Technical Physics, Vol. 45, No. 5, 2000, pp. 653–655. Translated from Zhurnal Tekhnicheskoĭ Fiziki, Vol. 70, No. 5, 2000, pp. 130–132.
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BRIEF COMMUNICATIONS

Ferrite and High-Temperature Superconductor Targets for Sputtering

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Received March 30, 1999
Final version of October 25, 1999

Abstract—A method is described of preparing targets for sputtering, which involves the use of plasma deposition of respective powders onto a cooled metal plate. It is demonstrated that the use of plasma technology enables one to produce, in a controlled atmosphere, intricately shaped ceramic targets characterized by a highly uniform composition and by reliable mechanical and thermal contact of the resultant coating with the holder plate. Experiments are performed on the sputtering of targets to prepare polycrystalline ferrite films for magnetooptical applications and epitaxial films of high-temperature superconductors. *© 2000 MAIK "Nauka/Interperiodica".*

The development of computer equipment, control systems, and means of communication stimulated investigations in the field of thin-film technologies from the standpoint of both the development of relevant equipment and improvements in the manufacturing technology, as well as of the practical utilization of thin metal, dielectric, magnetic, and other film coatings. Depending on the function and desired characteristics, thin films may be deposited by a variety of systems, including sputtering ones such as diode, triode, magnetron, and other dc systems or systems involving the use of RF discharge. Along with the choice of the type of sputtering system, special attention should be given to the technology of manufacturing the cathode assembly, in particular, the methods of preparing targets and the methods of securing and cooling these targets. A great variety of methods exist for preparing targets. The main methods of preparing nonmetallic targets include pressing with subsequent sintering or hot pressing. In this case, however, one often fails to solve the problem of joining a target and a cooled holder plate.

This paper deals with an ingenious method of preparing targets on a cooled holder plate, which we believe to be promising and quite universal, namely, a method involving the use of plasma deposition. In the case of plasma deposition, a gas–powder mixture is injected into a flow of low-temperature plasma where the particles are accelerated, heated to a preassigned mass-average temperature, melted, and subsequently cooled on the surface being deposited. The use of plasma technology enables one to produce, in a controlled atmosphere, intricately shaped targets of both metal and ceramic materials characterized by reliable thermal contact of the coating with the holder plate.

The plasma deposition was accomplished using the equipment developed by us [1]. The functional diagram

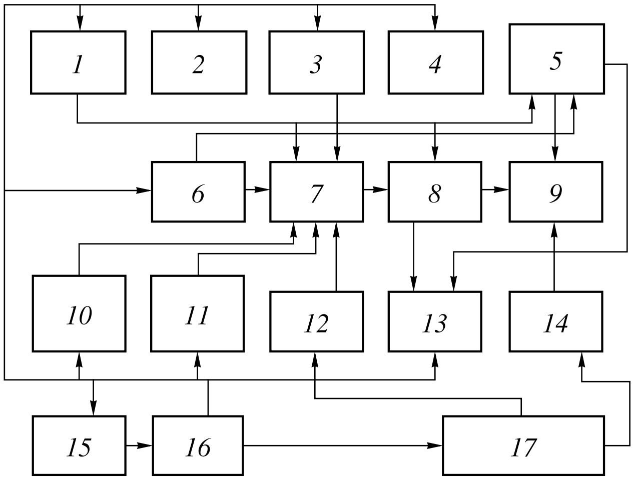

Fig. 1. The functional block diagram of the facility: (*1*) working gas delivery system, (*2*) transporting gas delivery system, (*3*) powder feeder, (*4*) feeder control unit, (*5*) device of generator mode of coating, (*6*) cooling system, (*7*) Vulkan-type plasma generator, (*8*) deposition chamber, (*9*) part subjected to deposition, (*10*) electric supply system of the plasma generator, (*11*) system for ignition of the plasma generator arc, (*12*) plasma generator-positioning mechanism, (*13*) exhaust and utilization system, (*14*) feed mechanism, (*15*) parameter measurement system, (*16*) control system of the facility, (*17*) system of control of relative positioning.

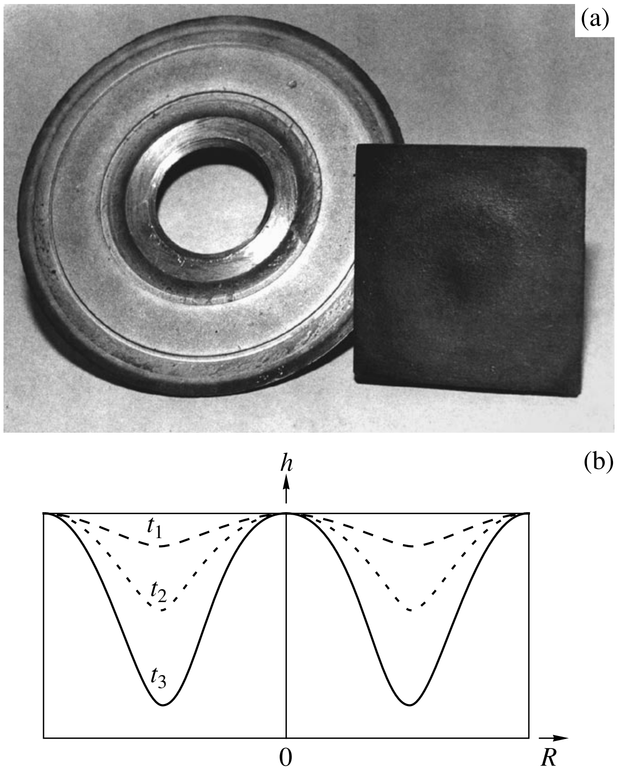

Fig. 2. (a) Exterior view of targets prepared by plasma deposition and (b) the formation of the erosion zone of a round target for different operation times t ($t_1 < t_2 < t_3$).

of the facility is given in Fig. 1. The main component of the facility is an electric-arc plasma generator with coaxial feed of powder designed to develop a flow of dispersed particles of preassigned density, temperature, and velocity.

Figure 2a illustrates plane targets of magnetic materials prepared by plasma deposition. In spite of fairly large dimensions (circular target diameter, 18 cm; thickness, 4 mm), the deposited coating is uniform, without visible cracks, spallation, or peeling off the plate (plate material, copper).

The metallographic studies of the coatings have revealed that their microstructure is typical of plasma deposition, with a characteristic form anisotropy of pores, which are, as a rule, oriented in parallel with the surface being deposited and have a depth of ~3 μm. The porosity of the coating, as well as its other properties, may be controlled by the process conditions of deposition, the optimum values of whose parameters for a number of oxide targets are given in the table.

It is known that materials of high resistivity, in particular, ferrites (10^3–10^6 Ω m), are usually sputtered in facilities with RF generators [2]. For sputtering of dielectrics in dc facilities, which are more efficient energetically, alloying additions are introduced into the composition of a target with a view to reducing its electric resistance (such additions may affect the quality of thin-film coating) [3].

The plasma deposition of a number of ferrite targets may be accomplished without alloying additions. It is known that the processing of ferrites in a reduction medium leads to a variation of the ferrite composition, loss of oxygen, an increase in the fraction of bivalent iron, and, as a result of this, to an increase in the electrical conductivity [4]. Analogous processes are observed when sputtering ferrites in a flow of low-temperature plasma. This makes possible the control of electrical conductivity within a fairly wide range owing to the choice of deposition conditions.

Note an important fact which is associated with the efficiency of utilization of the target material and largely defines the design and process singularities of manufacturing the cathode assembly. Because the intensity of sputtering of a material on a surface is nonuniform and the rate of sputtering is maximum along the axis of the discharge zone and decreases toward its periphery, an erosion zone is formed in the target in the course of operation, with the shape of that zone replicating the discharge shape (band, ring, ellipse, etc., Fig. 2b). As the erosion zone goes deeper, the angular distribution of bombarding ions varies, as a result of which the deposition rate decreases. The high efficiency of utilization of resulting targets was attained in our case by shaping their working surface, namely, by varying the thickness of the material being deposited in accordance with the profile of the erosion zone (Fig. 2b). The use of shaped targets of this type makes it possible to raise the utilization factor of the target material to 50%.

Table

Material of the target	Dispersion of powder, μm	Sputtering distance, mm	Power, kW	Plasma-forming gas		Transporting gas		Powder flow rate, kg/h
				composition	G, m^3/h	composition	gas flow rate, G, m^3/h	
$(BiY)_3(GaFe)_5O_{12}$	50–80	100	12–14	Ar	1.1	Ar + H_2	0.2 + 2	0.9
$BiDy_2Ga_{1.2}Fe_{3.8}O_{12}$	50–80	100	14	Ar	1.1	Ar + H_2	0.2 + 2	0.9
$CoFe_2O_4$	50–80	100	14	Ar	1.1	Ar + H_2	0.2 + 2	0.9
$xCoFe_2O_4(1-x)P_2O_5$	50–80	100	12	Ar	1.2	Ar + H_2	0.2 + 1.8	0.8
$YBa_2Cu_3O_7$	50–80	100	12	Ar	1.1	Ar + H_2	0.2 + 2	0.8

The above-described method was used to prepare conducting targets of ferrites $(BiY)_3(GaFe)_5O_{12}$, $Bi_{1.7}Y_{1.3}Al_{1.2}Fe_{3.8}O_{12}$, $BiDy_2Ga_{1.2}Fe_{3.8}O_{12}$, $CoFe_2O_4$, and $xCoFe_2O_4(1 - x)P_2O_5$, as well as of a high-temperature superconductor $YBa_2Cu_3O_7$. The material of the targets was synthesized by the ceramic technology.

The above-identified targets were used to prepare, by sputtering, polycrystalline ferrite films and epitaxial films of high-temperature superconductors. The sputtering of the target material was performed in a standard URMZ.279.050 provided with a dc sputtering source (triode system), in an argon atmosphere onto different substrates at a temperature of the latter of ~50°C and deposition rate of 2 A/s. The films thus prepared were in an amorphous state. The crystallization was effected by way of annealing the deposited films in air for a period of 3 h at a temperature from 600 to 900°C depending on the film composition. According to the data of X-ray spectral fluorescence analysis, the chemical composition of the prepared films is close to that of the targets used. The results of electron-microscopic and Auger-spectroscopic studies have revealed that oxide films are characterized by a uniform distribution of the components in the bulk of the film.

As was revealed by the results of studies of, for example, the magnetic and magnetooptical properties of ferrite films, the use of targets prepared by plasma sputtering proved quite efficient in developing magneto-optical storage media based on the use of polycrystalline ferrite films [5, 6].

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Translated by Henri A. Bronstein