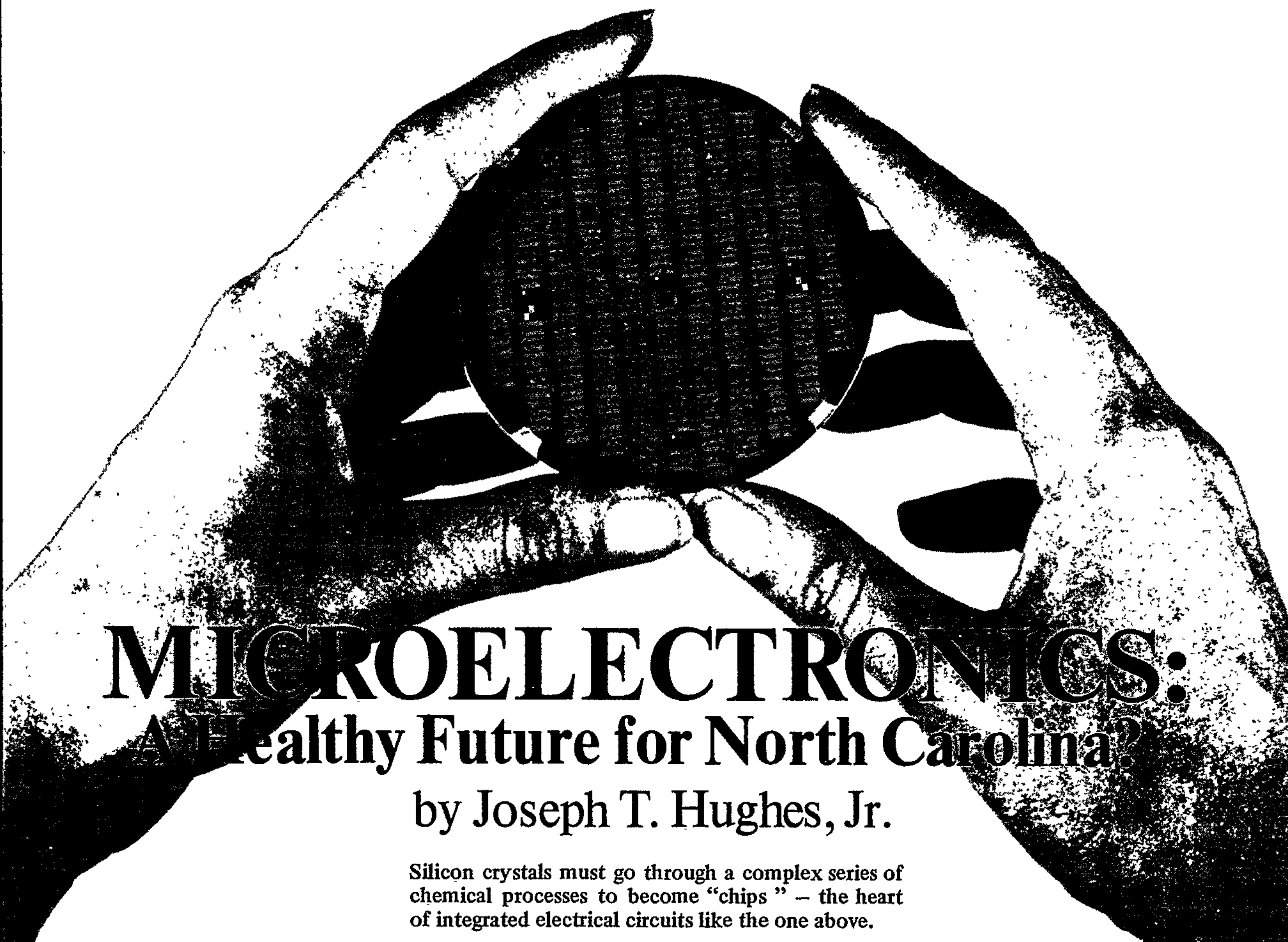

MICROELECTRONICS: A Healthy Future for North Carolina?

by Joseph T. Hughes, Jr.

Silicon crystals must go through a complex series of chemical processes to become "chips" – the heart of integrated electrical circuits like the one above.

It is imperative that we think of Southern industry as a spiritual movement and of ourselves as instruments in a Divine plan.

Millhands and Preachers
by Liston Pope

Microelectronics is expected to be the major growth industry for the remainder of the century . . . (the) new industrial revolution.

Microelectronics Center of North Carolina promotion brochure

In the last decades of the 19th century, the South began building what became the cornerstone of the region's economic base for the 20th century: the textile industry. The milltowns springing up across the Piedmont represented a moral crusade whose goal, in the words of one of its major advocates, Henry Grady, was "to lift the South from defeat and utter poverty to victory and plenty." But the promise of steady work overshadowed a hazard of the industry that only became widely understood three generations later: People who work around cotton dust for many years might become sick and disabled in the course of their employment.

As industrial developers and southern boosters approach the year 2000, they are banging the drums of a new crusade – the promise of the microelectronics industry. These advocates have marshalled the same kind of fervor as did their 19th century predecessors. But the industrial promoters of today face another kind of challenge this time around. As the problems associated with brown lung have received increasing attention throughout the textile belt – and as industrially-related health concerns have emerged throughout the country, industrial planners have been forced to recognize another dimension to their trade.

Planning ahead to prevent chronic health prob-

Photo by Chip Henderson, courtesy of N.C. Department of Commerce.

Joseph T. Hughes, Jr., who is completing a master's degree in public health at the University of North Carolina at Chapel Hill, directs the pesticide project of Farmworker Legal Services of North Carolina.

lems at the front end of an industry's development is much less costly to society in the long run than bearing the burden of sickness, suffering, or environmental cleanup in the distant future. As Governor Hunt's toxic substances advisor, Don Huisingh, recently noted regarding the microelectronics industry, "There are questions pertaining to human health effects that we need to explore thoroughly. We want to be able to anticipate what problems there may be . . . before we have dead bodies."

In the last few years, health-related issues – both inside the workplace and in the outside environment – have become a clear concern in formulating state policy on industrial recruitment. Several recent events have brought into question the state's traditional commitment to industrial growth at any price.

• In 1971, the General Assembly passed a bill directing the Department of Commerce, in conjunction with the Department of Natural Resources and Community Development (NRCD), to prepare an environmental impact analysis of prospective industry recruits.[1]

• In 1980, the Governor's office set up the Toxic Substances Project within the North Carolina Board of Science and Technology to evaluate the most frequently used and most dangerous toxic chemicals used in the state and to develop comprehensive profiles of each substance.

• In November 1980, under registration procedures required by the federal Resource Conservation and Recovery Act of 1976, stringent hazardous-waste guidelines went into effect.[2] They significantly increased the cost of disposing of toxic byproducts and sharpened the public's awareness of the need to protect groundwater supplies from chemical contamination.

• In June 1981, the United States Supreme Court, in a decision involving the cotton dust standard under the Occupational Safety and Health Act, rejected the use of cost/benefit analysis for worker health standards. The ruling is forcing a reevaluation of corporate policy with respect to occupational health hazards and use of control technology.[3]

• In 1981, the General Assembly passed the Waste Management Act of 1981, a legislative priority for Governor Hunt which provides the state with mechanisms for dealing with hazardous and low-level radioactive wastes.[4]

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[1]G.S. 143B-437, as recodified in 1977.

[2]42 U.S.C. 6901 *et. seq.*

[3]*American Textile Manufacturers Institute, Inc.* v. *Donovan*, 101 S.Ct. 2478 (1981).

[4]Chapter 704 of the 1981 Session Laws (Senate Bill 443).

Measuring the tradeoffs between jobs and the environment has entered the industrial-recruitment equation in North Carolina for the first time. Thus far, the results of this process have tended to pit industrial recruiters against environmentalists or worker advocates.

In 1979, for example, public controversy erupted over a proposed oil refinery on the banks of the Cape Fear River in Wilmington. The Department of Commerce (DOC) hailed the refinery as a great coup for the state and in its 1979 *Annual Report for Economic Development* ranked petroleum at the top of the list of industrial sectors by amount of investment capital committed to North Carolina during that year. Environmental groups joined with local citizens to protest threats to the

Worker Safety and Environmental Considerations

by George R. Herbert

On May 28, 1981, Mr. Herbert presented a "Statement Regarding Requested Budget Appropriations for Microelectronics Center of North Carolina" to the full Joint Appropriations Commitee of the General Assembly (see full text on pages 23-26). The portion of that "Statement" concerning worker and environmental considerations appears below (the table appeared as an appendix to the May 28 testimony).

Processes for the fabrication of integrated circuits involve a variety of chemicals, many of which are used in other industries with which we are more familiar. In general, the quantities used are much smaller than we are accustomed to thinking of when we hear reference to "industrial chemicals." While some of these chemicals require careful handling, integrated circuit production poses no unusual hazards to workers nor to the environment when compared to other major manufacturing sectors.

Chemicals are neutralized and removed from water used in the process, and scrubbers remove undesired vapors from discharged air. As a result, this industry represents no special threat to our environment. And with constantly advancing technology, newer facilities are recycling a high ecosystem, and state and federal agencies made extensive studies of potential hazards before issuing the required permits. By 1981, the demand for petroleum products had declined significantly from the 1979 peak, and the projected cost of building the refinery had increased from $400 million to $1 billion. Brunswick Energy Co. cancelled its plan to build the refinery, and the "committed" capital of 1979 never got off the books.

The "economic development vs. health and environment" debate has taken a strident turn over microelectronics recruitment as well. Supporters of the industry, such as Microelectronics Center Board Chairman George Herbert, have characterized health advocates as using "scare tactics" and "carefully extracted statistics" to portray employment in microelectronics as "exceptionally hazardous" (see box on this page). Worker advocates, such as the Durham-based North Carolina Occupational Safety and Health Project (NCOSH), have held a "citizens" hearing at which most speakers addressed potential hazards of the industry. While *The Charlotte Observer* and *The News and Observer* of Raleigh have each reported current environmental debates within the industry, neither has done a far-reaching analysis (such as the recent Pulitzer Prize-winning series on brown lung by *The Charlotte Observer*). More importantly, perhaps, no ongoing policy dialogue concerning the potential health hazards of the industry has emerged.

Much of the job-safety and health controversy in the microelectronics recruitment campaign revolves around the semiconductor sector of the industry, the fastest growing branch of the elec-

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percentage of their water, thereby reducing even further the amounts of water used and discharged.

For whatever special motives they may have, there are those who use carefully extracted statistics and scare tactics to portray employment in the microelectronics industry as exceptionally hazardous. They do so by extracting from the Department of Labor's report of "occupational injury and illness" only the "illness" rate of 0.9 cases per year per 100 full-time workers in 1978 noting this as being higher than the average for all private industry. They do not explain that the "illness" rate is only a tiny fraction of the total safety data nor that, because the definition of "illness" includes such concerns as skin irritation and eye strain, the "severity rate" for the semiconductor industry, measured by lost work days, is only 80 percent of that for all industry.

In fact, the microelectronics industry has one of the best safety records of all industrial categories, and its 1978 *occupational injury* and illness incidence rate of 6.4 reports per 100 full-time workers was 32 percent lower than the 9.4 rate for all private industry and less than one-half of the 13.1 figure for all manufacturing. (See the table of industries which clearly indicates the excellent comparative safety ranking of the semiconductor industry.)

The only conclusion that can be reached by an objective examination of the nature and record of the microelectronics industry is that it is a responsible industry, that it offers safe careers to its workers, and that North Carolina will benefit from having it among its "industry citizens." Special barriers to its existence or special studies of its operations are no more warranted for this industry than for the other manufacturing industries that are now operating in the state and would only serve to indicate a less than warm welcome.

Occupational Injury and Illness Rates for Selected Industries, U.S. (1978)

(Reports per year per 100 full-time workers)

Mobile Home Manufacturing	34.8
Boat building and repairing	22.8
Poultry and egg processing	22.8
Brick and clay tile	21.2
Malt beverages	19.3
Household furniture	16.5
Dairy products	15.8
Bakery products	13.8
Paper and allied products	13.5
Residential construction	13.3
All manufacturing	**13.2**
Agricultural production	12.8
Household appliances	12.6
Textile machinery	12.2
All private sector	**9.4**
Phosphate fertilizers	8.4
Chemicals and allied products	7.8
Cigarette manufacturing	7.7
Retail trade	7.5
Semiconductors	**6.4**
Engineering and scientific instruments	6.2
Computing equipment	4.4
Banking	1.5

Source: 1978 data from August 1980, report of Bureau of Labor Statistics, U.S. Department of Labor.

REPORT OF OCCUPATIONAL DISEASE for SELECTED INDUSTRY and DISEASE GROUPS IN CALIFORNIA

Percentages are reported incidences of a particular disease group divided by the total number of reported diseases.

Industry Sector	Skin Condition	Eye Condition	Chemical Burns
Electronic Components & Accessories	23.9%	27.1%	34.1%
All Manufacturing	35.8%	33.0%	12.9%

Source: Department of Health Services, State of California, "Tabulation of Reports of Illnesses in California Reported by Physicians," 1976. (This is the latest data available as of July 1981.)

tronic component manufacturing business and the most labor-intensive. This sector, which produces microchips and integrated electronic circuits, involves engraving a complex pattern of electric circuitry on a piece of silicon no larger than a fingernail. After silicon crystals are ground up and sliced into thin wafers using a diamond-edged saw (a process called wafer fabrication), they undergo a multi-staged etching, polishing, and cleaning process. Finally, photographic and electrochemical techniques, called photoresist, are used to impart special electrical characteristics to each individual microchip (see box on page 37 for a technical explanation).

Throughout this formulation process, numerous chemicals, organic solvents, and poisonous gases are used for electroplating, stripping, and degreasing the semiconductor components and the integrated circuit-boards. According to Hamilton Fairburn, assistant regional administrator of Region IX for the Occupational Safety and Health Administration (OSHA), the name "electronics industry" is misleading. "People think of it as wires, soldering and transistors," says Fairburn. "But when you get to the semiconductor industry, you're really talking about chemical reactions. It's a chemical industry."

Because of the growing health concerns about chemical use in the semiconductor sector, the National Institute for Occupational Safety and Health (NIOSH) has recently contracted with the Research Triangle Institute (RTI), based in the Research Triangle Park, to conduct an evaluation of worker health data throughout the industry. According to David A. Pasquini, director of the RTI study, "There are a lot of unanswered questions. I don't think that anybody has any answers yet." A preliminary draft of the RTI study lists a number of potential occupational health hazards in microelectronics including "occupational asthma" from breathing soldering and welding fumes; possible liver inflammations from the solvents carbon tetrachloride and trichloroethylene (TCE), both of which are suspected as cancer-causing agents; and unspecified health problems from exposure to ozone, arsine, and phosphine gases.

In 1978, the semiconductor industry had overall job-related illness and injury rates 50 percent lower than the all-manufacturing average, according to the U.S. Department of Labor. However, the number and severity of work-related illnesses, including occupational diseases, were much higher than average during the same year according to the California Department of Industrial Relations. The California data indicate, for example, that the semiconductor industry had an incidence rate in job-related *illnesses* four times higher than the rate in all employment sectors and two and one-half times higher than the all-manufacturing average.

Defenders of the microelectronics industry dispute the importance of the job-illness rate. Mr. Herbert, for example, says it represents only "a tiny fraction of the total safety data" and that it is inflated by minor irritations such as skin rashes and eye strains (see Herbert box). However, the proportion of skin and eye problems, as a percent of all reported illnesses, are lower in microelectronics than for all manufacturing sectors – 23.9

North Carolina Occupational Safety and Health Project (NCOSH) Director David Austin gives presentation at June 30 hearing on microelectronics.

Photo by Paul Cooper

and 27.1 percent respectively, compared to 35.8 and 33.0 percent. Hence, these problems could not have inflated the job-illness rate in microelectronics. But the proportion of chemical burns requiring medical attention, a more serious concern in the illness data, was more than two and one-half times higher than for the all-manufacturing average – 34.1 percent compared to 12.9 percent (see box on page 36). The source of these figures, the California Physicians' Occupational Illness Report,

What is a Silicon Chip?

by Tom Vass

Nearly all chips of microelectronic circuits are made on a wafer of silicon, a metallic element a little lighter than aluminum with a silvery luster. These chips are assembled into tiny electrical circuits which form the backbone of the computer systems in microwave ovens, calculators, computer memories, and thousands of other products. Microelectronic chips have a crystal structure whose atomic bonds allow the conduction of current by either positive or negative carriers when the proper dopants (chemicals) are added. The steps in the manufacturing processes of a chip are listed below, in a simplified way.

1) Chemically altering a purified form of sand called "ferro-grade" silicon produces high-quality polycrystalline silicon.

2) From this substance a single crystal seed, the size of a pea, is immersed in an oven at 1,400°C in a mixture of molten silicon dopants. The crystal seed is rotated and withdrawn continuously, allowing the mixture to solidify on the seed's surface, reproducing the atomic structure of the crystals.

3) When the single crystal approaches a manageable size, it is ground into a cylinder out of which thin, circular wafers three to five inches in diameter are cut. Each wafer is submerged in an acid bath to remove any extraneous substances left from the cutting procedure. The acid is heated to increase its cleaning ability. After the acid bath, the wafers are alternately rinsed in cold and then boiling water.

4) In a process called "photoresist/baking," the wafers are baked at 1,100°C in order to produce a thin upper layer of silicon oxide. A coating of light-sensitive chemicals is put on the layer of silicon oxide and the wafer is baked again.

5) The wafer is then exposed to a pattern of integrated circuitry by passing ultraviolet light through a glass mask, a process called "masking." The ultraviolet light leaves a pattern of the desired circuit on the wafer which is then baked at high temperatures.

6) After the pattern has hardened, the wafer is dipped in boiling sulphuric acid to remove materials from around the pattern and then rinsed. At this stage, the wafer is referred to as an "etched wafer."

7) The etched wafer is placed in a diffusion furnace containing either arsine, phosphine, or boron gas and heated to 1,000°C. The chemical gases, called dopants, enter the exposed areas of the circuit pattern, altering the atomic electrical characteristics of the silicon.

8) If more layers of circuitry are required on the wafer, the stages explained in numbers 4-7 are repeated.

9) Once the wafer has the required layers with complete circuitry imprints, it receives one more round of masking with photoresist chemicals and is masked with a thin layer of aluminum to define electrical contacts for connecting external wiring. The wafer is placed in an evaporation oven to rid it of unwanted metal traces, then coated with a layer of glass at a temperature of 420°C.

10) The finished wafer is etched with acid and rinsed with water. It is cut into individual chips, usually with a diamond saw. From this point, the chips can be bonded to ceramic frames and assembled into integrated circuit boards.

Process	Chemicals Used
Wafer Production	silicon, hydrogen
Wafer Cleaning	sulphuric acid (heated), nitric acid
Photoresist/Baking	xylene (1,000°C), hydrogen
Masking	none
Etching	hydrofluoric acid (heated), hydrochloric acid
Diffusion/Baking	arsine gas, or phosphine gas, or diborane gas (1,000°C)
Metal Masking	same as processes 3-6
Wafer Cutting	none
Assembly Into Boards	cyanide, epoxy resins, krypton gas, lead, trichloroethylene, freon, acetone, alcohol, solvents

Tom Vass is a member of the Conservation Council of N.C.

published by the state's Department of Health Services, is the only mandatory state-reporting system on worker health problems in the country.

In addition to potential worker hazards, the industry poses possible environmental threats. The concentrated use of chemicals may, for example, exacerbate the growing problem in the state of proper hazardous waste disposal. Even in California, which has state-approved hazardous waste disposal sites, semiconductor wastes continue to be improperly dumped into sewers and sanitary landfills, according to reports by *The Charlotte Observer*. Dr. David Storm, regional head of the California agency that manages hazardous wastes, said that Santa Clara County, the heart of silicon valley, produced 1,849 tons of toxic wastes in April 1980 (the most recent month for which statistics are available), 80-90 percent of which came from the 500 electronics plants in the county.

North Carolina currently does not have any approved sites for disposing of toxic wastes properly. Most of the state's wastes are either stored in drums or holding ponds on company property or, at large expense, shipped out of state to waste sites approved by the Environmental Protection Agency. North Carolina recently had its first known contamination of groundwater with toxic waste from a semiconductor operation when International Business Machines (IBM) revealed that chemical wastes from its Research Triangle Park facility began seeping into the water table three years ago. IBM generates approximately one million gallons of toxic wastes each year, 30 percent of which result from its semiconductor operations, according to a company spokesman.

The toxic waste problem for microelectonics producers may become even more acute in the near future, particularly in the Research Triangle area, with the opening of semiconductor plants by Raychem in Fuquay-Varina, Data General in Apex, and Hewlett-Packard in Wake Forest. In California's silicon valley, according to Dr. Storm, "The electronics industry wastes are not so great by volume, but they are some of the more nasty types."

The industrial revolution of the 21st century rolled symbolically into North Carolina in the spring of 1981 when the General Assembly approved $24.4 million for the Microelectronics Center of North Carolina (MCNC). Whether we will have microelectronics is now a moot question. Even before the MCNC appropriation, the electronics industry was the fourth largest industrial employer in the state, rapidly moving up on textiles, apparel, and furniture in terms of economic investment, number of employees, and, with the establishment of the MCNC, political clout. The question now becomes: How can state policymakers plan so as to understand and manage the potential threats which the microelectronics industry pose to the state's natural and human resources?

During the debates on the appropriation for MCNC, several citizen groups proposed mechanisms to research and explore the environmental and occupational health questions concerning the microelectronics industry. The Conservation Council of North Carolina suggested that a portion of the MCNC appropriation be earmarked for research into safe use of known toxic substances in the industry. In addition, NCOSH proposed the development of an environmental/occupational health advisory committee to MCNC to ensure ongoing input from a variety of persons with scientific backgrounds and to facilitate continued monitoring of the industry in its quest to control its chemical problems. But in the heat of legislative battle, no action on such a touchy topic was taken.

The influx of microelectronics firms represents a unique challenge to North Carolina policy planners and regulators. The potential hazards and harmful effects of the industry are still shrouded in scientific differences of opinion and uncertainty. Moreover, the 1980s appear to be a period of deregulation, cutbacks in funding of regulatory agencies, and a return of enforcement and monitoring responsibilities to the states. Consequently, state agencies such as the Departments of Labor and Human Resources, which now have the primary responsibility for protecting workers' health and monitoring toxic waste in the environment, will have to take major leadership roles in coping with scientific uncertainties and regulatory standards.

While this shift in responsibility from the federal to the state level poses a serious challenge, it also represents an opportunity for far-sighted North Carolina officials. If potential threats of the microelectronics industry to health and the environment are anticipated and examined seriously – not glossed over or dismissed as alarmist – the advent of the industry to North Carolina could provide a demonstration project for the nation. An economic development policy guided by sound, open-minded planning rather than excessive boosterism can not only net new jobs but also nurture good health. Only then will an important lesson from the industrial crusade of the 19th century be incorporated into the "new industrial revolution" of today. The health of workers and the protection of the environment must be considered in charting a major new course in economic development. □