with such major instruments as a chromospheric-photospheric telescope, a transit instrument, and a zenith telescope.

The Institute now consists of five scientific-research departments: the departments of time, meridian astronomy, photographic astronomy, solar physics, and variable stars. The Ulugbek Kitab International Latitude Station also ranks as an affiliate within the Institute.

Most of the Institute's problems are worked up in cooperation with other scientific organizations of the USSR. The research is coordinated by the Astronomical Council of the USSR Academy of Sciences. The investigations are based on observations made at the Institute. These observations, which cover long spans of time and are characterized by high density, offer extremely valuable material for study of the respective problems.

The Institute publishes transactions, circulars, and thematic collections. Its work is also published in special domestic and foreign editions.

U. A. Arifov. Basic Achievements and Problems in Research on the Interaction of Atomic Particles with the Surfaces of Solids.

In the years ahead, the scientific and engineering revolution in such modern industries as power, metallurgy, chemistry, electronics, space and interplanetary travel, harnessing of nuclear, thermonuclear, and solar power sources, development of materials with specified properties, and others, will be determined in decisive measure by the extent to which science is able to study and subdue a new working fluid for the industrial processes of the future—the ionized gases, i.e., controlled fluxes of atomic particles and low-temperature plasma.

There is no question that the immediate problematic tasks in industrial engineering and technology will involve the development and widespread use of approaches, methods, equipment, and systems that will permit establishment of monitoring and control of technological processes on the atomic and molecular levels.

It is therefore no surprise that interest in the phenomena accompanying the interaction of atomic particles (ions, electrons, photons, atoms, and molecules) with the surfaces of solids has shown a steady increase during recent years. Physical processes that were originally investigated only in connection with the work of ionic and electronic devices have now come into the spheres of influence of such important branches of science and engineering as the physics of plasma and magnetohydrodynamic devices, the physics of thermionic converters and gas lasers, supersonic motion of solid bodies in the ionosphere, ion engines, the erosion of the surfaces of the moon and other planets, ionic doping of semiconductors, and radiation physics. Research on the interactions of ion beams with single crystals is developing vigorously.

Emission processes are now widely used in various instruments and devices for measurement of very small currents, to obtain images of surfaces, for ionic etching, for production of thin films by cathode sputtering, in integrated circuitry, and in many other fields.

The stream of publications rises steadily, and new fields in which bombardment of solids with atomic particles plays an essential role are continually being turned up. Thus, studies of the interactions of atomic particles with the surfaces of solids are acquiring great importance for solid-state physics, nuclear physics, electronic engineering, space travel, power engineering, and many branches of today's and tomorrow's industry. During recent years, the physical-electronics school of the Uzbek Academy of Sciences has been responsible for important advances in the development of some of the aforementioned scientific trends.

Back in the 1940's, it was observed in a study of secondary emission that films of alkali halides are effective secondary-electron emitters. These early studies stimulated later broad-gauge investigation of the variety of phenomena that unfold simultaneously at the solid-vacuum interface. It was noted that the early studies were performed under inadequately controlled conditions, so that the nature of the phenomena attending the bombardment of metals by atomic particles was not clearly recognized at that time.

To keep the investigated surface clean up to and at the instant of measurement, it is necessary to use high surface temperatures and fast, inertialess methods of measurement under the conditions of surface bombardment by transient particle pulses. The dual-modulation method developed by the Institute of Electronics of the Uzbek Academy of Sciences satisfies these requirements.

It was established with the aid of the dual-modulation method that the scattering process is independent of target temperature and that the group of low-energy ions that appears at high target temperatures actually consists of evaporated ions and has the temperature-dependent lifetime that is characteristic for evaporation of an adsorbed film. Also detected was another group of secondary ions with substantially higher inertia that appear only at high temperatures as a result of evaporation, from the surface, of primary ions that have penetrated deep into the target. Use of the dual-modulation method made it possible to register for the first time the entire picture of the phenomena that take place on bombardment of metals by ions and to begin more profound study of the elementary phenomena of primary-ion scattering, evaporation and diffusion of interstitial ions, cathode sputtering, and secondary-electron emission.

The studies performed at the Uzbek Academy of Sciences over nearly a quarter of a century have aided substantially in the illumination of various aspects and features of the interaction of fast atoms, ions, and electrons with the surfaces of solids.

The basic laws governing the scattering of ions, electrons, and atoms of medium and low energies have now been ascertained; the characteristics of ion and electron emission have been determined, and peculiarities of cathode sputtering under the conditions of atomic-particle bombardment of targets have been established. The manner in which these phenomena depend on conditions on the bombarded surface and on many other interaction parameters has been studied. The mass- and charge-balance relationships of the colliding particles have been investigated experimentally and theoretically. Research is being done on the energy balance in the action of atomic particles on solids. Profound study is being given to the aforementioned phenomena and to possibilities for their practical application.

For the future, it would appear appropriate to develop scientific research in the following directions:

1) Interaction of low- and ultralow-energy atomic

particles (tens, units, and fractions of electron volts) with solids.

2) Bombardment of solids with atomic particles having energies in the hundreds of thousands and millions of electron volts.

3) The action of multiply charged ions on matter.

4) Interactions of laser radiation and slow positrons with the surfaces of solids.

5) Construction of a consistent and rigorous theoretical interpretation of the electronic and atomic emission processes and phenomena that are studied and used, as well as of processes on the surface and in the superficial layer.

É. I. Adirovich. Major Research Trends in the Fields of Physics and Astronomy at the Institute of the Uzbek Academy of Sciences.

1. The general expressions for the photoelectric voltage in a homogeneous semiconductor (photodiffusion, or the Dember effect) and in a semiconductor with a conduction-type junction (the photo-voltaic effect at a p-n junction) imply that V_{ph} cannot exceed the forbidden-band width E_g. Anomalous photoelectric voltages (APV) had been observed in thin PbS layers ($E_g = 0.4$ eV, $V_{ph} \approx 1-2$ V[1]), but this phenomenon (the APV effect) aroused great interest only after $V_{ph} \sim 100$ V was reported in[2] for CdTe films. It was shown that the APV effect is not peculiar to some narrow class of semiconductors, but can be produced on films of any semiconductor material (Ge, Si, GaAs, SiC, GaP, InP, ZnTe, $GaTe_3$, Sb_2Se_3, and others[3]). Maximum values of $V_{APV} \approx 6000$ V were obtained on chalcogenide films in[3].

The lux-volt V(B), temperature V(T), spectral $V(\lambda)$, polarization $V(\varphi_{pol})$, kinetic V(t), and other characteristics of the APV effect have been studied experimentally. The results of these investigations contain a large volume of information on the properties of APV films, but cannot give a definite answer concerning the nature of the APV effect. Two dilemmas must be resolved for this purpose: 1) is the APV film a single photocell or a battery consisting of a large number of microphotocells; 2) what is the mechanism of the elementary processes leading to the appearance of the APV effect (photodiffusive or photovoltaic).

The photocell theory[4] is based on the assumption of nonuniform distribution of the trapping levels in the APV film, resulting in the appearance of localized-photocarrier space charges. The inconsistency of this model is pointed out in[5], which gives a general theoretical proof of the necessity that V_{APV} be formed as a sum of small photoelectric voltages generated in individual microphotocells. Adirovich et al.[6] propose an experimental method that serves as the crucial test for establishment of the nature of the electronic processes in the individual microphotocells. It embodies the idea that the sign of V_{ph} should be reversed upon change in the angle of incidence of the light in the case of the normal Dember effect, but should remain the same in the photoeffect at the p-n junction and in the anomalous Dember effect. The photovoltaic and anomalous Dember effects are discriminated in short-wave excitation, when the anomalous Dember effect goes over to the normal one. Combined studies of the angular and spectral relations made it possible to establish that the APV effect is governed by the photodiffusive mechanism in films of Ge, Si, and GaAs, and by the photovoltaic mechanism in films of CdTe, GaP, and chalcogenides.

2. For V_{APV} to appear in a multilayered p-n-p-n-...-structure, it is necessary that the p-n and n-p junctions be unequally illuminated. Figure 1a shows that this is the case in APV films. This model is equivalent to a one-dimensional multilayered structure with a screen that leaves the p-n junctions exposed and shades the n-p junctions (Fig. 1b). Unlike the photoelectric voltages, the photomagnetic voltages across the p-n and n-p junctions do not subtract, but add[7,8]. In APV films, where the difference photoelectric effect is anomalously large, the additive photomagnetic effect across the p-n junctions should therefore be all the more enhanced.

This reasoning led to the discovery of the anomalously large photomagnetic effect (APME) in semiconductor films, which ranges into the tens and hundreds of volts[9]. Measurements of V_{APME} and I_{APME} on CdTe films up to $B \sim 300\,000$ lux and $H = 80$ kOe showed agreement between experiment and theory. The $V_{APME}(B)$ curves take the form shown in Fig. 2 (curves 1–6 and 8–10 represent $V_{APME}(B)$ for H from 20 Oe to 3.5 kOe; curve 7 is that of $V_{APV}(B)$). The $V_{APME}(H)$ dependence is linear up to $H \approx 50-60$ kOe, when $\mu H/c \ll 1$. Combined study of the photomagnetic and Hall photoelectric effects makes possible direct measurement of the carrier mobility ($\mu \sim 100$ cm^2/V-sec) and the number of micro p-n junctions in the APV film ($N \sim 10^4-10^5$). Spectral, temperature, and kinetic investigations were also carried out, and it was established that the carrier mobility is $\mu \propto T^{-2.1}$, that the lifetime in the band is $\tau \sim 10^{-10}$ sec, and that the lifetime at the trapping levels is $\tau_s \sim 10^{-6}$ sec.

The sensitivity of the photomagnetic effect in APV films is ≈ 5 mV/Oe, which is more than an order higher than the sensitivity of the Hall effect.

3. The APV effect and the APME effect in films are of interest not only for semiconductor physics, but also for optoelectronics, for which the problem of finding new physical principles for the transformation of light and optical signals is a very urgent one[10]. The optron with APV film used as a light receiver is based on the photogenerative rather than on the photoswitching principle, and therefore does not require an electric-power supply.

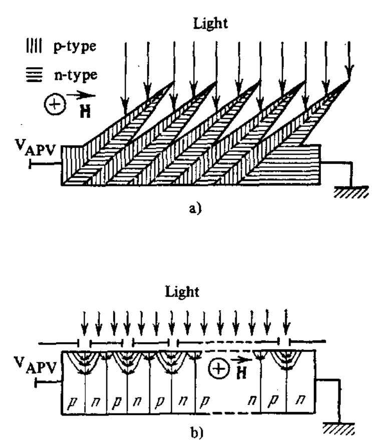

FIG. 1