S. V. Gaponov. *Ultrathin solid-state films and multilayered structures: methods of fabrication, study, and applications.* Films with a thickness of monatomic layers can be obtained either by slow deposition with precise control or by a pulsed method. The pulsed method requires natural mechanisms which stabilize the measured amount of the deposited material. Laser sputtering of materials in a vacuum has such properties. For definite parameters of the process, the

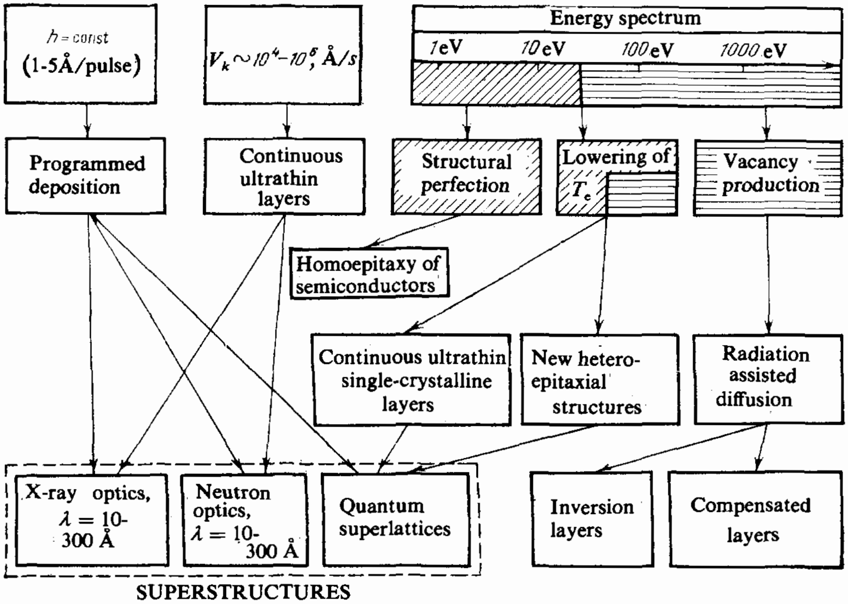

FIG. 1.

TABLE I. Semiconductor superlattices.

	Structure	Material	Layer thickness, Å
Conducting layers	Single crystal	InSb PbTe Be	50—100
Barrier layers	»	CdTe PbTe	20—50
	Amorphous	GaAs Ge C	10—20

screening of the target surface by the plasma lessens the dependence of the amount of evaporated material on the radiation intensity, and the width of the spreading pattern increases as the energy stored in the plasma cluster increases. Ultimately, the number of particles deposited per unit area of the plate positioned above the target remains constant over a comparatively wide range of intensities of the incident radiation. The high instantaneous sputtering velocity $v_k = 10^4$–10^6 Å/s and the rich spectrum of energies of the incident particles $E = 0.1$–10^3 eV allow the use of a laser plasma to fabricate different thin-layer structures. The possibilities of the laser method are summarized in Fig. 1.

The band structure in ultrathin InSb, PbTe, $Pb_{1-x}Sn_xTe$, Pbs, PbSe, and CdTe films was studied by optical methods based on size-quantization effects. In particular, the effective mass of the electrons at the bottom of the conduction band E_1 in InSb, the energy gap between the valence bands in Pbs and PbSe, and the effective mass of light holes in CdTe were determined. The dependence of the exciton binding energy on the thickness in ultrathin CdTe films and splitting of exciton levels were observed. Multilayered structures consisting of ultrathin semiconducting films (quantum superlattices) were studied. The set of materials used in the experiments is presented in Table I. Figure 2 shows a typical absorption spectrum of a superlattice and the current-voltage characteristic at room temperature.

The difficulties in fabricating multilayered optical components for soft x-ray radiation (10–300 Å) are linked to the absorption and low optical density, which are characteristic for all materials in this range. In spite of this, by using the characteristic features of the dielectric susceptibility near

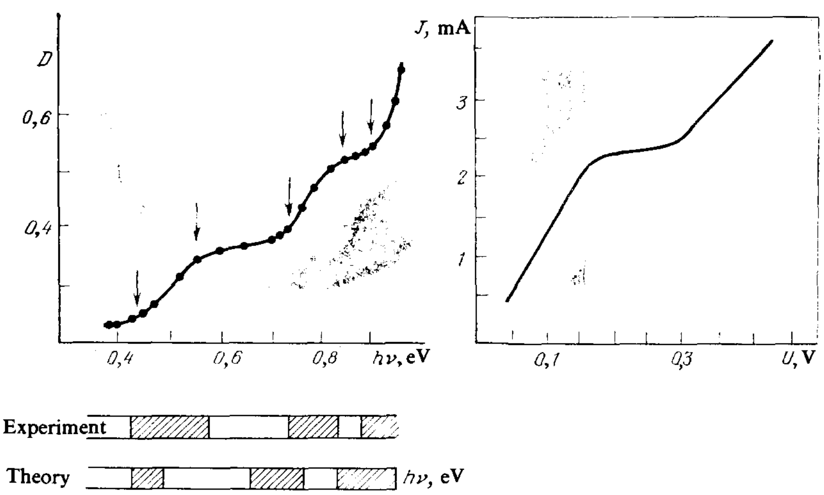

FIG. 2.

TABLE II.

λ, Å	Structure	N	θ, deg.	R_{exp}, %	R_t, %	$\frac{\lambda}{\Delta\lambda}\Big\vert_{exp}$	$\frac{\lambda}{\Delta\lambda}\Big\vert_t$
1,54	Ni (19Å)—C (22Å)	72	1,12	67	93	35	28
17,6	W (24Å)—C (41Å)	30	8,5	9,2	27,8	8,5	11
	Ni (19Å)—C (22Å)	72	12,5	4,6	25,5	70,5	49
24,3	W (24Å)—C (41Å)	30	11,5	5,6	17,5	—	10
	Ni (19Å)—C (22Å)	72	17,5	4,2	19,5	77	42
44,7	W (24Å)—C (41Å)	30	20	10	22	17	20
	Cr (16Å)—C (34Å)	40	27,7	21	33,6	33	39
	Ni (18,5Å)—C (43Å)	20	21,7	28	39,5	24	12,3
	Ni (19Å)—C (22Å)	72	33,5	19	25,5	49	33
	Ni (12Å)—C (28Å)	96	32,5	16	32	60	44,5
67	W (8Å)—C (26Å)	80	87,5	7	14	47,6	80

the K and L lines of different materials it is possible to construct over the entire range mirrors with reflection coefficients not less than 50%. This requires smooth initial surfaces (the rms height of the irregularities must not exceed 1–5 Å) and the ability to deposit ultrathin (up to 3–5 Å) layers of different (including also refractory) materials. The specific attributes of laser sputtering permit improving somewhat the initial surface and depositing ultrathin films. The results for multilayered x-ray optical materials are presented in Table II.

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