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PRODUCT ADAPTATION AND UPGRADING OF QUALITY

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INDIA.

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United Nations Development Programme

PRODUCT ADAPTATION AND UPGRADING OF QUALITY

DP/IND/72/045

INDIA

Technical report: Technology of power solid-state devices

Prepared for the Government of India
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of H.F. Mataré, expert in semiconductor technology

United Nations Industrial Development Organization
Vienna, 1976

Explanatory notes

Reference to "dollars" ($) indicates United States dollars.

A full stop (.) is used to indicate decimals.

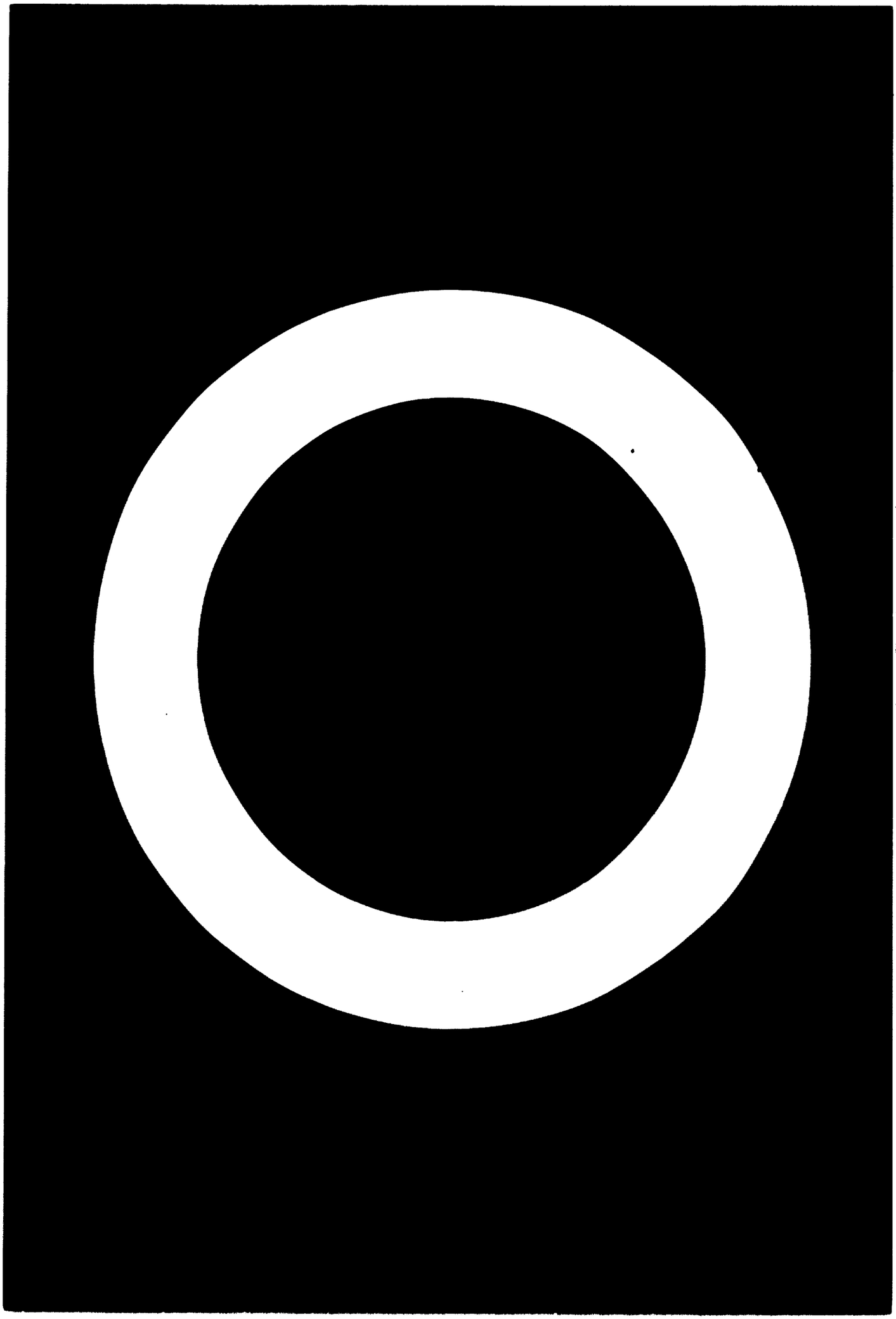
A comma (,) is used to separate thousands.

During the period of the mission, the value of the India rupee (Rs) in relation to the dollar was $1 = Rs 8.80.

ABSTRACT

The report covers the assignment of an expert in semiconductor technology who visited India for one month in 1976. The purpose of the visit was to assess the ability of the semiconductor industry to produce power solid-state devices and to suggest to manufacturers ways of adapting their products to meet the requirements of developed markets. The assignment was part of a project entitled "Project Adaptation and Upgrading of Quality" (DP/IND/72/045) sponsored by the United Nations Development Programme (UNDP) of which the United Nations Industrial Development Organization (UNIDO) was the executing agency.

The expert's general impression was that a great deal of hard work had gone into getting the power solid-state device industry onto its feet. In most places, production was running smoothly. While yield figures were very good, there was clearly room for improved environmental control. Discrete devices (power rectifiers, medium-power transistors, high-frequency transistors) were already being produced, and the industry was in a position to manufacture micro-circuits. There was considerable interest in the latest MOS (C-MOS) technology for computer and watch applications.



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INTRODUCTION

The project entitled "Product Adaptation and Upgrading of Quality" (DP/IND/72/045) is sponsored by the United Nations Development Programme (UNDP) and is part of a comprehensive export development plan drawn up by the Government of India. The project includes assignments by experts in the technology of integrated circuits, metal film resistors, tantalum capacitors, power transistors and solid-state devices. The United Nations Industrial Development Organization (UNIDO) was appointed executing agency for the project.

This report covers the assignment of an expert in semiconductor technology who visited India for one month (20 March to 19 April) in 1976. The purpose of the visit was to assess the situation of the semiconductor industry and to suggest to manufacturers ways of adapting their products to meet the requirements of developed markets. The Trade Development Authority of India (TDA) had requested the services of an expert who could give advice on the technology of power solid-state devices and thus assist the industry to proceed from the manufacture of low-power devices to the manufacture of high-power devices. Diffusion processes, mask-making facilities and packaging were areas singled out for special attention.

I. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

All plants visited showed good potential for production and growth. The power semiconductor industry has infrastructure problems, however, and it would seem advisable to set up industries to produce pure chemicals, pure gases, silicon crystals, stems and accessory parts, pure metals, and other essential materials. The need for sufficient electrical power, a good water supply, proximity to technical schools, access to libraries, and contacts with universities makes the choice of location a critical one. If the industry's role is to be more than that of an off-shore assembly facility, materials and equipment must be available, preferably from sources within the country. The labour force must be highly skilled and interested in technology. The necessary skills can usually be concentrated and kept more easily near technical centres.

Since profitability is a major driving force in modern technology, production volume should not be limited arbitrarily. Long delays in granting licences can kill the drive needed for this very demanding industrial activity.

Recommendations

1. Greater attention should be given to domestic industries supplying materials and equipment.

2. The secondary technical schools should be supported. The teaching of such subjects as metallurgy, chemistry, electronics, and precision mechanical engineering should be encouraged and improved.

3. The exchange of information and skills within the industry should be encouraged, so as to reduce the need for outside help.

4. Environmental problems should be considered when starting new industries, so as to reduce some of the problems encountered in production.

5. The choice of areas of activity for domestic industry should be based on a consideration of what is best for and most needed by India, and not solely on information concerning the latest advances in the United States. Consideration should be given to the possibility of manufacturing solar-thermal generators, solar panels, and equipment for infra-red communications.

6. Duty on materials and equipment needed for production should be levied only when suitable equivalents are available on the home market.

7. India should manufacture its own good-quality silicon monocrystal wafers. A new facility could be built for this purpose, or existing facilities at the Electronics Corporation of India could be improved and expanded. (Equipment to produce floating zone material up to three inches in diameter could be obtained cheaply from Belgium.)

II. VISITS TO COMPANIES

USHA Rectifier Corporation (India) Ltd

USHA Rectifier Corporation is a leading manufacturer of selenium rectifiers and all types of equipment based on rectifiers. The company obtained a licence for the production of silicon and selenium rectifiers. The selenium rectifiers are being manufactuerd to ISI specification 2511. Rectifiers could be made to meet DEF specification 5243 which proves stability under severe climatic conditions. The expert discussed with the Corporation the future silicon power rectifier and silicon-controlled rectifier lines. Devices produced are visibly of standard quality. Yield figures quoted (80%) are good and highly trained technical leadership is available. The company uses diffused chips (wafers), but is in the process of installing its own diffusion ovens.

Once a diffusion unit is operating full-time, export potential will be good, since this company is near to a supply centre for pure gases, chemicals and machine spares (New Delhi). There are some problems due to the difficulty of purchasing oxygen-free copper in India for bonding. Environmental control is also needed (dust control because of the high dust level from a nearby stone-cutting operation). The final economics and export potential will depend on output volume and the price of materials (encapsulation materials, silicon monocrystals, dopants, diffusants, gases, etc.).

Recommendations

1. Dust control should be installed.

2. Correct production flow through plant should be established. (Materials flow should follow a definite pattern: etching-cleaning-rinsing-drying-diffusion-metallization-passivation-mounting-testing, etc.)

3. Gettered gallium diffusion should be introduced. (This will allow the production of high quality diodes without the use of vacuum and loss of quartz tubes.)

4. Independent quality control should be established.

Continental Device India Ltd

Continental Device India is a public sector limited company with an annual turnover of approximately Rs 20 million. It employes about 600 people. Products range from epoxy-encapsulated metal-can and general-purpose transistors to Zener diodes. The company has been exporting to Europe and South-East Asia since 1971. There is an independent quality control department where every device is fully tested. The operation is a regular one with good dust and moisture control. There are diffusion and processing departments. Quality control is ably directed and embraces all process steps. The quality of the company's medium-power transistors seems good, and yield is excellent. There is no mask facility available yet. The expert indicated some improved methods for washing after etching and for efficient etching. The general set-up is logical and relatively clean, although the dust-free areas should not have rough wood panelling. Quality control methods seem to satisfy military specification requirements.

As the discussions with the technical personnel showed, there is the well known problem of the supporting industry. The company has its own machine shop, but it took a considerable time to induce producers of industrial gases (hydrogen, nitrogen, ammonia, etc.) to purify for semiconductor use (below 1 ppm). The expense of having such gases, and also pure chemicals, delivered by companies in Europe and the United States weighs heavily on over-all efficiency and profitability.

The training of the second echelon technical staff is also an issue. Streamlined technical training on the job has shown good results for machine operators, but staff working as technical assistants to plant managers or qualified scientists need a better understanding of technological processes. Staff who have completed courses at technical or trade schools are the logical interface between plant managers or physicists and production workers. These technicians can also make suggestions and participate in technical decisions and development. There is apparently a lack of schools with adequate equipment for the training of technicians in chemistry (analytical, quantitative) electrochemistry, electronics, mechanics, metallurgy, etc.

The export potential of this company is reasonably good. Especially for low-power devices, a competitive position has been built up. Medium-power

devices are being developed. The cost of materials (gas, stems, chemicals, silicon monocrystals, dopants, etc.) will determine profitability.

Recommendations

1. A mask-making facility common to other semiconductor plants in India should be provided through a central agency.

2. Clean rooms should be painted white (no wood panelling).

3. Pure gas supply facilities common to other semiconductor plants should be provided. There may be a similar need for centralized stem production (cf. Semiconductors Ltd).

Electronics Corporation of India Ltd.

Electronics Corporation of India Ltd (ECIL) has earned a good reputation for designing, developing and manufacturing sophisticated and high-precision eleotronic components, instruments and systems. The Corporation is engaged in the production of nuclear and other instruments for use in industry, agriculture, research and medicine. Instruments manufactured include oscilloscopes, pulse generators, ultrasonic flaw detectors, scintillation scanners, and medical spectrometers. ECIL is also involved in the design, development and manufacture of three different types of television, closed circuit television and commercial television systems. The Corporation employs about 2,300 persons and is expected to have a turnover of Rs 220 million for 1975/76.

Transistors and diodes are produced covering a broad frequency range up to 50 MHz. There are some problems of cleanliness in the mask-making and diffusion areas. The expert had lengthy discussions of leakage current and emitter base voltage problems caused by thermal donor and acceptor formation in silicon crystals used in extended diffusion runs in heated quartz tubes. Sources for silicon monocrystals and wafer quality tests were discussed. The new photoelectric scanner was described, and recommended for the testing facility.

The Corporation makes small Zener diodes by scribing, cleaving, alloying and etching. Demage due to cleavage after scribing was apparently not corrected. The expert recommended larger dicing and stronger etching.

Problems in oystal growth were disoussed and the importance of the horizontal gradient aoross the oruoible was explained in oonjunotion with the vertical gradient responsible for impurity segregation. The balance between solubility differenoe and segregation due to the vertical temperature gradient was discussed (comparison between Czochralski and floating-zone crystal growth). ECIL has at present a Czochralski puller of about the same size as the one at the India Institute of Technology in New Delhi; it would seem desirable to increase crystal-growing capacity at ECIL and in New Delhi (see recommendations).

ECIL has the advantage of being a self-sufficient operation with a captive market for devicos. This makes for a certain stability in an environment of government sponsored projects. Personnel and general cleanliness problems are similar to those of other concerns, but ECIL represents a good investment and promises to become a major source of modern semioonduotor devices.

The infrastructure in this relatively remote location had to be built up. This was easier in the case of ECIL, because a large number of plants and projects are combined here in a complex of varied technologies ranging from nuclear plants to systems groups (fuel cells, nuolear instrumentation, radar, microwave technology, etc.). The export competitiveness of the Corporation's products depends on the price to be paid for equipment and assistance. As this group is successfully growing its own silicon monocrystals, the expert recommends that growing facilities should be expanded to a size that allows the Corporation to supply semiconductor devioe producers with silicon crystals.

Recommendations

1. Wafer testing should be introduced.

2. Crystal growth output should be increased to serve other devioe manufacturers.

3. The local light level for production workers should be improved.

4. The problem of supplies of pure chemicals and gases should be solved in oonjunction with other manufacturers.

West Bengal State Electronics Development Corporation

The expert discussed the company's intention to start C-MOS production with the ultimate aim of manufacturing complete watch and computer circuits, quartz oscillators and LED-displays. It was suggested that companies in Europe and the United States might be contacted in preparation for a joint venture. The first step should be an off-shore assembly line with 60% of the completed circuits going for export. A gradual transfer of equipment and know-how was proposed. A proposal for an Indian company to start by acting as an assembly line for a United States company was not acted upon. The expert will try to clarify the proposal.

Several scientists from the nearby universities were invited to participate in a general discussion on industry trends. Questions were asked concerning a wide range of technologies including solar cells, organic semiconductors, new materials, optical communications, and microcircuits.

Khandelwal-Hermann Electronics Pvt. Ltd

This company produces selenium rectifiers under licence. It also produces photoelectric cells. Preparations are under way for the production of silicon medium-power devices (power transistors, silicon-controlled rectifiers and diodes) under licence. The company employs about 300 people and exports less than Rs 100,000 worth of its output.

The selenium-rectifier plant near Bombay is well organized. It is built along the lines of the German licensing company. Khandelwal has signed an agreement with Siemens (Federal Republic of Germany) to build a duplicate of the Siemens production plant for medium-power silicon-controlled and other rectifiers in Bombay. Some material for the plant has already arrived, and personnel have been sent to Siemens to learn the process. Questions were asked during discussions about the best process steps, materials, and encapsulation methods to use. The expert recommends that the operation should be started exactly along the lines indicated by Siemens. Later on, new methods for diffusion should be tried.

The beginning of this operation was delayed for 25 months owing to difficulties in obtaining government licences for the purchase of parts. There are sometimes difficulties of communication about materials. Khandelwal may have to face questions for example, if it orders pure selenium from Germany after ECIL has announced that it is producing pure selenium, although ECIL's material is not of the desired purity and is not produced in sufficient quantity for Khandelwal.

Hindustan Conductors Pvt. Ltd

Hindustan Conductors manufacturers solid-state devioes, especially small-power transistors and diodes, inoluding high-frequency devices. The company is preparing to produoe microcirouits. It employs approximately 300 workers and several engineers and technicians. It was built up with the assistance of Fairchild (United States) on an export oontract. The company's main production is in the field of entertainment transistors, Zener diodes, field effect transistors, silicon planar-epitaxial transistors, linoar intograted circuits (voltage regulators), and others. The set-up is logical according to a defined flow pattern. Diffusion and epitaxy yields are apparently good, and devices coming off the production line have been tested to satisfy modern requirements. There is a lack of optical equipment for mask making. Co-operation with Semiconductors Ltd would be useful, as the latter oompany has an optical installation for mask making but lacks epitaxial skill.

There is a drive toward microcircuits, and the company has the general skills needed to produce them. The company's teohnical manager has put forward the very reasonable proposal that there should be a central mask making facility or company for the semiconductor industry.

Hindustan Conductors is a reasonably clean operation with all major facilities: diffusion ovens, epitaxial furnaces, and vacuum coaters (aluminium and gold). Rooms are air-conditioned and dust-oontrolled. The relatively high humidity in the factory has to be oonsidered in the design of the hoods for final encapsulation. The company has reached the stage where homogeneous silicon wafers are required for high-yield devioes and microcircuit fabrication. Major problems stem from its isolated location. Transport of gases, chemicals and accessory materials is tedious, and staff have to drive for three-quarters of an hour to reach a library in Ahmedabad.

Recommendations

1. Consideration should be given to the possibility of teaming up with other manufaoturers to make masks.

2. A central manufacturer for all semiconductor producers should be found to supply pure gases and chemicals.

Santa Cruz Electronics Export Processing Zone (SEEPZ), Bombay

In the Zone, the concentration on export is greatly facilitated by an organization which takes care of all licensing and duty problems for the assembled companies. Buildings are available at low rents for subsidiaries engaged in off-shore assembly, which is geared entirely to export. One company assembles watch circuits which are imported as chips. Other groups do hybrid assembly work and assemble medium-power transistors.

A technical discussion held at the Zone was concerned with the questions of efficiency and companies interested in the facility. The problem is profitability, in spite of all the advantages offered. It arises because of the need for a technical infrastructure, supply problems, and the need for staff stability. (Since the learning process is long and costly, staff fluctuations may offset the advantages due to salary levels.)

Semiconductors Ltd. - Poona (Bombay)

The company was established in technical collaboration with the Raytheon Company of the United States. It produces a wide range of consumer and industrial devices. The oldest line produces ferrite rods and magnets, screw cores, and thermistors. Television diodes, low and high frequency transistors, photo transistors, and so forth are in production. There is a medium-power line in operation for silicon-controlled rectifiers, power transistors and varistors. The company's products have already found markets in Europe, the United States, the Middle East, the Far East and Bangla Desh. There are about 700 employees. A group of skilled engineers pursues the addition of such new technologies as medium-power transistors with glass passivation and moulded devices of varied types. There are two lines for discrete transistor production. One of these is strongly labour intensive: the other is operating with lead-frames and modern bonding equipment. Because of some minor problems of adjustment, the new line has certain technical shortcomings, but ultimately output should be more reliable than that of the old hand-operated unit. Problem areas are: humidity control, final encapsulation, supply of gases and water, and supply of electricity (the company has its own generator station). Interest in new technologies (solar cells, infra-red light emitters) is considerable. Export potential is good and

the level of production is considerable. The company has also started its own stem production. This may turn out to be too expensive, but the facility could eventually be converted into a central one for all semiconductor manufacturers in India. There is a need for sufficient electrical energy in remote locations like Nadiad and Poona. Schooling for the technical middle level should be strengthened.

Recommendations

1. A new device line with better humidity and dust control should be set up.

2. The company should make masks for Hindustan Conductors in exchange for epitaxial layer growth facilities.

3. Government support should be sought for a centralized supply industry for pure copper, pure chemicals, purified and dried gases and central stem production for the whole of India's semiconductor industry.

Annex I

LECTURES GIVEN

30 March - "Electronic Effects of Dislocations and Some Related Aspects of Epitaxy in Cheap Solar Cells", at Electronics Corporation of India, Hyderabad.

31 March - "Electronics of Dislocations in Epitaxy", at Centre of Advanced Study, University of Calcutta.

9 April - "Electronics of Grain Boundaries in Poly-crystalline Silicon Solar Cells", at Tata Institute of Fundamental Research, Bombay.

Annex II

ADDRESSES OF COMPANIES VISITED

Continental Device India Ltd
C-120 Naraina Industrial Area,
New Delhi - 110028

Electronics Corporation of India Ltd
Industrial Development Area at Cherlapalli,
Hyderabad - 40

Hindustan Conductors Pvt. Ltd
National High No.8
Dharmsinh Park,
Nadiad - 387001, Gujurat

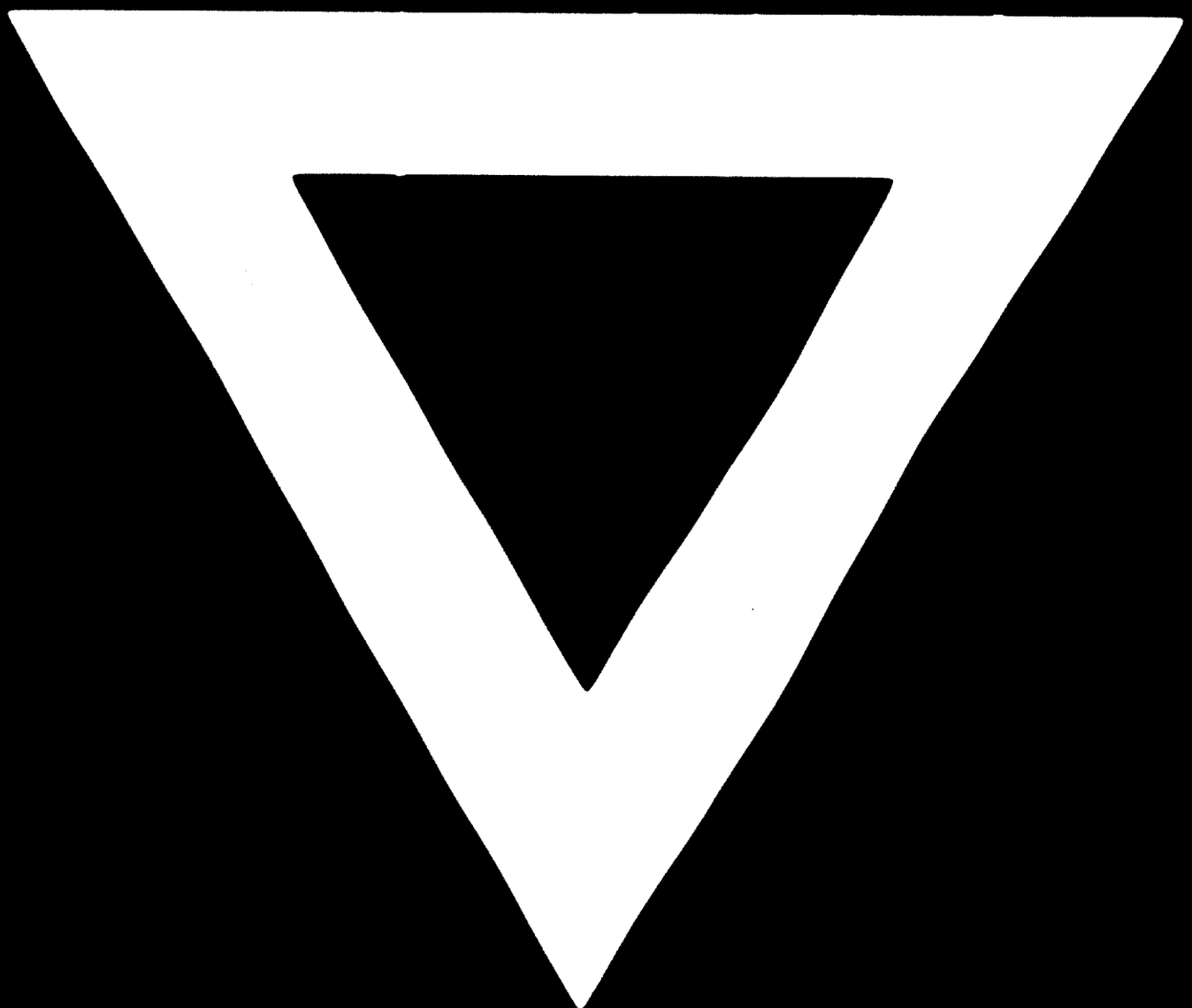
Khandelwal-Hermann Electronics Pvt. Ltd
Khandelwal Industrial Estate,
Bhandup,
Bombay - 400078

Semioonductor Ltd. Poona (Bombay)
Radio House, 6th floor,
6th Rampart Row,
Bombay

USHA Rectifier Corporation (India) Ltd
12/1 Mathura Road
Faridabad

West Bengal State Electronics Development Corporation,
225-K Acharya Jagdish Chanoha Bose Road,
Calcutta, (West Bengal)

C-273



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