOR HIGH TEMPERATURE ANNEALING OF MATERIALS IN THE MAGNETIC FIELD

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The vacuum unit is designed to anneal of samples of metals and alloys in a constant and alternating magnetic field in the temperature range 20…880°C under high vacuum. Study of changes in the physical and mechanical properties of structural materials due to magnetic fields exposure makes it possible to apply obtained results to deepen understanding of the physical processes during magnetic-thermal treatments, as well as to develop methods of directed change of properties.

INTRODUCTION

For investigation of the influence of constant and alternating magnetic fields on the structure and properties of different materials has been paid much attention. Magnetoplastic effect is well-known in magnetically ordered [1] and nonmagnetic materials [2]. The magnetic field has a significant impact on diffusive processes [3], change of the structural state and mechanical properties of the weld connections [4, 5], deformed [6, 7] and radiation-exposed [8] steels. Importance of understanding the physical processes under the influence of magnetic fields on the construction materials used in the experimental fusion devices and accelerator technique [9]. The mechanisms of influence of the alternating and impulsive fields on the defects of lattice are actively studied [10]. In researches of effects of influence of the magnetic fields in area of high temperatures applied to construction materials, which are actively co-operating with atmospheric gases, good vacuum terms are needed. In this connection we have designed and developed a compact unit for annealing of metals and alloys in magnetic fields in vacuum at temperatures from 20 °C to 880 °C.

DESCRIPTION OF UNIT

Unit consists of a vacuum chamber with the electrical resistivity furnace, electromagnet, systems of pumping and power supply.

The chart of unit is presented on Fig. 1.

Annealing of samples is produced in a vacuum chamber, consisting of two pieces - quartz retort with an outward and internal diameter, respectively 51 and 47 mm and high of 500 mm, in which is located annealing furnace; metal "cap" with split flange connection and communications for pumping. A quartz retort is connected with "cap" by vacuum rubber seal which has forced cooling by water. In removable flange are located the vacuumized electric inputs for power the furnace, reading the measurments of the thermocouple element and measuring of electrical resistivity of the annealed samples. EMF of the thermocouple element measured by nanovoltmeter, and electrical resistivity - with a potentiometer method. Specific electrical resistivity of the samples was measured directly in the process of annealing and after cooling at a room and nitric temperatures. Total volume of a vacuum chamber is approximately 1300 cm^3.

Pumping of the operating volume on a high vacuum can be carried out by two independent methods: by a oil vapor diffusion pump or consistently working sorption and mercury vapor diffusive pumps. Pressure of remaining gases in the operating volume of the unit with using the oil vapor pump is $(5…7)\cdot10^{-7}$ Torr with the temperature of furnace 855 °C. In the case of pumping the vacuum chamber with the consistently working sorption and mercury vapor pumps pressure of remaining gases is $(4…6)\cdot10^{-6}$ Torr. At annealing chemically active metals, such as titan and zirconium, and also their alloys, are used sorption and mercury vapor pumps. As experiments showed, annealing of these samples in a vacuum received with using of oil vapor diffusion pump, can affect on results at measuring of microhardness.

The heatimg element of furnace for annealing of the samples is made of niobium wire and fastened by the special clamps directly to massive current leads, which supplying the furnace with power. A power supply is stabilized, that allows to obtain a good temperature control during time. Drift of the annealing temperature at the temperature of furnace of 870 °C is within the limits of ±2 °C per hour. The maximal temperature of annealing obtained in the process of work is reached 887 °C. Sizes of internal (working) part of the furnace are: diameter is 15 mm, height is 97 mm. Temperature in the operated zone was measured by chromel-alumel thermocouple element in a ceramic cover, which together with samples is placed in the special quartz ampoule.

In the process of annealing the samples can be exposed to constant and alternating magnetic fields with frequency 50 Hz. The field is created by an external electromagnet, between the poles of which is located the operating volume of the vacuum chamber with annealing furnace (Fig. 1).

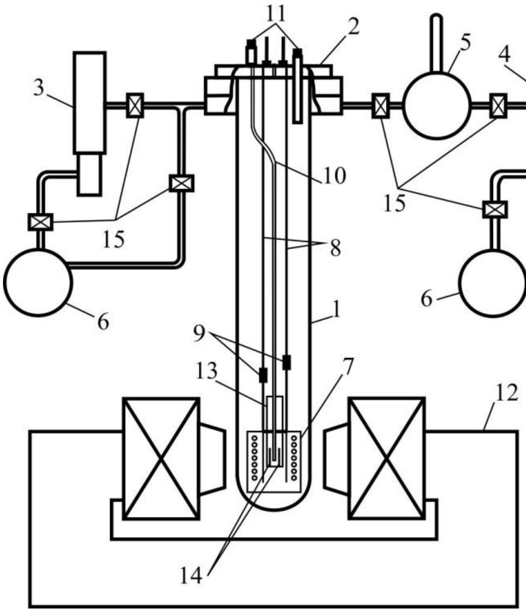

Fig. 1. 1 – quartz retort; 2 – metal "cap"; 3 – oil vapor diffusive pump; 4 – mercury vapor diffusive pump; 5 – sorption pump; 6 – forepump; 7 – annealing furnace; 8 – current leads for power the furnace; 9 – clamps for fastening the furnaece; 10 – thermocouple element chromel-alumel; 11 – vacuumized measuring inputs; 12 – electromagnet; 13– quartz ampoule for samples; 14 – annealed samples; 15 – vacuum valves

Maximal distance between poles is 52 mm. Magnetic circuit (core) of electromagnet is assembled of solenoid transformer steel thin plates and has a cross section 84×32 mm. The magnet poles, in a sectional plane parallel to the base, have the shape of an isosceles trapezoid, the smaller base of which is directed towards the center, and serve as hubs of the magnetic field in the gap. The narrowed parts of poles have the appearance of rectangle with sides 59×32 mm, that allows to create the homogeneous magnetic field in space where the annealed samples are located. The magnetic field strength inside of the furnace in horizontal direction is practically permanent, and on a vertical line on the distance of 30 mm it changes on ~ 2.5%. Magnetic field intensity was measured by the sensible sensor of Hall with the size of working area 1×1.5 mm. Permanent of the electromagnet in the center of gap is 0.0265 T/A. The magnitude of the magnetic field during the experiment ranged from 0.02 to 0.13 T. The power supply of magnet is carried out by the steady-state source of current.

Change of the magnetic field intensity along a central axial line in a gap between the poles of magnet showed on Fig. 2. Magnetic field intensity in the center of gap (in an area of the samples location) on ~ 17% less than the intensity near the surface of the pole.

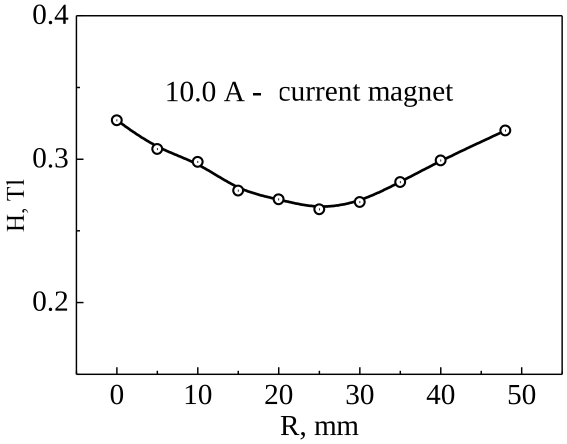

Fig. 2. Chart of the intensity change of the magnetic-field between poles in the gap of magnet

Fig. 3 shows the dependence of residual resistivity from the annealing temperature of titanium alloy samples VT6 in the initial state and deformed by the way of quasihydroextrusion on ~ 20% and rolling on ~ 30% at the temperature of liquid nitrogen. A vacuum chamber was pumped out by a oil vapor diffusion pump. At the fixed annealing temperature samples were hold during one hour in a vacuum not below $6\cdot10^{-7}$ Torr whereupon cooled down with speed, not exceeding 2.2 degree/hour. Remaining residual resistivity was measured at T = 77 with a fourpoint method.

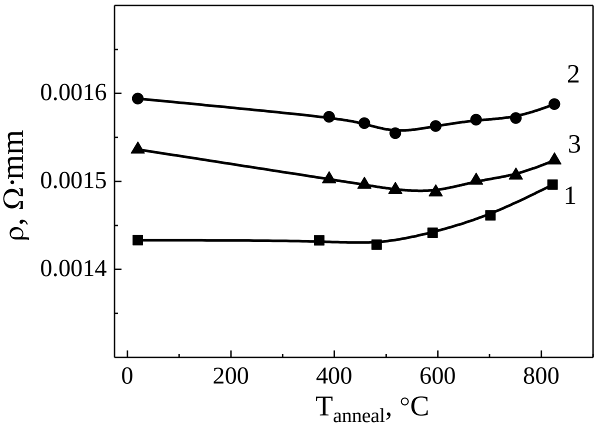

Fig. 3. Dependence of remaining residual resistivity at T=77 To of BT6 alloy from the annealing temperature: 1 – initial state; 2 – quasihydroextrusion deformation; 3 – rolling deformation

Increase of remaining residual resistivity of samples at the annealing temperatures of more than 500 °C could be connected with absorption of remaining gases in a vacuum chamber by the chemically active samples. In this case, however, the increase would be approximately identical for all samples. From Fig. 3 evidently that relative increase ρ after annealing in the interval of temperatures 500…800 °C maximal for the undeformed sample and goes down in ~ 2 times for the deformed samples, that can testify to different intensity of structural changes.

In the process of work of the unit was investigated influence of magnetothermal treatment on electrophysical and mechanical properties of clean Nickel and α-Ferrum and also on steel 15Х2НМФА depending on the degree of their low temperature deformation. The results of these experiments will be published later.

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ВАКУУМНАЯ УСТАНОВКА ДЛЯ ВЫСОКОТЕМПЕРАТУРНОГО ОТЖИГА МАТЕРИАЛОВ В МАГНИТНОМ ПОЛЕ

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Вакуумная установка предназначена для отжига образцов металлов и сплавов в постоянном и переменном магнитных полях в температурном интервале 20…880 °С и высоком вакууме. Изучение влияния магнитных полей на физико-механические свойства конструкционных материалов дает возможность применять полученные результаты для углубления представлений о физических процессах при магнитотермической обработке в различных условиях, а также для разработки приемов направленного воздействия на их свойства.

ВАКУУМНА УСТАНОВКА ДЛЯ ВИСОКОТЕМПЕРАТУРНОГО ВІДПАЛУ МАТЕРІАЛІВ У МАГНІТНОМУ ПОЛІ

Н.Б. Боброва, В.М. Горбатенко, П.А. Куценко, Є.Ю. Роскошна, В.І. Соколенко, А.О. Чупіков

Вакуумна установка призначена для відпалу зразків металів і сплавів у постійному і змінному магнітних полях у температурному інтервалі 20…880 °С і високому вакуумі. Вивчення зміни фізико-механічних властивостей конструкційних матеріалів внаслідок впливу магнітних полів дає можливість застосовувати отримані результати для поглиблення уявлень про фізичні процеси при магнітотермічній обробці в різних умовах, а також для розробки прийомів спрямованої зміни властивостей.