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# THE SOLID STATE

by

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Some of the following will be outdated by the time you read it! Such is the tremendous pace of progress in the field of solid state physics. Here all of the elements in the periodic table are being scrutinized, usually after purification to a degree thought impossible a few years back. Everyday ones, like Si, are taking on new significance in rectifiers and transistors. Little known ones, like Gd and Pr, are turning out to have beautiful magnetic applications. Even the jewelry metals—Pt, Au, Ag and Rh—have become indispensable as electrical contacts.

Faced with such odd combinations of metals, the unwary spectrographer may fail to identify, even misidentify an element. To aid him, this article thus stresses the materials used in the more common solid state devices, giving brief descriptions of their uses and principles.

## LUMINESCENCE

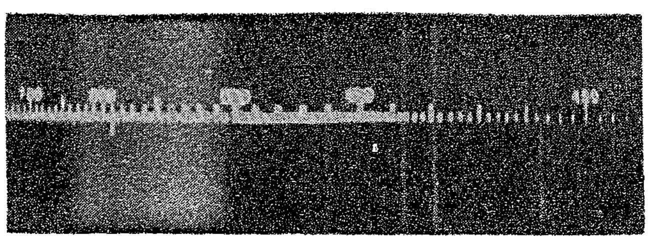
When light is emitted from a material which receives energy, the phenomenon is called "luminescence". Fluorescence and phosphorescence are similar in that the energy source is light or x-rays of wavelength shorter than the light emitted. It is spoken of as phosphorescence when the light persists for as little as a second to as long as several hours. Luminescence can also be achieved by having electrons impinge on a surface (cathodoluminescence), through the application of electric fields (electroluminescence), by heating a crystal previously activated at a lower temperature (thermoluminescence), or by the mechanical energy of crushing a crystal (triboluminescence).

### Phosphorescence and Cathodoluminescence

Luminescent materials consist of a salt containing an activator impurity. Zinc sulfide is perhaps the most common base and in nature traces of Cu or Mn serve as activators. To achieve different colors and decay times, chemists start with pure zinc sulfide and add salts of Ag, Bi, Ce, Cr, Cu, Mn or Sn. The valence of the salt is important since, for the emission of visible light, the energy transition must be between 1.5 and 3.0 ev. In recent years, phosphors using Na, Li, Au or triply charged Al, Sc, Ga and In have been developed. Tramp elements must be avoided, particularly bivalent Fe, Ni and Ce which, by permitting a radiationless transition, quench the phosphorescence. The most commonly used phosphors in fluorescent lights, television and oscilloscope screens are zinc sulfide, cadmium sulfide, zinc selenide and mixtures thereof. Considerable research in other materials has uncovered exciting possibilities in certain titanates, silicates, phosphates and tungstates.

### Electroluminescence

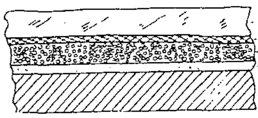
Close at hand is a brand new type of lighting with possibilities as far-reaching as the fluorescent lamp of the 1930's. Already commercial names exist: Westinghouse's Panelighting, Sylvania's Panelescent Lamps. When a voltage is impressed on a sandwich consisting of two transparent slices of insulator with a phosphor between, light is emitted. Again such materials as Cu-activated zinc sulfide are employed. Because of the potentialities, a great deal of research is under way on methods and materials to improve the efficiency of the process. All III-V compounds are, in theory, predicted to be electroluminescent. Some, such as gallium phosphide, gallium arsenide, indium phosphide and boron nitride have been found so. Recently, aluminum nitride was studied by Dr. G. A. Wolff and associates



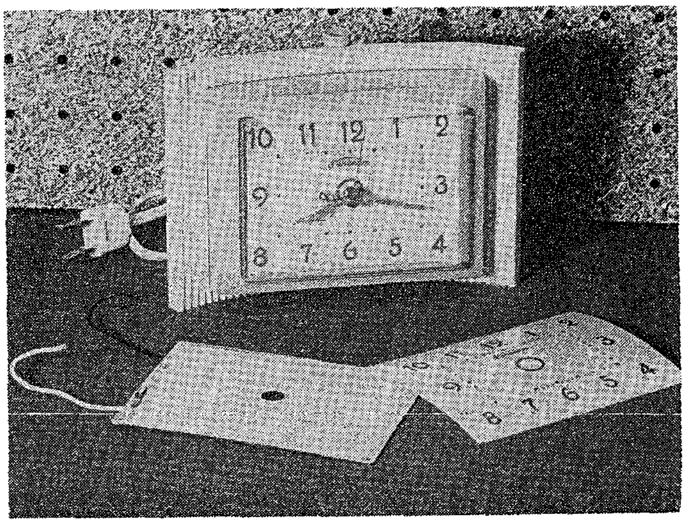
**A spectrogram taken at Ft. Monmouth Signal Corps Engineering Laboratories, of the light emitted by an electroluminescent panel of aluminum nitride. On the left is a wide band of light. The sharp lines were identified as originating from molecular nitrogen. It has not definitely been decided whether the nitrogen in the aluminum nitride or in the atmosphere is the source of these lines.**

at Fort Monmouth, who found that the spectrum of activated AlN consists not only of broad spectral bands but also of a series of narrow bands. These have been identified as the second positive system of nitrogen but the origin has not definitely been established.

Although the efficiency of present-day electroluminescence is too low for lighting purposes, several commercial applications exist. A clock containing a Sylvania Panelescent night light is in thousands of homes. Number displays for computers and digital read-out meters are an accomplished fact. Automobile manufacturers are looking into dashboard lighting and projection television is an intriguing possibility, too.




**Cross section of a typical electroluminescent panel.**



**The above bedroom clock illustrates one of the commercial applications of Panelescent Lamps, a thin area type of light source pioneered and developed by Sylvania Electric Products, Inc., Salem, Mass. The Panelescent lamp shown at the left, is constructed of several thin ceramic layers on a metal plate. When energized by an electric field this lamp emits a soft, uniform light over its entire area. Coupled with the plastic overlay sheet, shown at the right, this lamp becomes the clock face, illuminating the numerals and hands by silhouette. A dimmer makes it possible to adjust the brightness of the lamp for sleeping comfort.**

### Scintillation Counters

Radioactivity as well as x-rays will ionize certain crystals which, in turn, will convert a portion of the absorbed energy to light. Combined with a multiplier-phototube detector, the crystal is called a scintillation counter. Because of its high efficiency, the most commonly used crystal for the detection of gamma and x-rays is Tl (around 0.1%) activated sodium iodide. The material must be free of K because $K^{40}$, a naturally occurring isotope, is radioactive and would contribute to background noise. Anthracene is used for the detection of beta particles. In order to optimize the energy conversion, the crystal is often surrounded with highly reflecting evaporated layers of oxides of Al or Mg. The entrance window is either uv- transmitting glass or quartz since the light emitted by NaI peaks at 4100A, anthracene at 4500A. Cs-Sb surfaces are used on the phototube to obtain good response in this region.

According to Harshaw Chemical Co., for the detection of thermal neutrons (Eu) lithium iodide is best, the $Li^6$ isotope being preferred for fast neutron detection at liquid nitrogen temperatures. (Tl) cesium iodide is recommended for the detection of heavy particles, electrons and mesons. Despite its high background, (Tl) potassium iodide is often used because it is not hygroscopic.

## THE DETECTION OF ELECTROMAGNETIC RADIATION

Semiconductors have long been used for the detection of electromagnetic energy, their electrical conductivity increasing when irradiated. Lead sulfide and selenide photocells and barrier layer cells of cuprous oxide or Se are examples. Demands for increased sensitivity and shorter response times have led to the development of Ge and indium antimonide cells. Evacuated phototubes detect radiation by liberating electrons from their alkali metal surfaces and, as their name implies, multiplier phototubes consist of nine or more stages for greatly increased sensitivity to light.

In the infrared, the quantum energy is small and the above devices have limitations. Improved sensitivity is obtained through changes in the temperature of the receiving element. For instance, thermocouples and thermopiles consist of two dissimilar metals at the junction of which a voltage is generated when it is heated. The resistance of metals changes with temperature and this effect was used in the past as a means of detecting infrared. More recently thermistors, which are semiconductors, have found expanded application for both the measurement of heat and the detection of infrared. The resistance change with temperature of a thermistor is many times that of any metal.

The photographic emulsion is, of course, the most widely used solid state device for measuring and recording electromagnetic radiation. It depends on the change of silver halide crystals in a gelatin medium to a form where they are easily reduced to metallic silver. Despite the fact that the mechanism is the subject of many treatises, a full understanding of it is unknown. Production of photographic emulsions remains an art in which the manufacturers tinker with dyes and recipes to achieve sensitivity for various wavelengths, changes in contrast, graininess, etc.

Xerography is a related photo effect in which light discharges electrostatically charged Se powder thus forming an image for copying. A dry, rapid and inexpensive process, it is widely used for copying line work.

## DEVICES BASED ON SEMICONDUCTORS

By definition, a semiconductor is a material which is a rather poor conductor of electricity, the conductivity of which may be radically changed by small changes in its physical condition. A few applications of this principle have already been described. To a large extent, Ge or Si is employed, but intermetallic compounds of Group III and V elements as well as IV appear so promising that much research is being conducted on such unlikely materials as gallium arsenide and aluminum phosphide. Group IV combinations such as silicon carbide may one day find use at high temperatures.

### Rectifiers and Solar Batteries

Metal semiconductor rectifiers have been known for years. Se sprayed with low-melting alloys of Sn, Pb, Bi and Cd is one type. Another is cuprous oxide on which a metal such as Au, Ag or Al is evaporated or low-melting alloys sprayed. When Mg is bonded to CuS rectification occurs, but only at the spots bonded.

In the above, rectification takes place because electrons can travel more readily in one direction than in the other. There are limitations, however. Efficiency (or % rectification), operation at high temperatures, voltage and frequencies all leave much to be desired. Here the newer point-contact diodes of Ge and Si are far superior. In these, rectifying contact is made by pressing a pointed wire of W or Mo-W against a thin wafer of Ge or Si. Ohmic contact to the other side of the wafer is usually made with soft solder for Si, plated Rh for Ge. Electron flow is achieved through traces of impurities dispersed in the base semiconductor which is otherwise fantastically pure. For example, the price of Si depends on the B content, the best current grade having the almost unbelievable maximum specification of 0.5 ppb. Zone refining reduces the trace-element content far below spectroscopic sensitivity.

Point-contact Si and Ge rectifiers find their niche in electronics where they are used as detectors especially at microwave frequencies. Having little contact surface to dissipate heat, they are not suitable for power applications. This is the province of the p-n (positive-negative) junction rectifier which consists of an n-type crystal of Si bonded to a layer of p-type crystal. Starting with the pure crystal, the p-type material is obtained by doping with Group III elements (Al, Ga, In); Group V element doping (Sb, As) gives rise to n-type where the current is carried by free electrons. The actual junction may be obtained either by varying the impurities abruptly as the crystal is grown or by adding different impurities.

In power rectifiers, Si is rapidly taking the lead, especially at high currents. Below 100 volts and around 25 amperes, Se seems to be preferred and above 1000 volts vacuum tubes are still favored. But at 50-800 volts and for currents of 1-250 amperes—the range of broadest application—the Si junction rectifier is most efficient electrically and takes little physical space.

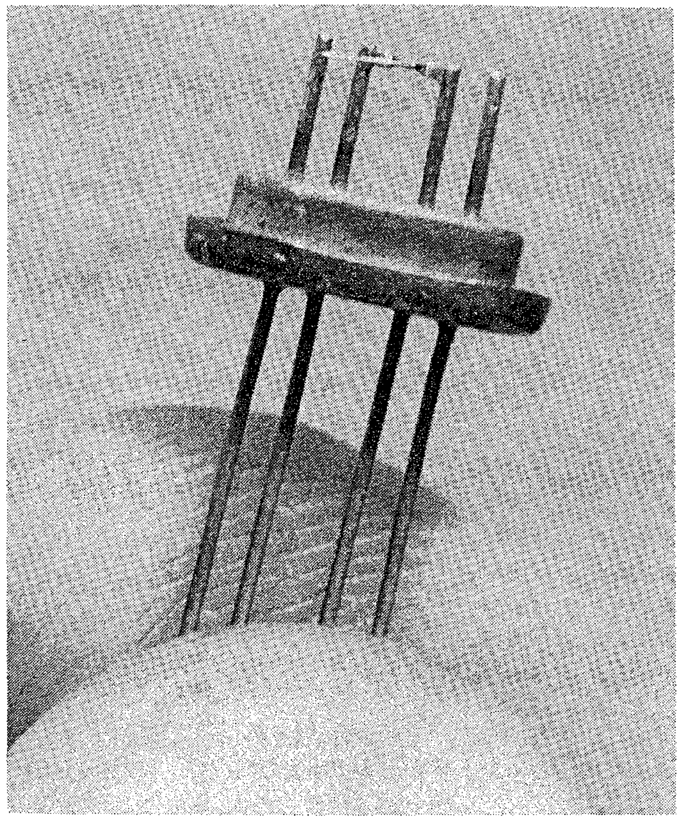
Another use for junction diodes is in utilizing energy directly from the sun. At high light intensities, a voltage is generated in a junction diode sufficient to provide power for special applications. Not only is this effect being used in sattelite instruments, but in down-to-earth batteries for rural telephone lines in the South.

## Transistors

While two layers of Si or Ge have rectifying action, three layers behave as amplifiers. The outer two layers are of the same sign so that there are two possibilities, p-n-p or n-p-n. Through various geometrical designs, many transistor devices have been obtained which, to a large extent, have displaced the vacuum tube. Completely transistorized circuits are now commonplace because of their unrivaled ruggedness, efficiency, reproducibility and minuteness.

The starting point of a typical junction transistor is a large single crystal of Ge doped with Sb. After being cut into a tiny slab about .005″ thick, an In pellet is held on each side of the Ge and the assembly is heated in a hydrogen atmosphere at the melting point of the In. The latter diffuses into the Ge to form both junctions. A Ni wire connector is soldered, or sometimes bonded with Au to the center of the Ge wafer.

Transparent to the near infrared, Ge transistors are also used to detect light. As phototransistors, General Transistor Corp. reports that they are particularly applicable at high frequencies, being sensitive out to at least 1 megacycle. Their tiny size and low power requirements make them useful in several commercial devices including burglar alarms, sound track transducers for moving picture projectors and punched card sorters.



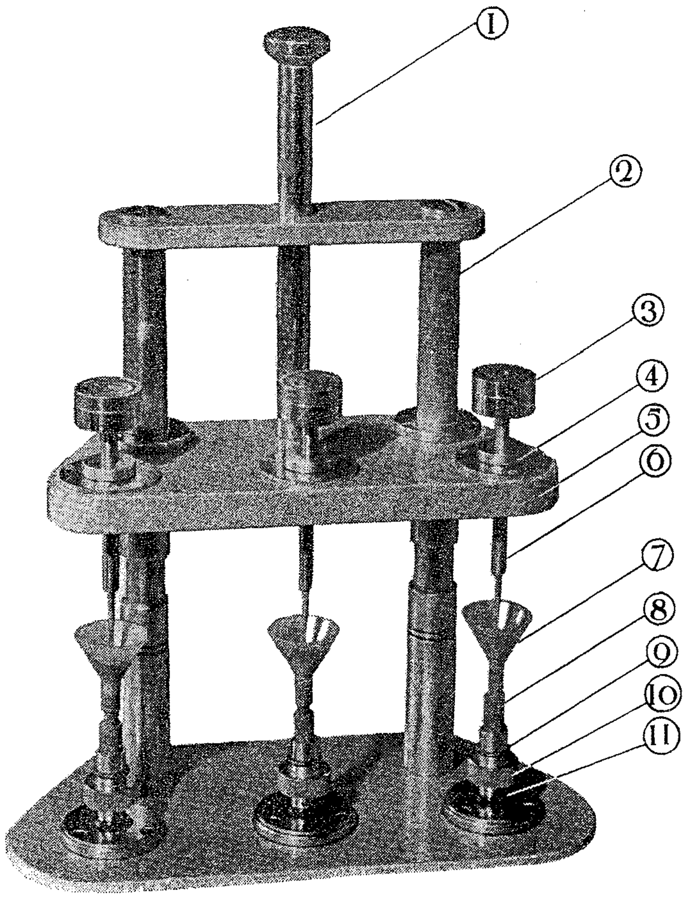
**Atop the four vertical "posts" in the photograph are the inner working parts of an experimental transistor developed by the Bell Telephone Laboratories. The tiny "junction tetrode" bridged between the two posts in the center is dwarfed by the finger and thumb. This device has been used to produce more than a billion oscillations per second. It will perform well into the ultra-high frequency range used for television signals, certain types of radar, and large bundles of telephone conversations. The tiny wires seen in the photograph are made of gold and are less than half as thick as a human hair.**

At present Ge is the preferred transistor material although Si is used in some applications. SiC looks promising at high temperatures. Many interesting materials such as elemental B, AlB alloys, II-VI, III-V, and ternary compounds are being studied for possible application as transistors.

## Thermistors and Varistors

Semiconductors have a negative temperature coefficient of resistance as contrasted with metals. In certain sintered materials the coefficient may be 500 times as high as in metals. One type of thermistor is made by blending oxides of Mn, Ni and Co together with a binder and firing to a ceramic. Another mixture consists of iron oxide and magnesium or zinc chromate. Thermistors can, of course, be used directly to measure heat and, as has been mentioned, they are becoming important in measuring weak infrared radiation. They also function as voltage regulators, low-frequency oscillators, temperature controllers and manometers.

Varistors (General Electric trademark) are rather unusual non-linear resistors in which the resistance decreases enormously with increased voltage. This property makes them useful as voltage regulators with highly inductive loads and advantage is taken of their non-linear characteristics in frequency multipliers. Silicon carbide is practically the only material employed.

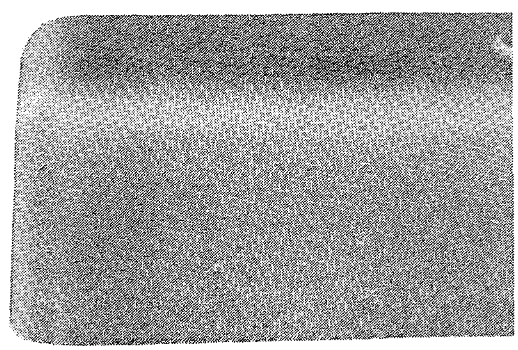



# ELPAC

for automatically loading graphite electrodes

The electrode (8) is secured in the interchangeable holder (10) which is screwed to the vibrator (11). A 60° plastic funnel (7) is fitted over the electrode cavity. Bracket (5) is lowered on the guides (2) by means of rod (1) and the plunger (6) allowed to rest in the bottom of the electrode cavity.

The plunger, which has provision for specific weights (3) at one end, slides freely in the self-aligning bushing (4). The analytical powder is introduced into the funnel by means of a spatula, and the machine switched on with the rheostat set at a suitable motor starting speed. Rheostat setting may be adjusted to suit the relevant material and plunger sizes.



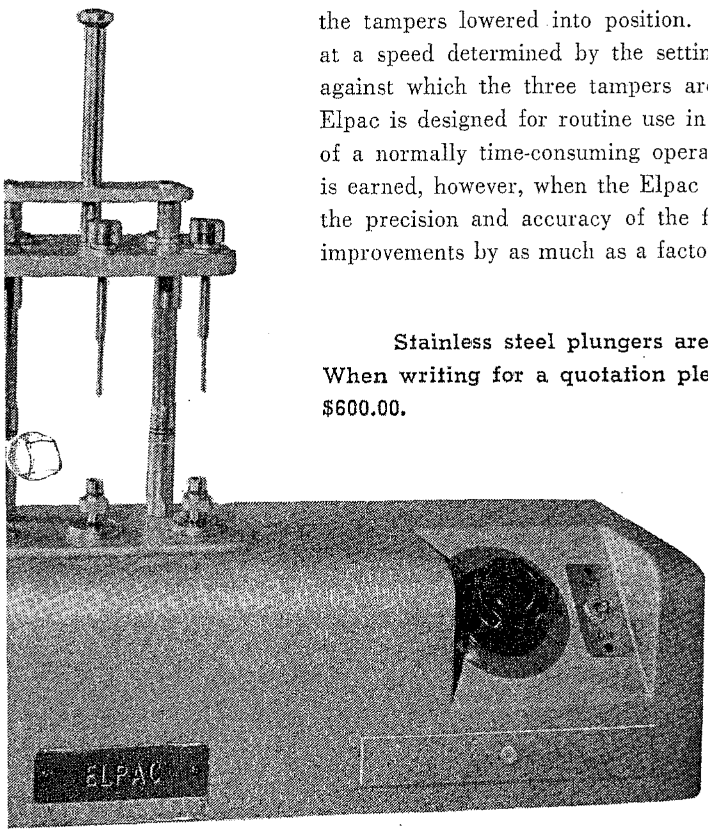
1) Material is packed into electrodes in seconds as compared with minutes by hand.
2) Weighing operation is removed entirely.
3) Machine packed electrodes give superior precision of analysis values compared with hand packed electrodes.
4) Amount of material packed into electrodes is reproducible within 1%.
5) Three electrodes may be packed simultaneously.
6) An inexperienced machine operator can pack more material into each electrode than an experiencd technician can pack by hand. A 30% increase is not uncommon and offers greatly improved sensitivity.
7) Elpac is adaptable for use with 1/8″ electrodes which are so valuable for cutting down on arc wandering.

Precision and speed are the two keywords in the production control laboratory. A new instrument designed to push back these frontiers another notch is the Elpac, which automatically loads powders into spectroscopic electrodes by means of a vibrating tamper. In but seconds, the powder is compacted to form a uniform, dense tablet right in the electrode crater.

Patented by Dr. A. Strasheim and E. J. Tappere at the National Physical Research Laboratory of the South African Council for Scientific and Industrial Research, the instrument is manufactured by Jayco Instruments (Pty.) Ltd., Cape Town. It is distributed exclusively in the United States and Canada by ourselves.

In operation, three electrodes are placed in holders on the base of the Elpac with a funnel mounted on top of each. A quantity of powder is dumped into the funnels and the tampers lowered into position. When switched on, the tampers move up and down at a speed determined by the setting on a rheostat. The mechanism consists of a cam against which the three tampers are spring loaded in an oil bath. Ruggedly built, the Elpac is designed for routine use in the production laboratory where the increased speed of a normally time-consuming operation will be welcomed. An equally important bonus is earned, however, when the Elpac is used. Because variations in loading are minimized, the precision and accuracy of the final results are enhanced. Dr. Strasheim has shown improvements by as much as a factor of two over hand-packing methods.

**Stainless steel plungers are custom designed for the electrode type you use. When writing for a quotation please specify your choice. Elpac is priced at about $600.00.**

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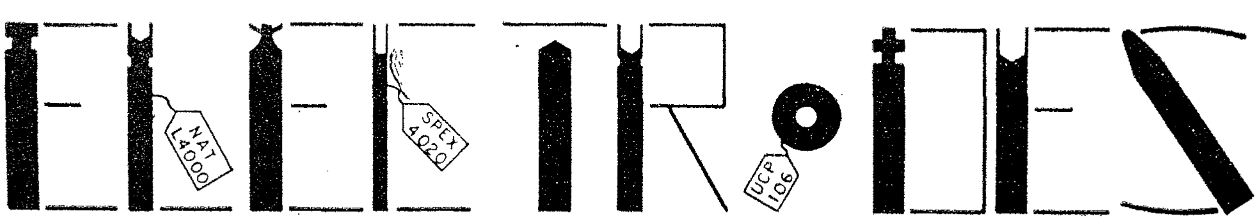
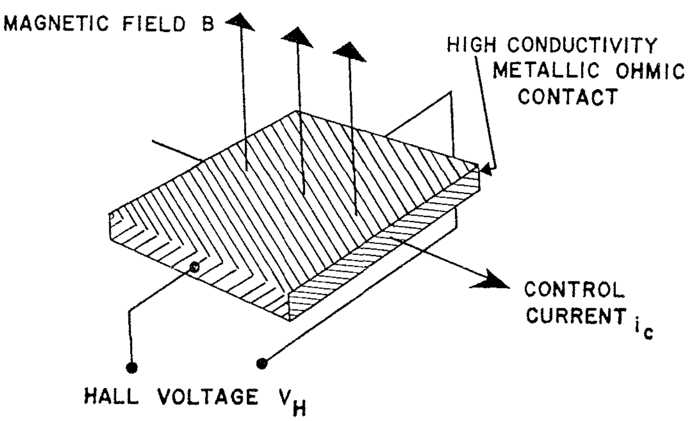


Texas Instruments has now announced the Sensistor, a Si resistor with a positive coefficient of resistance very close to the negative coefficient of transistors. This, of course, suggests a compensator for transistors for use in instruments to operate over wide temperature ranges.

## Magnetic and Electric Effects

Semiconductors have turned long known effects into practicality. For although many principles had been discovered years ago, none of the then available materials permitted the profitable utilization of the effect. With the growth of semiconductor physics, such things as the Hall generator, Peltier refrigerator and magnetostrictive transducers are now reaching the commercial stage.

In the Hall effect, a potential in the z-direction is produced when a current in the x-direction and a magnetic field in the y-direction are applied to such materials as indium antimonide or arsenide. Westinghouse has suggested its Hall Generator for use in analog computers where two quantities are to be multiplied; as a means of measuring high currents in a bus bar without making contact to it; to regulate or measure power directly (wattmeter); to probe the intensity of a magnetic field.




**Schematic of the Westinghouse Hall Generator fabricated of indium arsenide. Current and magnetic field are multiplied for a wide variety of applications.**

When a direct current is passed through an ohmic metal-semiconductor contact, cooling is produced at the junction. Known as the Peltier effect, it is fascinating because it means a refrigerator without moving parts. The Russians have reported such a household refrigerator in production and American manufacturers have shown prototypes. Bismuth telluride has been found to have the best thermoelectric power of all materials studied for this application thus far.

A related phenomenon, the Seebeck effect, may be used to produce electricity directly from heat. In the hinterlands of the Soviet Union where there are no power lines, radios are simply plugged into kerosene lamps. The heat from the lamp produces enough electricity in a frame of thermoelectric elements to power small appliances.

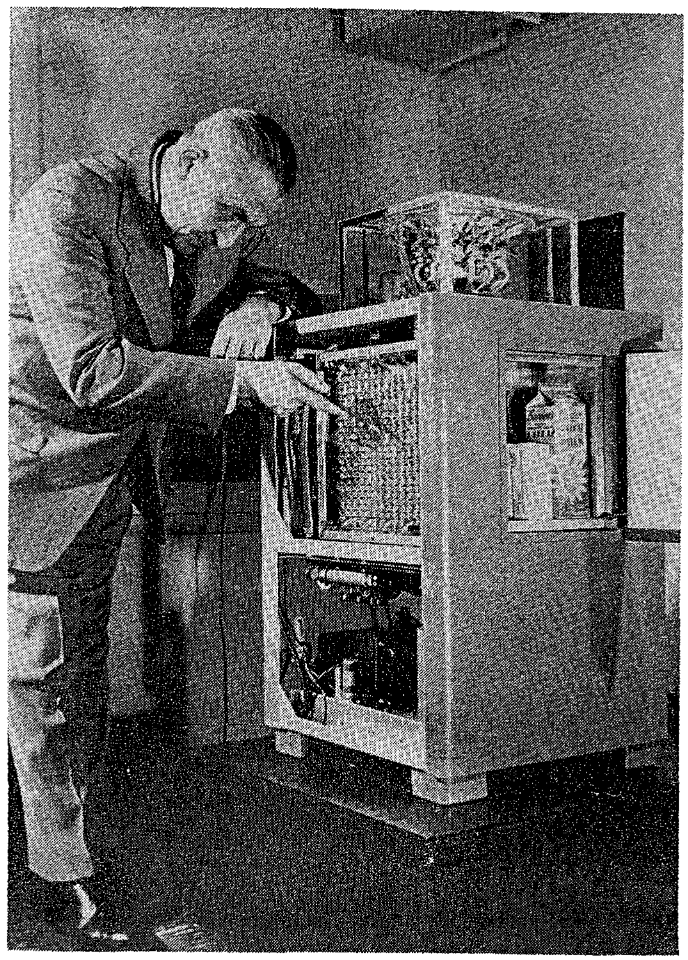
The decreased mobility of charge carriers in a magnetic field leads to magnetoresistive devices. Here a multitude of applications exist: magnetic switches, low-frequency amplifiers, magnetic control elements, the gaussistor amplifier. A potentiometer having no moving parts and completely free of contact noise is a recent development. Bi appears to be the material most often used in these applications.

## FERROELECTRICS AND PIEZOELECTRICS

Ferroelectrics are dielectrics possessing spontaneous electric polarization. Attributes of this property are pyroelectricity (release of charge on heating), piezoelectricity (release of charge by pressure), and hysteresis in the electric displacement with respect to an applied field. Before the war, all known ferroelectrics were made of either rochelle salt or ammonium dihydrogen phosphate (ADP). Intensive research since 1946 has uncovered 20 or so new ones and it now appears that the phenomenon may be quite common.

Of the new compounds, barium titanate and $Pb(Ti,Zr)O_3$ have proven best. In ceramic form, they are employed as sound transducers (record pickups), as high permittivity dielectrics and as dielectric amplifier materials. Single crystals of $BaTiO_3$ are employed as memory elements, taking advantage of electrical hysteresis. One problem with ferroelectrics is that their properties drift with time.

Many compounds are piezoelectric without being ferroelectric. These are employed as single crystals in sound and radio transmission and receiving systems. Quartz has, of course, long been used as an oscillator. During the war, because of the shortage of natural quartz, means were devised for growing quartz crystals synthetically. Upon the exact shape and size of the crystal slice depend not only the frequency of oscillation but also the temperature dependency of the frequency.



**A noiseless electronic refrigerator, with no moving parts, has been developed by scientists of the Radio Corporation of America. Shown in this picture taken at RCA's David Sarnoff Research Center, Princeton, N. J., the new refrigerator has one-cubic-foot food storage compartment and a 6-cubic-inch ice tray.**

## MAGNETIC DEVICES

During the last few years, there has been increased interest in non-metallic magnetic materials especially at the high frequencies of microwave transmission. Ferrites are such materials. Named after the parent compound, $MgFe_2O_4$, ferrites have the spinel structure $AB_2O_4$ where A is a divalent and B is a trivalent metal. Compounds of this type owe their magnetism to the fact that A and B atoms occupy specific sites in the structural unit cell. Chemical substitution alters the atomic arrangement leading to predictable changes in the magnetic properties, and, as a result, ferrites are readily modified for a particular purpose.

In most ferrites. "B" is Fe although Al and Ga will occasionally be found. "A" may be Ni, Cu, Zn, Mn or Mg in most commercial ferrites. Manufactured like ceramics, ferrites can be made in almost any shape or size. They are used on memory drums, transformer cores, magnetic amplifiers, and in a variety of microwave applications where their high resistivity makes them ideal. Gyrators (forward wave completely out of phase with reflected wave), circulators (reflected wave completely attenuated), isolators (propagation of one frequency in the wave guide), and detectors are some microwave applications.

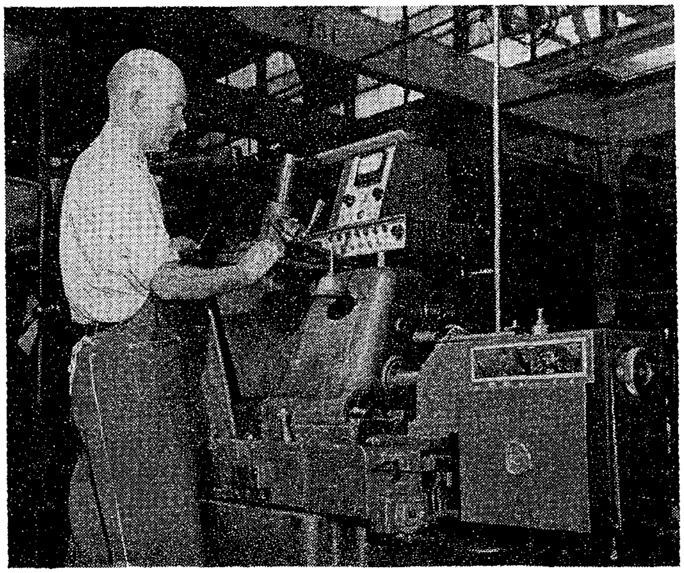
Recently rare earth garnet materials such as yttrium iron garnet ($3Y_2O_3.5Fe_2O_3$) have found isolator applications. Extremely narrow band widths (50 oersteds) make the garnets a very acceptable substitute for single crystal ferrites.

By comparison with ferromagnetic materials, paramagnetic ones have found little use. Two important exceptions are: the use of paramagnetic salts to obtain temperatures close to absolute zero through adiabatic demagnetization and the maser (Microwave Amplification by Stimulated Emission of Radiation). The first masers employed gaseous $NH_3$ but recently a solid state maser was devised. Single crystals of ruby (alumina with a percent or so of Cr) and Cr doped potassium cobalt (III) cyanide have proven most useful. Although thus far masers will operate only at liquid helium temperatures, they are being used as sensitive detectors with extremely low inherent noise. Placed at the focus of radio telescopes, masers are picking up signals from distant galaxies. The military is interested in the maser, detection of faint signals being a continual problem.

Magnetostriction occurs in Ni and Fe alloys which, when subjected to a magnetic field, change in length along the axis of the field. A promising application of this Joule effect is the new "Inchworm" motor devised by Airborne Instruments Laboratory. With it microinch displacements can be made in a controlled, reproducible manner. For machining bearings, cams and other parts to extremely close tolerances, the "Inchworm" is replacing expensive lapped lead screws. The inverse of the Joule effect, named after Villari, relates to the change in magnetism of a material upon being stressed in a magnetic field. Very sensitive microphones for detecting enemy submarines, strain gages and phonograph pickups are typical applications.

## SUPERCONDUCTIVITY

The phenomenon of superconductivity, where certain metals lose all measurable electrical resistance below a critical temperature, has been known for some time. Only recently, however, has a technical breakthrough plus a need brought forth a practical device: the cryotron developed at Raytheon. It had been known that the critical temperature depends on the magnetic field present. Thus modulating the field produces large resistance changes. In flip-flop circuits for digital computers, the cryotron holds special promise. In practice, the cryotron involves winding one superconducting wire about another superconducting wire. The field needed to produce the normal conducting state is greater for the central wire and it remains superconducting in operation. Ta wire is used for the control core and Nb or Pb wire in the winding. The time constant of the circuit decreases as the central wire is made smaller so that with thin wires a practical computer is obtained.



**Airborne Instruments Laboratory's Inchworm Motor mounted on a centerless grinder. In this application, it is used to control the diameter of needle bearings to millionths of an inch. Through magnetostriction, the length of a metal rod is adjusted by varying the magnetic field. Changes in its length displace the grinding tool accordingly.**

## CONCLUSIONS

Where does solid state physics begin and metallurgy or inorganic chemistry end? The borderline is so diffuse that we cannot hope to cover the no-man's land. In metallurgy are alloys with unusual properties: NiFe combinations which have varying magnetic permeability with temperature for use as compensating elements in automobile speedometers; PtCo alloys with a magnetizing force 50 times that of carbon steel; NiFeMn alloys with tremendous magnetic permeability; resistance alloys with temperature coefficients near zero (Wilbur B. Driver's Evanohm containing Ni, Cr, Al and Cu); Invar (FeNi) with a coefficient of expansion close to zero for use as one side of thermostatic bimetals; other FeNi alloys with a constant modulus of elasticity over varying temperatures making them ideal for weighing scale springs, Bourdon tubes, tuning forks. Then left to the domain of inorganic chemistry there are the catalysts which have brought about immense changes in the cracking of petroleum and the production of other chemicals. Not to be forgotten are the ion-exchange resins which have become so useful in softening water, separating rare earths and in chemical analysis.

The mushrooming of solid-state sciences has created numerous industries centered especially around rather esoteric elements and compounds. Who would have foreseen 20 years ago that germanium, barium titanate, yttrium iron garnet, gadolinium ethyl sulfate or gallium-indium compounds would be items of commercial importance? Apart from their novelty, the purity levels of some are many orders greater than even "chemically pure" standards. These low levels of impurities plus the unusual elements tax the analytical chemist and the spectrochemist to the hilt. While the contribution from the analytical chemist to the actual device may appear to be remote, it is his precision measurements which help the engineer and production department to develop products of great significance to our economy and defense.

## DETERMINATION OF BORON AND SILICON

We'd like to call attention to a recent article by J. E. Paterson and W. F. Grimes (*Anal. Chem.* 30, 1900, 1958) which employs selective volatilization for the determination of boron and silicon. Copper fluoride is added to the material to be analyzed and, under the heat of an arc, silicon and boron fluorides distill off to be detected spectrographically at extremely low levels. Selective volatilization has, of course, been employed before in spectrographic techniques, the carrier distillation technique of Scribner and Mullin being perhaps the most widely known and used example. (Incidentally, most spectrographers prefer AgCl to gallium oxide originally specified.) The present technique is unique in that two elements only are singled out and it points up a possible scheme for improving the sensitivity of many elements through the formation of volatile compounds in the arc.

Another feature of the Paterson, Grimes article is that it is in far more widespread use already than would be indicated in the text where it is limited to low-alloy steels. Actually, even before the paper was given at the last Pittsburgh Conference, spectrographers became aware of the technique and tried it successfully in their own problems. John Gillespie of Wah Chang Corporation, Glen Cove, L. I., and Johann Raudsepp, Ledoux & Co., Teaneck, N. J., have found it extremely useful in determining fractional ppm of boron in niobium and zirconium oxides. John Norris of Union Carbide Nuclear Laboratories, Oak Ridge, states that similar techniques have long been used for the analysis of uranium salts.

We are supplying copper fluoride prepared in the manner prescribed by Paterson and Grimes because the material is not available from the usual sources.

6003 **Copper Fluoride, spectrographic grade**, free of silicon and boron
**per 10g.** .................................... $ 6.00

## GETTING TO KNOW US!

March 2-6 is the annual Pittsburgh conference where, among a great many features, there will be an opportunity for "shop talk". Some of our new standards to be displayed this year are:

1033 **Rare Earth Qual Mix**, containing 16 elements so proportioned that a few lines of each of the elements appear when burned in a dc arc.
**per two grams** ............................ $ 20.00

1032 **Rare Earth L Standards**, for semi-quantitative analysis of unknowns containing rare earths.
**per set of 4** .............................. $ 49.00

1031 **Rare Earth Spex Mix**, for semi-quantitative analysis of "pure" rare earths.
**per two grams** ............................ $ 36.00

1030 **Rare Earth Element Kit**, contains small quantities of 14 rare earth elements plus scandium and yttrium. ....................... **per kit** $ 50.00

1040 **Noble Metals Element Kit**, contains small quantities of high purity salts of the following elements: gallium, gold, hafnium, indium, iridium, palladium, platinum, rhenium, rhodium, ruthenium. .................. **per kit** $ 50.00

Also among our wares will be:

**Qual Mix Atlas**—an invaluable reference for qualitative analysis.

**Elpac**—for loading electrodes.

**A Universal Arc-Spark Stand**—for modernizing your spectrograph.

**A Calculating Board**—for converting % transmittance to intensity ratio.

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