spot respectively. In the general form

$$W'_\lambda = \frac{\int_0^{2\pi}\int_0^{\pi/2} \Phi(\theta, \psi) G \sin\theta \cos\theta \, d\psi \, d\theta}{\int_0^{2\pi}\int_0^{\pi/2} D \sin\theta \cos\theta \, d\psi \, d\theta};$$

here $\Phi(\theta, \psi)$ in some general law of line-intensity distribution for some element over the surface of the star in the given phase. The integral in the numerator is S(P), in the denominator S*; S* is easily found when the law of limb darkening of the continuous radiation is given.

From the comprehensive study of all the available spectral data, we derived for the law $\Phi(\theta, \psi)$ three expressions: $\sin^3\{a\varphi_m + [(1+a)\pi/2]\}$ for the rare earths (φ_m is the magnetic latitude, a is a parameter that is different for different elements); $\cos^2\alpha$ for the elements of the iron peak, where α is the angular distance from the center of the spot, and $\cos^2(\alpha/2)$ for Si II. The areas S(P) for the elements which have a sufficient number of the lines used for constructing the growth curves were computed for a number of phases. The procedure for finding the laws $\Phi(\theta, \psi)$ and the mathematical details of the computation of S(P) are presented in [5]. We constructed for the entire set of chemical elements more than 20 separate growth curves, from which we found, using the standard method, the "observable" values of the microturbulence velocities v'_t. Investigation of the problem showed that to obtain the true value (v_t) of the velocity in a given spot, the relation $v_t = v'_t r$ must be used. The values of r for different elements in different phases range from 1.5 to 5. This means that the values of v'_t obtained from a growth curve by the "standard" method should be increased 1.5–5 times. Computing the magnetic coordinates of the center of each spot on the stellar surface, we find that the turbulence velocities vary over the stellar surface from 1.5–2.0 km/sec near the equator to 11–13 km/sec at the latitude $\varphi_m = \pm 45°$.

The illustrative determination of v_t for α^2CVn already shows that if we want to study the atmospheres of magnetic stars through their spectra, then a substantial modification of the existing methods of investigation is necessary.

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M. I. Elinson. Problems of Functional Microelectronics. Microelectronics is the new scientific-technical direction in radioelectronics that is solving the problem of the construction of complex radioelectronic equipment with preset operational parameters, the requisite degree of reliability, and acceptable dimensional, energy, and cost characteristics by the method of cell (technological) and functional (physical) integration accompanied by equipment-component microminiaturization.

Microelectronics has produced a radical change in the approach to circuit design, has produced a permanent fusion of physics, chemistry, technology, circuit engineering and cybernetics, and has, in the final analysis, caused a radical reorganization of the electronics industry.

Cell integration has preserved the old principle of radioelectronics based on the fact that the realization of any function presupposes the development of an electrical circuit that operates according to the laws of circuit theory.

This is the cause of the sharp rise in the complication of equipment in proportion to the complication of the function to be performed. It turns out that even at the high and optimum degree of integration ($\gtrsim 10^3$ components to a crystal) equipment reliability, which will be required within the next few years, will be intolerably low.

A general formulation of the problem of the optimum physical realization of the means of processing large masses of information is necessary. One of the possible ideas for the solution of this problem is the idea of functional microelectronics (FME).

The essence of FME consists in an attempt to find a new system of basic radioelectronic elements which would, in contrast to the traditional elements (e.g., transistors), possess more abundant functional possibilities.

Several directions for FME are discussed: optoelectronic devices which are primarily applicable to the problems of bionics, since neuronlike cells are promising elements for the construction of the next-generation computers; new semiconductor devices, such as Gunn and S diodes, and devices with charge migration; acoustoelectronic devices based on the interaction of current carriers with acoustic waves; and magnetic devices based on the use of cylindrical magnetic domains.

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K. A. Valiev. Present-day Semiconductor Microelectronics and the Prospects of its Development. The most typical product of microelectronics is semiconductor integrated circuits, which are a group of electronic devices (transistors, diodes, resistances, capacitors) realized in a single technological process in a single semiconductor crystal and connected together by thin pellicular metallic conductors into an electronic device—"circuit." Typical values of the area of the integrated-circuit "crystal" range from 1 to 10 mm^2; the number of electronic devices constructed on such a crystal and joined into a circuit varies from scores to several thousands. The area occupied by one element on the crystal ranges from 10^{-3} to 10^{-2} mm^2. The electrical insulation of the elements from each other is realized by means of counter-biased p-n junctions or thin layers of a dielectric.

Figures 1 and 2 show the structures of the most typi-

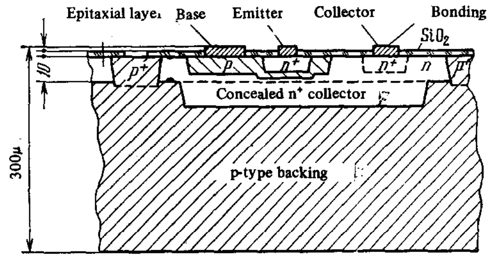

FIG. 1. The structure of an integrated bipolar transistor with a "concealed layer" and a (p-n)-junction insulation.

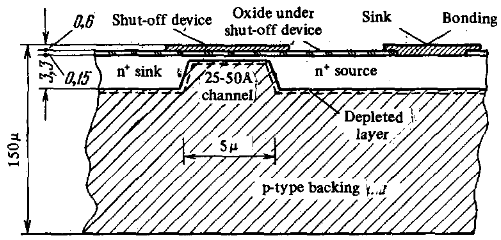

FIG. 2. The structure of a MDS transistor with an n-channel

cal elements of integrated semiconductor devices—of an integrated bipolar transistor and a metal-dielectric-semiconductor (MDS) field transistor.

As can be seen in Fig. 1, the structure of an integrated bipolar transistor consists of six semiconductor layers, each of thickness of the order of a micron and doped to a given level with a donor or an acceptor impurity. The dimensions of the structure in the plan range from 2–3 μ to scores of microns. The geometrical dimensions of the plan and cross section of the structure should be maintained to within 5–10%; a similar accuracy is required in the doping.

The technological methods of fabricating integrated circuits employ the latest advances in solid state and semiconductor physics: the methods of diffusive and ion-radiation doping, the growth of single-crystal layers, the physics of the p-n junction and of metal-semiconductor and semiconductor-dielectric contacts, the methods of material evaporation and metal- and dielectric-film deposition, the methods of thermal-diffusion and ultrasonic welding of metals, image forming in polymeric photosensitive materials under the action of light and electron beams, etc. The functional properties of integrated circuits are determined by the phenomena of carrier scattering, recombination-generation processes in the volume of the semiconductor and on the semiconductor-dielectric surfaces, and radiation effects. In the investigation of the device structures of integrated circuits, we employ many of the physical methods used to investigate the properties of solids: x-ray, electron-microscopic, opticospectral, electrophysical, photoelectric, etc. Thus, the development of the technological methods of microelectronics is an example of the industrial assimilation of the latest physical methods of modifying the properties of materials, and of the latest methods of physical experiment.

The main trends of development of microelectronics lie in increasing the number of elements making up integrated circuits and in increasing the number of performable functions, as well as in increasing the speed of response of microcircuits. Let us consider what limits the speed of response and the maximum degree of complexity (degree of integration) of integrated circuits.

Analysis shows that $P\tau$ (where P is the power dissipated by the switching (logic) element and τ is the switching time), i.e., the work done by the external source on one switching, remains constant for the present level of technological development. At present $P\tau = 100$ pJ.

The uncertainty principle, $\Delta E \sim h/\tau$, yields $\Delta E = 10^{-12}$ pJ for $\tau = 10^{-9}$ sec. Thus, the result attained is worse than the quantum-mechanical limit by 14 orders of magnitude.

Closer to the result attained is the statistical limit of the dissipated power. The logic element is a bistable device. Before an operation is performed it is not known which of the two states the element is in. Thus, the element has an entropy $k \ln 2$, where k is the Boltzmann constant. The performance of a logic operation brings the element into one of the states, and the entropy vanishes. An amount of work $A = kT \ln 2 = 10^{-9}$ pJ for $T = 300$ °K should then be done; this is better than the attained result by 11 orders of magnitude.

At a signal level of V volts the power dissipated by the logical element is equal to $P = V^2/R$, where R is the active component of the impedance. The switching delay time for the logical element is determined by its RC-constant ($\tau = RC$). Combining the two relations, we obtain $P\tau = V^2C$. Thus, it is an experimental fact that at the present level of technology and for a standardized ($V = \text{const}$) supply voltage the equation $P\tau = \text{const}$ indicates the constancy of C. The capacity C of the logic element is determined by the area of the p-n junctions constituting the physical structure of the logical element. The evolution in integrated circuit technology is characterized by a gradual decrease of this area (or of the gap between the lines making up its structural diagram). In the technology of the fastest circuits the standard gap is equal to 2.5–5 μ and is practically at the limit of physical resolution limit imposed by diffraction of visible light. Standard gaps $l \leq 1$ μ will possibly be obtained only with the aid of an electron beam.

The standard voltage V feeding the logic element is equal to 5 V. This value has been chosen so as to ensure nonlinear threshold properties of the transmission function of the logic element in the wide temperature range of from −60 °C to 125 °C and stability of operation for up to ±10% supply-voltage drifts. As the supply voltage decreases, the threshold character of the transmission characteristics weakens. At voltages $V \leq kT/q$ the nonlinear properties of the characteristics disappear.

For elements with a high degree of integration it is possible to decrease the supply voltage to ~1 V. Then the normal value of the energy expended by the external source on one switching of the logic element is 10 pJ, and, with allowance for further reduction of the dimensions of the structure, it may attain the 1-pJ level.

Estimates show that when the surface area of the integrated-circuit frame is of the order of 1 cm^2, a 0.25-W power disspation in air is possible. This means that for a 1-mW power consumption by each logic element, a crystal in which 250 logic elements have been formed may be placed in the frame. However, for fast integrated circuits, the characteristic value of the power consumable by one element is 25 mW. In this case a

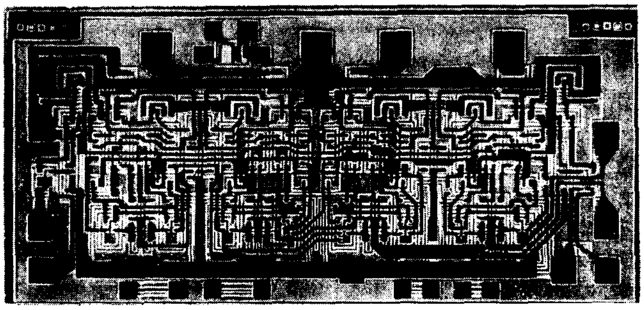

FIG. 3. Topology of a binary-decade counter.

crystal with 10 logic elements may be placed in the frame.

The maximum degrees of integration have been attained for integrated circuits based on MDS transistors, owing to the low dissipated power (for a low speed of response), the smallness of the area occupied by the MDS-integrated transistors on the crystals, and the relative simplicity of the technological process. The most complex MDS-integrated circuits perform the function of an entire calculator: for example, four arithmetic operations with eight-digit words. The most complex fast bipolar circuits contain 1000 and more electronic devices.

As an example, we present in Fig. 3 the topology (a photograph of the crystal) of a relatively simple integrated circuit—binary-decade counter. The crystal dimensions are 1.4×3.0 mm and it contains 130 components.

Subnanosecond logic circuits (switching time less than 10^{-9} sec) can be produced with ordinary bipolar transistors. The minimum transistor switching time is determined by the time of transit through the base of the carrier injected from the emitter: $\tau_{tr} = L/v_{max}$. The highest drift velocity v_{max} is equal to $\sim10^6$ cm/sec. On the other hand, the minimum thickness of the base is determined by the voltage V applied to the base junction and by the field intensity at which an electrical breakdown begins: $V = L_b E_{br}$, where $E_{br} = 10^6$ V/cm. In consequence

$$\tau_{tr} = L_б/v_{max} = V/E_{tr}\ v_{max} \approx 10^{-12}\ \text{sec}.$$

To obtain such values of the switching time, however, we must work at submicron dimensions, for which we can hardly see any prospects.

The switching time of logic elements constructed on the basis of the Gunn effect is determined by the time of transit through a charge domain in the interelectrode space, since the RC-constant of the device turns out to be small ($\sim10^{-11}$ sec), while the transit time is equal to $\sim10^{-10}$ sec. The energy expenditures on one switching is then not less than 1 pJ. The dimensions of the device are assumed in these estimates to be higher than 10 μ, which is entirely attainable at the present level of semiconductor technology. Thus, the devices that operate on the basis of the Gunn effect turn out to be very promising for the construction of logic elements with a switching time of 0.1–1 nsec., guaranteeing a power consumption of the order of 1 pJ per switching.

The signal-transmission lines of computers based on logical elements with a switching time of less than 1 nsec should be of the waveguide type—microstrip or coaxial. The fastest circuits which can be connected up by conventional wiring lines can have signal-propagation delay times and switching fronts of the order of 2–3 nsec.

Future prospects of microelectronic devices for the computer industry are linked with the development of optoelectronic devices and techniques.

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S. V. Bogdanov and D. V. Sheloput. The Current State of Acoustooptics. The beginning of the report deals briefly with the history of the problem. It is noted that in spite of the fact that light diffraction by ultrasound was theoretically and experimentally studied as far back as in the thirties, only with the appearance of high-power coherent-light sources (lasers) did this phenomenon find practical application and be of interest again.

Further, the theory of this problem is considered and it is noted that two different situations usually obtain: Raman-Nath and Bragg diffractions[1]. Relations for the diffracted-light intensity are given for both types of diffraction. It is noted that in any of these cases: 1) a change in the sound frequency leads to a change in the direction of propagation of the diffracted light, 2) the frequency of the diffracted light differs from the frequency of the incident light by the sound frequency (or a multiple of it), 3) the diffracted-light intensity depends on the sound intensity, and 4) the diffraction efficiency depends on a certain combination of the parameters of the material $M_2 = n_0 p^2/\rho v^3$ (n_0 is the refractive index, p is the photoelastic constant, ρ is the density, and v is the sound velocity).

These distinctive features of light diffraction by ultrasound allows the construction of a number of acoustooptic devices for controlling laser radiation: 1) modulators, 2) deflectors, 3) devices for frequency shifting, 4) optical filters with tunable transparency, 5) optical shut-off devices, 6) scanners, and 7) phase modulators (the last two devices use light refraction). The performances of these devices are briefly described in the report. The present state of these performances is reflected in the report by a table in which the parameters of the modulators, deflectors, and scanners are given. It is noted that at present not only are the acoustooptical devices not inferior in all their principal parameters to the electrooptical devices, but in a number of their characteristics—the operating voltage, simplicity of construction, considerable freedom in the choice of material—they are superior.

It is noted in the report that considerable progress has been made in the choice of materials for the optical-band acoustooptical devices. Thus, for example, the authors have proposed glass[2] with a quality $M_2 = 1200$, which is a record value. The power of the electrical driving signal for the acoustooptical modulator constructed with this material is, for a 100% efficiency, only about 250 mW. At the same time, for the infrared band, the best material is still germanium, which was