SELECTION OF MICROELECTRONIC SUBJECT MATTER FOR INDUSTRIAL ARTS INSTRUCTION

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The purpose of this study was to derive industrial arts subject matter, suitable for use at the secondary school level, from the technology of microelectronics. This subject matter was to reflect the technology of the microelectronic industry and also be compatible with the objectives of industrial arts education.

The study involved three major steps. The first step was the arrangement of information about the technology of microelectronics into groups of information denoted by conventional electric terms. In the second step, industrial arts subject matter was selected from the groups of information by using Olson's "curricular components" as "categories of subject matter". The third step involved the placing of the selected subject matter under the technical, avocational, and consumer functions of industrial arts.

The sources of information about the technology of microelectronics were 312 periodicals dealing with the electronic industry for the years 1963, 1964, and 1965. The derived subject matter was presented in both narrative and topical outline forms.

TABLE OF CONTENTS

LIST OF TABLES

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CHAPTER I

INTRODUCTION

Recent developments in the technology of industry should be reflected in industrial arts subject matter. By such reflection the value of industrial arts as " . . . an answer to the problem of educating boys and girls to live in a world which may be accurately characterized as industrial and technological"[1] will be enhanced.

The achievement of the implications of this statement requires a constant review of the developments in the technology of industry for the purpose of selecting subject matter material to be used in industrial arts instruction.

In those fields of industry where developments in technology occur with the greatest rapidity, the need for up-to-date subject matter is the greatest. One field of industry with a great frequency of new developments is in electronics. A recent major advancement in the electronics industry is the development of the technology of microelectronics.

This study was designed to identify and present, in an organized form, subject matter material from the technology of microelectronics for use by teachers of secondary level industrial arts in electronics classes.

This study was greatly influenced by the point of view developed

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[1]Gordon O. Wilber, Industrial Arts in General Education, (2nd Ed. Revised). (Scranton, Pennsylvania: International Textbook Company, 1954), p. 1.

by Delmar W. Olson in his book, Industrial Arts and Technology.[2] This point of view asserts that industrial arts subject matter should reflect the technology of American industry, while at the same time being compatible with the objectives of industrial arts.

Specifically, this study was concerned with deriving a body of subject matter from the technology of microelectronics and then organizing this subject matter into a form for use in industrial arts electronics classes.

Hypothesis

Based on four years of observation of the growth of microelectronics, and on numerous discussions with teachers of industrial arts electronics, the writer formulated the following hypothesis for this study:

The technology of microelectronics contains definite industrial arts subject matter which can be identified and organized for use in industrial arts electronics courses.

Purpose of the Study

The main purpose of this study was to select subject matter from available literature dealing with the technology of microelectronics, and present this subject matter for use in secondary school level industrial arts classes.

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[2]Delmar W. Olson, Industrial Arts and Technology. (Englewood Clifts, N. J.: Prentice-Hall, Inc. , 1963).

Specifically, the purpose of the study was to identify micro-electronic subject matter in selected literature and organize it for use in industrial arts electronics in the following areas:

1. The area of consumer knowledge in the field of electronic equipment.
2. The area of servicing, repair, and installation of electronic equipment.
3. The area of manufacturing processes used in the production of electronic equipment.
4. The area of avocational interests in electronic equipment.

The main source of data for this study was electronic periodicals of the past three years (1963-1966).

Need for the Study

In order for an industrial arts teacher to keep subject matter up-to-date, he should constantly review advances and developments in industry. He should incorporate into his courses that material which he has gathered from his review of industrial progress. In this manner he enhances the value of his courses, and can assure his students of an up-to-date presentation of facets of American industry.

In the fast changing electronics field, constant review by the industrial arts teacher is even more important. Progress in electronic technology has invoked such a change in concepts, processes, operations, use and installation of electronic equipment, and production of the equipment that it has made obsolete much of the technology of five years ago.

Little, if any, has been written about the technology of microelectronics as subject matter for industrial arts. This important phase of electronic technology should be included in industrial arts instruction. Subject matter concerned with microelectronics is essential to the understanding of the modern electronics industry, consumer goods, service and installation of electronic equipment, and avocational implications of microelectronics.

There is a need for derivation and presentation of microelectronic subject matter for use by industrial arts teachers who teach general electricity-electronics. Some of these teachers lack an in-depth background in electronics which would allow them to make extensive investigations of microelectronics in search of subject matter.

This study should be of value to these teachers of electronics by making available microelectronic subject matter derived from recent technology of microelectronics.

Assumptions

There were two basic assumptions underlying this study. The first and most fundamental assumption was that industrial arts subject matter should reflect the technology of industry. This assumption was employed in this study in the following form: microelectronic subject matter should reflect the technology of the microelectronic industry.

The second basic assumption was that up-to-date technology of microelectronics would be found in electronic publications available by subscription.

Delimitation

For the purpose of this study, the following delimitations were established:

1. That this study be only concerned with the selection of subject matter for industrial arts electronics which reflects the technology of industrial microelectronics.
2. That this study exclude experimental microelectronic subject matter.
3. That no attempt be made to establish a grade level at which the selected subject matter should be presented.
4. That no formal evaluation of the derived subject matter in this study will be attempted, although members of the Industrial Arts Department, Virginia Polytechnic Institute, will be consulted during the course of the study.

Terminology

Terminology is defined as the special or technical expression used in art, science, or business. Terms related to industrial arts and the technology of microelectronics are listed below:

<u>Course of study</u>: a guide prepared by administrators, supervisors, and teachers of a particular school or school system as an aid to teaching a given subject or area of study for a given grade or study group.[3]

<u>Electronics</u>: pertaining to electron devices or to circuits or

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[3]Carter V. Good, (ed.), <u>Dictionary of Education</u>. (New York: McGraw-Hill Book Co., Inc., 1959), p. 143.

systems utilizing electron devices, including electron tubes, magnetic amplifiers, transistors, and other devices that do the work of electron tubes.[4]

Microelectronics: term used to describe any electronic circuit, subsystem, or system whose parts density exceeds by any order of magnitude or more, that attainable utilizing conventional components.[5]

Subject matter: the facts, information, knowledge, or content constituting the substance of any course of study and to be acquired by the learner, as distinguished from the methods, disciplines, and activities that give form to a course: the content of education as contrasted with the science of educating.[6]

Technology: industrial science; the science or systematic knowledge of the industrial arts, especially as applied to manufacturing.[7]

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[4]Charles Susskind, (ed.), The Encyclopedia of Electronics. (New York: Rheinhold Publishing Corporation, 1962), p. 467.

[5]Ibid.

[6]Good, op. cit., p. 535.

[7]Webster's New Collegiate Dictionary. (Cambridge, Mass.: The Riverside Press, 1956), p. 872.

CHAPTER II

REVIEW OF LITERATURE

Presented in this chapter is a review of some pertinent literature concerning the selection of industrial arts subject matter. A very superficial survey of the professional literature in the field of industrial arts leaves little doubt that the analysis of trades and industrial skills has been the major method of selecting industrial arts subject matter.[8]

Although analysis of trades and industrial skills is appropriate to vocational industrial education, its use has been challenged when applied to industrial arts education. For example, Ericson and Seefeld point out:

> It will soon become clear that a study of operations which skilled workers are expected to perform will throw light upon only a segment of the needed teaching content for industrial arts.[9]

Following this criticism, Ericson and Seefeld expand the scope of trade and skill analysis to include a number of phases or areas of industry in addition to tool processes and operations.

Friese, on the other hand, appears to be in opposition to any

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[8] Robert G. Hammond, "Determining Content in Industrial Arts," Industrial Arts and Vocational Education, Vol. 50, No. 10, (May, 1961), pp. 24-25.

[9] Emmanuel E. Ericson and Kermit Seefeld, Teaching the Industrial Arts. (Peoria, Illinois, Chas. A. Bennett Co., Inc., 1960), pp. 276-477.

form of trade and skill analysis as the basis for obtaining industrial arts subject matter. Included among the objections he lists are:

(1) the circumscribing nature of analysis with its tendency to make a course lose its freshness;

(2) its non-adaptability to general industrial arts;

(3) its tendency to prevent student initiative and original planning.[10]

Wilber also objects to the analysis of trades and industrial skills in order to obtain industrial arts subject matter. He states that there is one primary purpose for subject matter, namely, " . . . to achieve the objectives of the particular course in question."[11] He then defines objectives in terms of changed behavior on the part of the student, and further states that subject matter should be evaluated by the question: "Does it contribute significantly toward bringing about one or more of the desired behavior changes?"[12]

Kerns also supports the use of course objectives in selecting industrial arts subject matter. He lists nine desirable objectives for industrial arts to be used in subject matter selection.[13] Miller and

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[10]John F. Friese, "Analysis of Course-of-Study Materials for Industrial Arts," Industrial Arts and Vocational Education, Vol. 42, No. 9, (Sept. 1953), pp. 208-211.

[11]Gordon O. Wilber, Industrial Arts in General Education. (Scranton, Pennsylvania: International Text Book Company, 1948) p. 58.

[12]Ibid.

[13]M. Ray Karnes, "Improving Industrial Arts Education: Some Dimensions of the Problem," Industrial Arts Teacher, May-June, 1960, p. 19.

Smalley also state that proper selection of industrial arts subject matter begins with an analysis of course objectives.[14]

Use of course objectives in selecting industrial arts subject matter is only part of the picture however; there is still the question of what shall be the source of the subject matter for industrial arts? One point of view, held by Fierer and Lindbeck, is that curriculum content should come from the changing technology.[15] Stadt states that subject matter specialists should search the literature of their field to identify forces which are generated by industry and to select materials which lend intelligibility to these forces.[16]

Olson also supports the principle of technology as a source of industrial arts subject matter, and has proposed a plan for the derivation of subject matter from technology through the use of course objectives.[17]

As previously pointed out, this study adopted Olson's point of view. For this reason, it is more intensively reviewed than other literature cited herein.

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[14]Rex Miller and Lee H. Smalley, Slected Reading in Industrial Arts. (Bloomington, Illinois: McKnight & McKnight Publishing Company, 1963), p. 356.

[15]John L. Fierer and John R. Lindbeck, Industrial Arts Education. (Washington, D.C.: The Center for Applied Research in Education, Inc., 1964), p. 90.

[16]Ronald W. Stadt, "A Method of Selecting Content for Lending Intelligibility to Industry: A Critique and a Proposal." (Unpublished Doctor's Dissertation, University of Illinois, 1962).

[17]Delmar Wlater Olson, Technology and Industrial Arts. (Columbus, Ohio: Epsilon Pi Tau, Inc., 1957)

In his proposal, Olson presented six functions or purposes of industrial arts: the social function, the cultural function, the orientation function, the technical function, the consumer function, and the avocational function. These functions were then defined by Olson as being "statements of mission of industrial arts which identify its purposes and constitute its objectives and guiding principles."[18]

Through an analysis of these functions, Olson obtained "curricular components," which he defines as "those elements, or necessary parts, of subject matter which together constitute the body of subject matter for industrial arts."[19]

Following this analysis of the functions of industrial arts, Olson proceeded to:

1. Establish systems of classification for the categories of industries.
2. Analyze the categories of industries for general nature and industrial arts subject matter.
3. Identify basic industrial materials processes, products, occupations, services, and information, as revealing of the content of industrial arts subject matter.
4. Derive "curricular components" from the categories of industries.

Olson thus derived two sets of curricular components. The first set was obtained through an analysis of the functions (objectives) of

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[18] Ibid., p. 5.

[19] Ibid., p. 105.

industrial arts. This set of curricular components was considered ". . . as representative of subject matter elements inherent in the function."[20]

The second set of curricular components came from an analysis of the industries categories. This set of curricular components was ". . . basic elements of the industries which, when taken together, identify and characterize the respective industries."[21]

These two sets of curricular components were added together and the identical terms eliminated. This resulted in a master list of 92 curricular components. This master list is presented in Table 1.

Of these curricular components, Olson says:

> Each component is a body of subject matter, and when they are all compiled into a master list . . ., the basic elements of subject matter for industrial arts, as drawn from industry, will be identified.[22]

For the special area of electronics, Olson developed a list of 19 curricular components representative of the electronics industry. This list of electronic curricular components is presented in Table 2.

Taken singly, these curricular components are to be considered as units, blocks, or categories which serve to identify industrial arts subject matter. Taken in total, the subject matter identified by the curricular components is to be considered reflective of the technology of the industry analyzed through the components.

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[20] Ibid, p. 106.

[21] Ibid, p. 166.

[22] Ibid, p. 103.

TABLE 1

MASTER LIST OF CURRICULAR COMPONENTS AS

CATEGORIES OF SUBJECT MATTER

Aesthetics	Human engineering	Processes
Analysis	Inspection	Problems
Applications	Installation	Production
Assembly	Instruments	Products
Automation	Integration	Records
Chemistry	Interpretation	Recreation
Circuit	Invention	Regulation
Communications	Investigation	Representations
Computers	Jigs	Reproduction
Conservation	Legislation	Research
Construction	Library Work	Safety
Controls	Lubrication	Salvage
Creating	Machines	Selection
Decorating	Management	Services
Design	Manufacturing	Solutions
Development	Materials	Specifications
Diagnosis	Mathematics	Standards
Dies	Mechanics	Structures
Discovering	Mechanisms	Study
Distribution	Mining	Supervision
Drawing	Molds	Supplies
Editing	Models	Surveys
Engineering	Occupations	Synthetics
Equipment	Operation	Systems
Exhibits	Organization	Techniques
Experiment	Physics	Testing
Evaluation	Planning	Theories
Fastening	Power	Tools
Finishes	Presentations	Transportation
Fixtures	Preserving	Utilization
Hobbies	Principles	

TABLE 2

ELECTRONIC CURRICULAR COMPONENTS

Research	Invention	Principles
Experiment	Manufacture	Installation
Design	Theories	Systems
Development	Circuits	Materials
Services	Operation	Application
Engineering	Processes	
Components	Physics	

Material identified and organized as subject matter under these curricular components is both reflective of technology and compatible with the objectives of industrial arts education.

CHAPTER III

PROCEDURE

An assumption in this study was that periodical literature dealing with electronics contained information about the technology of microelectronics. The author proposed that a methodical search of this literature would reveal this information, and that industrial arts subject matter could be derived from it.

The study was divided into three phases: (1) the selection of tentative subject matter for industrial arts from the literature dealing with the technology of microelectronics; (2) the derivation and organization of subject matter from this tentative subject matter by application of Olson's "curricular components" and "functions" classification; (3) the presentation of the derived subject matter in a form for use in industrial arts at the secondary school level.

Selection of tentative subject matter from literature dealing with microelectronics: Since the subject matter presented in this study was intended for use in industrial arts electronics courses (in which the majority of subject matter is concerned with conventional electronics), it was felt that the microelectronic subject matter should be related in some manner to conventional electronics.

This would help keep the selected microelectronic subject matter compatible with conventional electronics subject matter. The terms listed below helped establish this relationship and provided a method of organizing the tentative subject matter.

1. Transistors	2. Transformers	3. Inductors
4. Resistors	5. Switches	6. Amps
7. Circuits	8. Connectors	9. Ohms
10. Capacitors	11. Cells	12. Volts

As the examination of the literature proceeded, items of information which seemed to have value as tentative subject matter were compared with this list of terms. If an item could be related to one of these terms, it was written down on a three inch by five inch card. The card was then identified by writing the term related to the tentative subject matter in the upper right-hand corner of the card. At the completion of the examination of literature, this procedure resulted in a body of tentative subject matter dealing with microelectronic technology listed under terms common to conventional electronics.

This organization on cards of the tentative subject matter taken from the literature greatly simplified the next step, which involved the derivation and organization of subject matter from this body of tentative subject matter.

Derivation of subject matter from the body of tentative subject matter: The procedure outlined thus far gave a body of microelectronic information classified by conventional electronic terms. In order to select or derive subject matter appropriate for industrial arts from this collection, it was decided to use Olson's "curricular components" and his "technical, consumer, and avocational functions" as set forth in his proposal for the "derivation of subject matter to reflect technology."

The "cultural, social, and orientation functions," as defined by Olson, were not used in the organization of this subject matter for the following reasons:

The "cultural function" of industrial arts, according to Olson, should develop within the student an appreciation of the style and design of the products of industry. Through this function, the student is encouraged to recognize the aesthetic value of industrial products as well as the value in performing the jobs for which they were designed.

However, due to their nature, not all industrial products lend themselves to aesthetic design. Among those which do not are electronic circuits. Since aesthetic design is not a part of developing or manufacturing electronic circuits, it is not included in industrial arts electronic subject matter. It can also be noted that, while Olson includes aesthetics in his master list of curricular components (Table 1), it is not included in his list of electronic curricular components (Table 2).

The "social function" of industrial arts, again according to Olson, is concerned with developing desirable social habits and attitudes through experiences in the industrial arts shop or laboratory. This development of social intelligence occurs largely through the interaction of the students as they pursue various activities. Such activities are dependent upon what the teacher designates as being appropriate with regard to the subject being studied. Olson does not include in his electronic curricular components any element which could be termed social in nature. For these reasons it was felt that electronic subject matter, by itself, would not contribute toward social development, and was not included in this study.

The basic value of the orientation function, according to Olson, is its role in assisting the pupil in making an occupational choice which may lead him into vocational preparation in the final years of his educational program. Olson recommends that this function be fulfilled to a large degree through field trips, interviews, films, counselling, and reading. Such items are more dependent upon the individual teacher's resources, than upon actual subject matter. For this reason the orientation function was not used in this study.

The curricular components used for this purpose are listed below.

Research	Principles	Manufacture
Invention	Theories	Installation
Design	Systems	Operation
Development	Circuits	Services
Engineering	Materials	Application
Physics	Processes	Components

These curricular components were used as categories of subject matter. Items of tentative subject matter were compared with this list. If an item of tentative subject matter could be categorized as subject matter under one of the above curricular components, it was written on a new three inch by five inch card. This card was then labeled by placing the appropriate curricular component in the upper right-hand corner of the card. This procedure, although admittedly somewhat lengthy and subjective, resulted in the selection of a body of subject matter organized into categories that reflected technology and at the same time was compatible with the objectives of industrial arts.

To provide further organization of this subject matter compatible with industrial arts objectives, the derived subject matter was arranged under the three selected functions of industrial arts. Subject matter related to a particular function was placed under that function. Thus Olson's three functions used in this study provided both a means of giving organization to the subject matter, and a means of establishing the relationship of the subject matter to objectives of industrial arts. The curricular components served to identify the subject matter, within the body of tentative subject matter, that was reflective of the technology of microelectronics.

Presenting the subject matter: The subject matter derived by the foregoing process was presented in both narrative and topical outline forms. This was done for the convenience of persons using this study as source material for industrial arts electronics instruction.

Sources of Data

For the purposes of this study, it was assumed that up-to-date microelectronic technology was presented in the periodic publications dealing with electronics. It was felt that this source of subject matter was of particular importance to those persons who develop course content, since such publications are readily available.

The following publications were reviewed as sources of subject matter for this study:

1. The Bell Telephone Magazine

   Bell System Publication

   New York, N. Y.

   Published four times a year

2. Electronics

   Mc-Graw-Hill, Inc.

   New York, N. Y.

   Published Weekly

3. Electronics Engineering

   Morgan Brothers (Publishing) Limited

   London, England

   Published Monthly

4. Electronic Industries

   Chilton Company

   Philadelphia, Pa.

   Published Monthly

5. Electronics World

   Ziff-Davis Publishing Company

   Chicago, Illinois

   Published Monthly

6. QST

   American Radio Relay League, Inc.

   Newington, Connecticut

   Published Monthly

To provide breadth and depth in the selection of subject matter for industrial arts microelectronics, it was decided to examine and analyze each issue of the above publications for the period January 1963 to January 1966. This examination and analysis included 312 individual issues of the publications listed. Examination and analysis were made of 36 issues of each of the following publications for the indicated time period: Electronic Engineering, Electronics World, Electronic Industries, and QST. One hundred fifty-six issues of Electronics were examined and analyzed. Twelve issues of the Bell Telephone Magazine were also examined and analyzed.

The Bell Telephone Magazine is the only "house organ" in the selected publication, and is the only publication in which a presentation favoring a particular company is highly probable. QST is a publication of the American Radio Relay League, Inc. The American Radio Relay League is an organization of "ham" radio operators, and its publication was included in this study for the purpose of providing source material for the avocational function of industrial arts.

The publication, Electronics Engineering, although a British publication, was included in this study for two reasons. The publication reflects the technological achievements made in American electronics industries, and the author's experience led him to believe that this publication would present a more objective view of these achievements than would an American publication.

CHAPTER IV

RESULTS

The main purpose of this study was to select subject matter from available literature dealing with the technology of microelectronics, and present this subject matter for use in secondary school level industrial arts. The subject matter selected and presented in this chapter fulfills Olson's requirement that industrial arts subject matter reflect the technology of industry, while at the same time being compatible with the objectives of industrial arts.

In order to present this material in a manner which allows quick identification of the subject matter itself and also in a manner more suitable as a reference source for lesson planning, this chapter was divided into two sections. The first section presents the subject matter in a narrative form suitable for use as a reference source in lesson planning. The second section is a topical outline showing more clearly the items of technology contained within the body of subject matter.

The subject matter was organized under three of Olson's functions of industrial arts, in order to keep the subject matter as compatible as possible with industrial arts objectives. One of these functions, the technical function, was subdivided into two sections. This division allowed presentation of material concerned with repair, servicing, and installation of microelectronic equipment to be presented separately from the material concerning the manufacturing process used in producing microelectronic equipment.

The first section of this chapter is concerned with the technical function of microelectronic subject matter. The next two sections deal, respectively, with the consumer function and the avocational function. Presented at the beginning of each function is a brief description of the purpose of that function. Documentation is included where specific ideas are introduced, however, because of the nature of the organization followed, detailed documentation seemed unnecessary.

The Technical Function

The technical function of industrial arts is expressed by Wilber in a list of "Important Objectives of Industrial Arts" as:

> To explore industry and American industrial civilization in terms of its organization, raw materials, processes and operations, products, and occupations.[23]

Olson listed as one of the elements of the technical function:

> How industry employes technical processes and scientific principles to convert materials into products.[24]

This section of Chapter IV presents in a narrative form subject matter relating to the technical function of microelectronic technology. To facilitate this presentation, the technical function is divided into two sub-headings: (A) manufacturing processes used in the production of microelectronic equipment, and (B) servicing, installation, and repair of microelectronic equipment.

Manufacturing Processes. There are three approaches to the production of microelectronic circuits; monolithic, thin-film, and hybrid

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[23]Wilber, op. cit., p. 58.

[24]Olson, op. cit., p. 20.

circuits. The monolithic approach is a semiconductor technique in which both the active components (transistors) and the passive components (resistors and capacitors) are formed on or in a tiny "chip" of semiconductor material.

The thin-film approach to microelectronic circuits is one in which the passive components are deposited as layers of material on an inert substance (known as a substrate) such as glass. The active components are then attached to the passive thin-film components by means of micro-miniature leads.

The third approach is the hybrid microelectronic circuit. This approach is used because of certain limitations imposed by the monolithic and thin-film approaches. In this approach, discrete components are used in conjunction with either thin-film or monolithic techniques. The hybrid approach is used particularly when desired inductance cannot be achieved by either the thin-film or monolithic techniques. These hybrid circuits are often used during circuit development so that resistors, capacitors, transistors, and inductors can be changed by the designer.

Monolithic Circuits. Of the three approaches to producing microelectronic circuits, the monolithic approach produces the smallest (in physical size) circuits.

> A monolithic integrated circuit is one in which more than one electrical component is fabricated and interconnected as a single, solid circuit element.[25]

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[25] Leslie Solomon, "Integrated Circuits," Electronics World, Vol. 72, No. 3, (September, 1964), p. 29.

The technique used to produce the monolithic circuit is a chemical process known as "diffusion". The process of diffusion can be simply illustrated by comparing it to the process of staining wood.

If the surface of the wood to be stained (diffused) is cleaned, and a suitable mask with the desired shape cutout of its interior is placed over the area to be stained (diffused), then an application of the stain (diffusing chemical) is applied to the mask, the result will be a stained (diffused) area with the desired shape in the wood. The depth of stain (diffusion) in the wood is controlled by the amount of stain (diffusing chemical) applied to the wood.

By varying the arrangement of the various diffusion layers in a monolithic device, it is possible to create transistors, diodes, resistors, and capacitors. Each component performs its function because of the differences existing at the interfaces between the various diffused layers.[26]

The chip in which this diffusion takes place starts out as a "P" or "N" type crystal rod drawn to six inches in length and one inch in diameter.[27] Using a diamond saw, this crystal is cut into many thin wafers. These wafers are lapped flat and chemically etched to form a smooth, shiny surface. A completed wafer is about one inch in diameter and about .005 of an inch thick.

The masks used to control the shape of the diffused areas are made

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[26] Solomon, loc. cit., p. 30.

[27] N-type conductivity is the conductivity associated with conduction electrons in a semiconductor.

P-type conductivity is the conductivity associated with holes in a semiconductor which are equivalent to positive charges.

many thousand times larger than the final usable size. These masks are drawn by skilled draftsmen on a scale thousands of times larger than the final size of the mask. This is done to insure the accuracy of the edges of the mask and its cut-out area. These masks are then photographed and reduced in size about 250,000 times before they reach working proportions. About 400 of these masks would fit on a twenty-five cent piece.[28]

By photo-chemical processes, the masks are processed, resulting in the removal of the desired cut-out area from the final film.

Starting with the silicon wafer, the layers are diffused to the required depth and shape by the desired "P" and "N" type of diffusing materials. Other masks are then used to apply either other diffusions or a silicon-dioxide insulating layer.

Resistance in monolithic devices is obtained by using the bulk resistivity of one of the diffused areas. The resistance value obtained is proportional to sheet resistivity and pattern length, and inversely proportional to pattern width.

At the completion of the diffusion process, the wafer will contain up to several hundred individual monolithic circuits (chips). A close microscopic inspection of the wafer may show that many of the individual chips have faults due to pinhole imperfections, improper diffusion, or some other flaw that will make the circuit inoperative. These faulty circuits are marked for removal at a later step in the production.

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[28] Solomon, loc. cit.

The wafer is then cut into individual chips, much in the same manner that glass is cut to size. A diamond scribe is used to make the fine separation scratches on the wafer between the individual circuits. The wafer is then mechanically separated along these lines into uniform dice. The faulty dice are removed from the production-run at this time.

The individual dice are then thoroughly cleaned, dried, and once again inspected for defects. Using high temperature alloy, the dice are mounted in headers. The header-connecter leads are then spot-welded to their connecting points. After the lead welding, each circuit is given a final optical inspection to guarantee that it has not been damaged. After the optical inspection, the circuit is then closed up in its mount and tested.

A step-by-step sequence of the production of a monolithic circuit is presented below.

1. Silicon wafer is placed in a furnace containing an oxidizing atmosphere of about 1200 degrees centigrade. Oxygen penetrates the crystal's surface to form inert, stable silicon dioxide.
2. Photo-etching technique is then used to remove the surface coating in such a pattern as to produce separate areas for individual transistors, resistors, and capacitors.
3. Wafers are placed in a high-temperature furnace with gaseous boron. The boron diffuses through the openings made by the mask to produce the "P" material.

4. The wafer is then photo-etched again to produce openings for transistors.
5. Another photo-etch is used to locate the emitter area and collector contacts. In another high-temperature step phospherous is deposited and diffused to produce "N" type areas employed for the transistor emitter.
6. Next, photo-etching is used to produce cutout areas that will be used for interconnection contacts. The wafers are then placed in a vacuum chamber where aluminum is evaporated from a hot filament to produce an even coating of the metal over the surface of the chip.
7. In the final step the aluminum is masked and etched to form interconnections. In this step, it is extremely important that the final mask achieve perfect register with the interconnection points of the previous layers which have been diffused in preceding steps.

<u>Disadvantages of monolithic circuits</u>. One of the limitations of the monolithic technique is the presence of distributed diodes connecting the fabricated components to the silicon substrate material. One way of reducing the diode-effect is to make sure they are back-biased. This, however, does not do away with leakage currents which may flow, and with unwanted coupling capacitances which are present in any diode.

Another limitation of the monolithic process is the difficulty in obtaining proper passive components. The range of the resistors, which are practical, is only about 20 to 20,000 ohms, which places a severe restriction on circuit design. In addition, the resistors, even within the practical range, have a rather large temperature coefficient.

The capacitors are actually reversed biased diodes and care must be taken to make sure they stay reversed-biased. The value of these capacitors is a function of the applied reverse voltage.

To overcome these disadvantages, a technique known as "Isolated Monolithic Circuits" has been developed. This process starts with a lapped and polished silicon wafer about 0.010 inch thick upon whose surface a thin layer of SiO_2 is formed by heating in an oxidizing atmosphere. Grooves are then etched around the areas which are to be isolated by a normal photo-etch process. Very highly doped "N" or "P" type silicon is deposited or grown within the grooves and then covered by SiO_2 formed by another heating period.

The grooves and surface are covered with polycrystalline material. The wafer is turned over and the original silicon wafer material is ground off until the polycrystalline material is reached. The surface is then polished and etched to leave small islands of the original silicon wafer. These islands act merely as a structural agent. Each of the islands may be treated as a separate "chip" and processed in the same manner as in the normal monolithic process.

Because of the glass insulation, it is no longer necessary to back bias the isolation diodes and less than 1/10 the stray capacitances are present. Also the leakage current between elements is greatly reduced. Another advantage is the possibility of making both P-N-P and

N-P-N transistors on the same substrate.[29]

Thin-film Circuit (first cousin of the familiar printed circuit).

> The major difference between thin-film circuits and conventional printed circuits is one of thickness. Although a printed circuit uses so-called microminiature components soldered to wiring plated on the insulating substrate, this type of circuit is still some large fraction of an inch in thickness.[30]

In the case of thin-film circuits, however, the thickness of the circuit can be measured in microns. Thin-film circuits are actually thinner than a human hair. The thin-film circuits are fabricated from various chemical elements to form capacitors and resistors of various values.

A simple example will serve to illustrate one process by which thin-film circuits are deposited on a substrate. If a candle flame is used as the source of soot, this soot can be deposited on a piece of glass much the same as thin-film deposition takes place. If some geometric shape is placed on the surface of the glass, then this shape can be outlined in soot on the glass. Either a shape within the mask can be deposited or a shape formed by the outside edge of the mask can be deposited, or both, designs can be deposited.

If, instead of the candle, various chemical elements were burned, so that their elements or composition were transformed into "soot," these elements could then be deposited on the inert substrate. If this chemical "soot" would take the shape dictated by some shielded shape

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[29]Carl Todd, "Integrated Circuit Techniques," Electronics World, Vol. 74, No. 5, (November, 1965), pp. 25-86.

[30]Todd, loc. cit., p. 31.

on the surface of the substrate, the resulting pattern would have the same electrical characteristic as the material that was burned.

If the deposited chemical "soot" has a certain resistance value per unit area, then the resultant deposited shape would have a resistance dependent on its area. By varying the shape and areas of deposition, different values of resistance can be obtained.

> . . . the resistances are often expressed in ohms per square. Further designation is unnecessary since resistance per square centimeter is the same as resistance per square inch.[31]

The resistivity of a thin film appears to be influenced not only by thickness, but also by other factors, such as zone structure and possibly traces of impurities difficult to control.

If, on the other hand, a metallic layer were deposited on the insulating (inert) substrate, and then this layer were covered by a thin insulating layer, and then another metallic layer were deposited directly over the first metallic layer (and the insulating layer), it becomes possible to build a very thin capacitor with dimensions on the order of microns.

Of course the capacitance value of such a capacitor can become quite large due to the thiness of the dielectric between the metallic layers.

Actual deposition of thin films is accomplished by the transposition of matter from a heated evaporation source (much like a vacuum

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[31]John R. Collins, "Fixed Resistors," Electronics World, Vol. 70, No. 3, (September, 1963), p. 46.

tube cathode) to a condensation surface (substrate) in a vacuum.

Because the electrical parameters of thin-film components depend largely on their geometrics, the masks used to shape these components are made many times oversize so that they can be made clean and very sharp-edged. The masks are then photographically reduced to their final size using a high-resolution photo technique.

Two methods have been developed which are in common use in making masks for thin-film work. These two methods are outlined below.

Steps in making "In Contact" masks:

1. Substrate is coated with a thin film of evaporated copper.
2. Photo-lacquer is spread evenly over the copper and dried.
3. A photo positive of the circuit is placed in close contact with the lacquer. The unshielded lacquer is exposed to ultraviolet light.
4. The unexposed lacquer is removed during development and the unprotected copper is etched away in ferric chloride.
5. Nickel chrome alloy is deposited through the high definition "in contact" mask.
6. The unwanted nickel chrome alloy is removed by etching away the copper mask underlay, leaving patterns of close tolerance.

A second method of producing thin-film masks is called "Out of Contact". The steps in the production of this type of mask are outlined below.

1. Copper foil is cleaned with pumice and water, and then dried.

2. Photo lacquer is spread evenly over the foil and dried.
3. A photo positive is placed in close contact with the lacquer. The unshielded lacquer is exposed to ultraviolet light.
4. The unexposed lacquer is removed during development and the pattern is dyed.
5. The foil is backed with an acid-resisting cellulose lacquer.
6. The unwanted copper is etched away in ferric chloride and the lacquer and cellulose are removed in a solvent.

Problems of mask register, jigs and holding equipment and obtaining extremely accurate resistance have been eliminated by one manufacturer of thin-film circuits. General Dynamics/Astronautics has developed a "maskless" process for producing thin-film circuits.

In this process, continuous films of three metals are deposited on a substrate within a vacuum chamber. All the other work is done outside the vacuum chamber. General Dynamics' scientists have developed selective etching solutions and anodization methods which permit the processing of each of the three metals on the substrate without affecting the other two metals.

The etching process defines resistor and conductor patterns; anodization defines capacitor electrode patterns and forms dielectrics for capacitors. "Direct etching of films holds the errors in value of resistors to less than 5% without trimming and permits resistor values up to one megohm per 1/4 square."[32]

Anodization permits a capacitor figure of merit 50 times higher than that obtained with a vacuum evaporated silicon monozide dielectric. Capacitor tolerance also can be controlled to better than 5% without trimming.

Advantages of the thin-film process. The position of the resistance film on the surface of the substrate makes it possible to trim a resistor physically to a precise value. It is also possible to control the value of the resistance during deposition of the resistor material by monitoring it with a precision bridge. The process is then stopped at the appropriate point and the resistance is "frozen" at that level.

Another advantage of thin-film circuits is that capacitors fabricated by the thin-film technique are not voltage sensitive as in the case of "P-N" junction capacitance.

Hybrid Circuits. These circuits are usually used to overcome some of the shortcomings found in either the monolithic or thin-film circuits. Such hybrid circuits are usually a combination of monolithic and thin-film circuits, or thin-film circuits with discrete components such as inductors, resistors, etc.

Much developmental work is done with hybrid circuits since it is easy to substitute parts in the circuit. Hybrid circuits will probably be the first circuits to appear in consumer products which feature

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[32] ________ "Maskless Thin Film Production," Electronic Industries, Vol. 22, No. 2, (February, 1963), p. 164.

microelectronic circuits in their construction.

Servicing, repair, and installation. The future technician will not be able to replace resistors, capacitors, or other discrete components in microelectronic equipment. He will not be able to measure voltage at the pins of vacuum tubes. Instead, the technician will replace particular circuit functions whenever failure occurs in that equipment which employs microelectronic circuits.

> If the trouble is in the mixer circuit, the entire integrated mixer will be removed and replaced. Trouble-shooting time will be reduced, thus cutting the service charge. This should enhance the image of the technician and also make it pay for the consumer to have his set repaired rather than discarding it and purchasing new equipment.[33]

Test equipment for working on microelectronic equipment will be essentially the same as that used on conventional circuits. However, the use of test jigs and fixtures will be required in addition to this test equipment. These jigs and fixtures will be similar to the ones used on the production line for testing integrated circuits.

In connecting various components and in packaging microelectronic circuits, various methods and techniques are being used. The most popular method of making joints and connections is soldering; though welding has aroused much interest among packaging engineers. However, welding has not yet proved itself to be superior to soldering. Soldering is about 30% less expensive than welding. One reason is that welding is slower than soldering when compared to the number of connec-

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[33] ________ "The Integrated Circuit in Industry," Electronics World, Vol. 74, No. 5, (February, 1965), p. 38.

tions that can be made by soldering.[34]

Connecting systems now being used in the industry are the micromodule, Dot, hybrid, and integrated systems. In the Dot system, all elements are pellet shaped. Available elements include resistors, diodes, transistors, and capacitors. The diameter of these pellets or discs, ranges from 0.050 inch to 0.250 inch; thickness are 0.062 inch and 0.030 inch.

To assemble the Dot-type circuits, pellet-diameter-sized holes are drilled or punched in an insulating board which is as thick as the element being used. The pellets are placed in holes, and held there by force fit or adhesive. A conductive pattern is screened onto the insulating board and elements to form the completed circuit.

Another Dot system mounts the elements on flat wire matrices which are punched to provide the desired interconnection system. The element is then soldered to one of the wire patterns. Next, another pattern is affixed to the partial assembly. In this manner a completed circuit is built up. Encapsulation completes the assembly.

The Dot system has several advantages. It permits automation of assembly; replacement of individual circuit elements is possible, at least in board-pellet form; and designers can select substrates to provide heat conduction for high heat dissipated elements.

In the micromodule approach to packaging, the basic elements

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[34]David McElory, Electronic Industries, Vol. 23, No. 2. (February, 1964), p. 56.

in the assembly wafer contain one or more of a specific component, for example, only resistors would be on one wafer, capacitors on another, etc.

To assemble, the wafers needed to form the desired circuit function are stacked in a prescribed order. Spacers between the wafers control the separation. Connections between the wafers and to external sources are provided by riser wires placed in contact with the conductive areas on the wafer edges.

Basic Bonds. One of the most common bonding techniques in use today is ball bonding. Gold wire is fed through a capillary tube with a hole diameter slightly larger than the wire diameter. The ball is formed by cutting the wire with a hydrogen flame. The diameter of the ball formed at the end of a 2 mil wire is between 4 and 5 mils. The ball, held at the end of the capillary tube, is positioned over the area where the lead contact is to be made; then pressed firmly onto the metallized pad. The ball is deformed about 50% by this pressure. Ball bonds provide a comparatively large area of bond and have a high degree of adhesion.

Wedge Bonds. In wedge bonding, the wire itself is placed against the bonding pad, then compressed with a "wedge" tool to form the bond.

This type of bond offers two advantages. Because two or more bonds can be made in series, a number of elements can be interconnected with one length of wire. Second, the bonding area is small; thus connections of small metallized widths are possible. This method is often called "stitch bonding" because two such bonds are usually formed. The results resemble a stitch.

Soldering tools.

The CIRCON Pulse Dot Micro-soldering system combines the quick heat characteristics of the soldering gun with the small size of a soldering pencil, and provides the added features of foot-switch control and carefully measured solder.[35]

The circuit of this system consists of a variable autotransformer followed by a step-down transformer connected to the soldering loop. Temperature control is achieved by approximate setting of the auto-transformer and by finer control through the use of the foot switch. The small soldering loop is mounted in a pencil type handle.

To make a solder joint using this equipment, the operator dips the loop into the flux. This makes the loop stickey enough to pick up a solder ball. CIRCON furnishes solder balls in 12 graded sizes from 0.005 inch in diameter to 0.06 inch in diameter. To prevent oxidation of the solder balls during storage, each ball is gold-plated.

Solder and flux are deposited at the point to be soldered, the loop is held against the joint, and the foot switch is depressed and released when the solder joint is complete.

Standard soldering loops are available from one to three watts. These loops are made from 0.015 inch to 0.025 inch in diameter nichrome wire. Because of the small size of the components, this soldering system is normally used in conjunction with a binocular microscope.

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[35]Walter H. Buchsbaum, "New Soldering Tools and Techniques," Electronics World, Vol. 73, No. 2, (February, 1963), p.66.

Resistance soldering. Another soldering system consists of a resistance soldering fixture and control unit. A binocular microscope is used to observe the positioning of the soldering tool. The circuit to which the microelectronic device is to be joined is pre-tinned so that sufficient solder is deposited on the circuit, but it is also possible to apply solder during the soldering cycle. Once the soldering probes are positioned, they are lowered onto the lead ribbon and held against the pad with a preset pressure. When a footswitch is depressed, AC is applied across the soldering probes, heating up the ribbon and melting the solder. The heating cycle can be carefully adjusted for the particular type of solder joint, and once this adjustment is made, the cycle will then be automatically repeated for every subsequent soldering operation that may be required.

Soldering iron power. Listed below are the power requirements for microelectronic soldering equipment.[36]

Power (watts)	Tip Size (inches)	Application
12 - 18	1/32 - 1/16	0.020 inch thick p/c board, integrated circuits.
20 - 20	1/16 - 3/16	0.30 inch thick p/c board, miniature components.

Glossary of micro-circuit terms. To aid in understanding the terminology of microelectronics and to provide a list of words helpful

[36]Buchsbaum, loc. cit., p. 66.

in understanding the industry and technology, a glossary of terms is presented below.

Micro-circuit terms:[37]

ACTIVE ELEMENT - An element which displays transistance such as gain or control.

ACTIVE SUBSTRATE - A substrate for an integrated circuit in which a portion of the substrate displays transistance.

ARRAY DEVICE - A multitude of similar, basic, couples, or integrated devices without separate enclosures, each having at least one of its electrodes connected to a common conductor or all connected in series.

ARTWORK - Artwork is an accurately scaled configuration which is used to produce the master pattern.

ASSEMBLY - A number of parts or subassemblies or any combination thereof joined together to perform a specific function.

BASE - An insulating support for the printed pattern. It may consist of a flexible or rigid material.

BASIC DEVICE - The simplest useful device exhibiting a basic solid-state phenomenon.

BIONICS - The art which treats electronic simulation of biological phenomena.

BOND STRENGTH - A measure of the stress required to separate a layer of material from the base to which it is bonded. It is measured in pounds of inch of width (peel strength) obtained by peeling the layer, and in pounds per square inch (pull strength) obtained by a perpendicular pull applied to a surface of the layer.

BOSS - Use TERMINAL AREA.

CERAMIC-BASED MICROMINIATURE CIRCUITRY - Microminiature circuitry printed on a ceramic substrate. Usually consists of combination of resistive, capacitive, or conductive elements fired on a wafer-

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[37] Courtesy of Autonetics, Electronics Industries, Vol. 22, No. 6, (June, 1963), p. C17-C32.

like piece of ceramic.

CHARACTERISTICS - Any dimensional, visual, functional, mechanical, electrical, chemical, physical, or material feature or property; and any process-control element which describes and establishes the design, fabrication, and operating requirements of an article.

CHEMICALLY REDUCED PRINTER CIRCUIT - A printed circuit formed by the chemical reduction of a metallic compound.

CHEMICALLY DEPOSITED PRINTED CIRCUIT - A printed circuit formed on a base by the reaction of chemicals.

CHIP - Use SUBSTRATE.

CIRCUIT ELEMENT - A basic constituent of a circuit, exclusive of interconnections.

COLD WELD - The joining together of two metals (without an intermediate material) by the application of pressure only, without an electrical current or elevated temperature.

COMPONENT PARTS DENSITY - Use PARTS DENSITY.

CONDUCTIVE PATTERN - A design formed from an electrically conductive material on an insulating base.

CONDUCTOR - A single conductive line forming an electrical connection between terminal areas.

CONTROLLED PART - An item which requires the application of specialized manufacturing and procurement techniques.

CORDWOOD - The technique of producing modules by bundling parts as closely as possible and interconnecting them into circuits by welding or soldering the leads together.

CRITICAL ITEM - An item whose failure could result in hazardous or unsafe conditions or prevent performance of the tactical function of the end item.

DEFINITION - The fidelity of reproduction of pattern edges in the printed circuit relative to the original master pattern.

DEGRADATION - A gradual deterioration in performance. The synonym - DRIFT - is often used for electronic equipment.

DEPOSITION - The process of applying a material to a base by means of vacuum, electrical, chemical, screening, or vapor method.

DEVICE - A combination of physical materials to form a part comprised of one or more active elements.

ELECTRON BEAM MACHINING - The process of using a controlled electron beam to weld or shape a piece of material.

ELEMENT - Increment of volume of a part that displays an electrical phenomenon.

EMISSIVITY - The related power (of a surface or a material composing a surface) to emit heat by radiation.

ENVELOPE DIAMETER - A dimension of an opening or hole, as in a tube or missile airframe, that describes the extent to which an object irregularly shaped can be accommodated as it rests in the opening or as it slides in the opening either at an angle or straight. The term is used especially in reference to accommodating electronic equipment within the airframe of a missle.

ETCHANT - A solution used, by chemical reaction, to remove the unwanted portion of a conductive material bonded to a base.

FABRICATION TOLERANCE - In the construction and assembly of an equipment or portion thereof, the maximum variation in the characteristics of a part which, when related to the other variations of the other part comprising this equipment, will permit operation of the equipment within specified limits.

FEEDTHROUGH - Use **INTERFACING CONNECTION.**

FINGER - Use **PRINTED CONTACT.**

GRID - A two-dimensional network consisting of a set of equally spaced parallel lines superimposed upon another set of equally spaced parallel lines so that the lines of one set are perpendicular to the lines of the other, thereby forming square areas. The intersections of the lines provide the basis for an incremental location system.

GUARD BAND - The unused area which serves to isolate elements in a printed circuit.

INTERFACE - The junction point or surface between two different media.

INTERFACIAL CONNECTION - A conductor which connects conductive patterns on opposite sides of the base.

LAND - Use **TERMINAL AREA.**

MASK - An implement, usually a thin sheet of metal containing an open pattern, which shields selected portions of a base during deposition process. Also, an implement used to shield selected portions of photosensitive material during photo processing.

MASTER DRAWING - A drawing showing the dimensional limits or grid location applicable to any or all parts of a printed circuit, including the base.

MASTER PATTERN - A one-to-one scale pattern which is used to produce the printed circuit within the accuracy specified in the master drawing.

MATRIX - Use GRID.

MECHANIZED ASSEMBLY - The joining together of parts and/or subassemblies with the aid of operators and semiautomatic equipment.

MICROMINIATURIZATION - The technique of packaging a microminiature part or assembly composed of elements radically different in shape and form factor. Electronic parts are replaced by active and passive elements through use of fabrication processes such as screening, vapor deposition, diffusion, and photoetching.

MINIATURIZATION - The technique of packaging by reducing size and weight of electronic parts in step with the change from vacuum tube to transistors and diodes.

PAD - Use TERMINAL AREA.

PARTS DENSITY - The number of parts per unit volume.

PASSIVE SUBSTRATE - A substrate which exhibits no effect of transistance.

PEEL STRENGTH - See definition for BOND STRENGTH.

PRINTED CONTACT - That portion of a printed circuit used to connect the circuit to a plug-in receptacle and to perform the function of a pin in a male plug.

PRINTED ELEMENT - An element in printed form, such as a printed inductor, resistor, capacitor, or transmission line.

PRINTED-WIRING SUBSTRATE - A conductor pattern printed on a substrate.

PRINTING - The act or art of reproducing a pattern on a surface by means of various processes, such as vapor deposition, photo-etching, embossing, or diffusion.

PULL STRENGTH - See BOND STRENGTH.

REDUNDANCY - That design which makes additional electrical paths available to a function.

REGISTER MARK - A register mark is a mark used to establish the relative position of one or more printed-wiring patterns or portions thereof, with respect to their desired locations on one or both sides of a printed wiring base.

RESIST - Resist is a material such as ink, paint, metallic plating, etc. used to protect the desired portions of the printed conductive pattern from the action of the etching, solder, or plating.

SEPARATE PART - A replaceable part, the body of which is not chemically bonded to the base, excluding the effects of protective coating, solder, and potting materials.

SUBMINIATURIZATION - The technique of packaging miniaturized parts using unusual assembly techniques for increased volumetric efficiency.

SUBSTRATE - A wafer-like piece of insulating material which may serve as a physical support or base and thermal sink for a printed pattern.

TAB - Use PRINTED CONTACT.

TERMINAL AREA - A portion of a printed circuit used for making electrical connections to the conductive pattern, such as the enlarged portion of conductor material.

THERMOCOMPRESSION BONDING - The joining together of two materials without an intermediate material by the application of pressure and heat in the absence of electrical current.

THIN FILM CIRCUIT - The combination on a single passive substrate, such as glass or ceramic, of a number of elements entirely in the form of deposited films of conducting, semiconducting, or insulating materials. The method and sequence of deposition, physical location, and shape of the film provide the interconnections on the common physical support.

TRANSISTANCE - An electronic characteristic exhibited in the form of voltage or current gain or in the ability to control voltage or currents in a precise and nonlinear manner.

UNDERCUT - The reduction of the cross section of a metalfoil conductor caused by the etchant's removal of metal from beneath the edge of the resist.

WAFER - Use SUBSTRATE.

WIRING PATTERN - Use CONDUCTIVE PATTERN.

The Consumer Function

The consumer function of industrial arts has long been accepted as a legitimate objective of the discipline. Bonser was probably the first to recognize consumer knowledge as an objective of industrial arts.[38] Olson designates one of the six functions of industrial arts as the consumer function.[39] Wilber states that an objective of industrial arts in secondary education is

> to increase consumer knowledge to a point where students can select, buy, use and maintain the products of industry intelligently.[40]

This study revealed little use of microelectronics in consumer goods. The most common consumer use of microelectronics is the hearing aids. Zenith was the first company to produce a consumer product using a microelectronic device. This application of microelectronics is in the Zenith "Arcadic" hearing aid.

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[38]Olson, citing Charles R. Richards, "A New Name," Manual Training Magazine, Vol. 1, No. 1, (October, 1904), pp. 32-33.

[39]Ibid, pp. 83-85

[40]Wilber, op. cit., p. 50.

Beyond the use of microelectronics in hearing aids, this study discovered no other general consumer product using microelectronic circuits. The prohibitive factor in the use of these devices in consumer products appears to be cost. "Experts agree that the extent of use of microelectronics in consumer products will be determined by cost."[41]

Cost per circuit is very important in the use of integrated circuits. In addition to the cost of the masks used in making up a particular circuit, many things can go wrong during the manufacturing process which causes the price-per-circuit to increase. Because so many things can go wrong during the manufacturing process, the yield of operating chips can be anywhere between 10 and 50 percent of the number available from a wafer.[42]

In addition to these factors, the process of testing and mounting the wafer in its final holder also adds to the cost per unit. Because very few consumer products use microelectronic circuits, these circuits are more expensive than their conventional counterparts.

There is still another problem with consumer microelectronics. The lack of standardization on the part of manufacturers keeps the price per unit up. Where one manufacturer has a desire for a particular circuit, another will want to use his own circuit. This means separate forms of the circuit; video amplifiers, for example, would have to be

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[41]Solomon, loc. cit., p. 30.

[42]Solomon, loc. cit., p. 28.

made in separate forms for each manufacturer.

> Conservative estimates are that integrated circuits will start arriving about 1969 - 1970, probably starting with the large manufacturers who have both integrated facilities already in operation within the corporate structure.[43]

Size is not expected to play an important part in microelectronic consumer products at this time. The size difference between transistor circuits and integrated circuits will not be as great as the size difference between vacuum-tube devices and transistor-printed circuit devices. This is due to the fact that final size of integrated circuit products is dependent upon the size of other components that go into making up the finished product. In the case of most electronic consumer products, the final size is dependent upon the size of the speakers, picture tube, etc.

> It is impractical to use these tiny components when a 5-inch speaker, or a 19-inch picture tube will govern, to a large degree, the ultimate size of the product.[44]

With high cost per-circuit and lack of a major advantage in size reduction being prohibitive factors in the economy of microelectronics for consumer goods, the only advantage in the use of microelectronics would be reliability.

> The reliability of all forms of electronic circuits depends greatly on the interconnection of components. The advantages that integrated circuits offer over all the other approaches is

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[43]Solomon, loc. cit., p. 48

[44]__________ Electronics World, Vol. 74, No. 5, (November, 1965), p. 38.

> that there are fewer interconnecting wires. The great majority of the interconnections are achieved by using evaporated thin-aluminum films over the top of the circuit itself. These, in turn, become an integral part of the block and are completely stable.[45]

Using these techniques, extremely high reliability factors are realized, something on the order of 500 per cent over conventional circuits.

However, there is little chance in the near future that the advantage of reliability will outweigh the disadvantages of cost and lack of significant size reduction. Wide-spread consumer use of microelectronics is still in the future.

If the general trend is examined, it becomes evident that manufacturers of TV equipment have been going from vacuum tubes to transistors. However, when TV sets are ready for complete "transistorization," integrated circuits may be used extensively because they will be less costly than transistors and other discrete components.[46]

The Avocational Function

One of the Seven Cardinal Principles announced as an objective of American public education by the National Education Association in 1919, was the Worthy Use of Leisure Time". This statement was probably a result of the influence of John Dewey, who pointed out in 1916 that

> . . . . education has no more serious responsibility than making

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45 ________ Electronic Industries, Vol. 22, No. 6, (June, 1963), p. 65.

46 ________ "The Integrated Circuit Industry," Electronics World, Vol. 72, No. 11, (November, 1965), p. 38.

> adequate provision for enjoyment of recreative leisure; not only for the sake of immediate health, but still more if possible for the sake of its lasting effect on the habits of the mind . . .[47]

In light of the above statements, the avocational function of industrial arts becomes a legitimate and worthwhile objective of industrial arts education.

> Three basic media for recreation are inherent in industrial arts. They are: the crafts, the home workshop, and the "do-it-yourself" activities. Through these, objectives of recreation can be achieved and the recreation mission of industrial arts accomplished.[48]

However, microelectronics offers little, if any, opportunity for industrial arts to offer avocational opportunities or activities. No evidence was found in this study which even indicates that avocational interests are being served by microelectronics.

Examination of Olson's "Recreation Media," with reference to microelectronics, will reveal the factors which hinder or prevent microelectronics from fulfilling the avocational function of industrial arts.

<u>The home workshop</u>.

> The home workshop is what the name implies. Originally it was the home repair shop with economic and utilitarian purpose. Since the advent of light, portable machine tools it has become the home hobby shop. The home workshop may be equipped with any of several materials. For purposes herein, it includes any home shop facility for the processing of, and constructing with materials.[49]

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[47] John Dewey, <u>Democracy and Education</u>, New York: (The Macmillan Co., 1916), p. 24.

[48] Olson, <u>op. cit</u>., p. 97.

[49] <u>Ibid</u>.

Many home workshops (as referred to by Olson) are, in fact, equipped to accomplish certain electricity-electronic activities. However, the cost and complexity of the equipment necessary to repair, fabricate, or experiment with microelectronic devices precludes their use in the average workshop.

In addition to the prohibitive cost of equipment, the cost of materials used in microelectronic devices would keep these materials beyond the reach of the hobbiest. The complex techniques necessary to fabricate or repair these microelectronic devices would also prevent the development of avocational interests in this area of electronics.

The do-it-yourself activities.

> These activities center generally about the home, including construction, maintenance, repair, remodeling, and such. The original purpose in the movement was essentially economic, but many of its advocates find their recreation in it, especially those whose daily work is not of the shop type.[50]

As previously pointed out, the cost of equipment, materials, etc., prohibits avocational activity in the home workshop. In addition, home repair, modification, or remodeling of microelectronic equipment is precluded for a very important reason. The reason is the lack of microelectronic devices with which the "do-it-yourselfer" can come in contact. With such a lack of something to work on, the home-repair man cannot, of course, develop his avocational interests along these lines.

In the future when more consumer goods contain microelectronic

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[50] *Ibid.*

devices, there will still be little chance of home-repair buffs being able to engage in repair of these devices. Reliability of these devices is of such a high order (500% over conventional circuits) that there will be almost no reason to make repairs. Even if breakdown does occur, the microelectronic device will not just be repaired, but replaced.

The crafts. Crafts employ what is known as craft-materials, (leather, wood, etc.) and by its very nature rules out microelectronics as a craft activity.

Ham radio. This area is of special interest because it is an avocational area primarily concerned with electronics. However, this study revealed nothing to indicate that microelectronics is being used in this area. In addition to the high cost of microelectronic devices, ham radio is not compatible to these devices. Microelectronic devices are rated in the microwatt and nanowatt range of components, while most ham gear ranges in power ratings of 5 to 1000 watts. Thus the power requirement of ham gear precludes the use of microelectronic devices. Also the difficulty of obtaining proper inductances in microelectronic circuits precludes their use in ham receiving equipment.

Accordingly, there is no indication that radio amateurs will be using microelectronic equipment in the near future.

TOPICAL OUTLINE OF SUBJECT MATTER

I. The Technical Function

   A. Types of microelectronic circuits

      1. Monolithic

      2. Thin-film

3. Hybrid

B. Processes used in manufacturing monolithic circuits.

1. Growing "P" or "N" type crystals

2. Cutting crystals into wafers

3. Lapping wafers

4. Making masks for diffusion process

5. Diffusing crystals by the desired "P" and "N" material

6. Inspecting

7. Cutting of individual circuits from the wafer

8. Inspecting

9. Mountaining in header

10. Inspecting

11. Testing

C. Advantages of monolithic circuits

1. Smallest of the three types of circuits

2. More components per given volume

3. Less weight

4. High reliability

D. Disadvantages of monolithic circuits

1. Contains voltage sensitive distributed capacitances

2. Difficult to obtain proper passive components

E. Processes used in manufacturing thin-film circuits

1. Selection of inert substrate

2. Making masks for deposition

3. Depositing desired materials on substrate

4. Inspecting

5. Testing

F. Advantages of thin-film circuits

1. Easier to obtain desired resistances

2. Circuits may be more easily repaired

3. Absence of voltage sensitive "P-N" junction capacitances

G. Disadvantages of thin-film circuits

1. Larger than monolithic

2. Larger packaging requirements

H. Processes used in manufacturing hybrid circuits

1. Combine monolithic and thin-film circuits

2. Combine thin-film circuits and discrete components

I. Advantages of hybrid circuits

1. Very easy to change discrete components

2. Able to obtain desired value of inductances not obtainable with other two types.

J. Disadvantages of hybrid circuits

1. Largest of the three circuits

II. The Consumer Function

A. Except for the use of microelectronics in hearing aids, this study found no use of microelectronics in consumer goods due to the following reasons:

1. Cost of present microelectronic circuits

a. Cost due to lack of standardization on the part of the manufacturers

b. Cost due to low yield during production of circuits

c. Cost of testing circuits

2. Reduction in physical size of consumer products due to use of microelectronics of no particular advantage.

III. The Avocational Function

A. This study found no use of microelectronics in avocational pursuits for the following reasons:

1. Cost of present microelectronic cirucits

2. Special tools necessary to work on microelectronic circuits

3. Lack of power compatibility with amateur radio equipment

4. Lack of consumer products containing microelectronic circuits

CHAPTER V

SUMMARY AND CONCLUSION

The purpose of this study was to select subject matter from available literature dealing with the technology of microelectronics, and present this subject matter for use in secondary school level industrial arts.

The study involved the selection of tentative industrial arts subject matter from information about microelectronics contained in 312 electronic journals. Through an analysis of this tentative subject matter, using Olson's "curricular components" and "functions of industrial arts," the author derived a body of industrial arts subject matter reflecting the technology of microelectronics and compatible with the objectives of industrial arts. This subject matter was then organized and presented in narrative and topical outline forms.

This study revealed there is a great deal of industrial arts subject matter material to be found in the literature dealing with the technology of microelectronics. However, the great majority of this subject matter is limited to the technical function of industrial arts. Significantly lesser amounts of subject matter, relating to the consumer function and the avocational function were found in this study.

The Consumer Function. The heavy emphasis of use of microelectronic technology in military, space exploration, and computer circuitry has served to forestall the use of microelectronics technology to any significant degree in the consumer field. High cost of materials is also a contributing factor. With the exception of the hearing aid, little or no application of microelectronics is being made to general consumer products. The study revealed the problem of cost and the related problem of rate-of-production are key factors in determining when the consumer will be able to obtain goods containing microelectronic circuitry. Lack of standardization of circuits by different manufacturers was also stated as a factor limiting the production of microelectronic consumer goods.

The Avocational Function. Advanced technology, cost of equipment, and lack of materials are all factors which prevent the generation of avocational interests in microelectronics.

Lack of an opportunity to come in contact with consumer products containing microelectronic equipment is another reason avocational interests in microelectronics is almost non-existent.

Radio amateurs (Hams) do not employ microelectronics due to power requirements which are not compatible with microelectronics circuitry.

The Technical Function. The technical function proved to be the richest area of subject matter material. It was within the technical function that the greatest amount of subject matter material was obtained.

Subject matter material concerning manufacturing processes, interconnection methods, differentation between various types of microelectronics (monolithic, thin-film, hybrid) was found to be in great abundance in the electronic journals which were examined.

Of the 21 representative curricular components identified by Olson as being unique to industrial arts electronics, the following 14 were found by this study to be most closely associated with microelectronic technology:

Research	Design	Physics	Circuits
Invention	Development	Principles	Materials
Experiment	Engineering	Theories	Processes
Components	Manufacture		

Of these 14 components the following five were emphasized in the examined electronic journals as being most closely associated with the technology of microelectronics:

Research	Materials	Physics	Processes
Principles			

Conclusion

This study revealed that the industrial arts subject matter which was derived from the technology of microelectronics as presented in 312 electronic journals was concentrated in the technical function of industrial arts.

Little or no information was presented in the electronic journals from which subject matter could be derived for the consumer and avocational functions of industrial arts.

Subject matter was derived within the technical function for the areas of manufacturing processes, servicing, repair, and installation of microelectronic equipment. Subject matter for the consumer and avocational functions of industrial arts was not derived due to a lack of information concerning these functions.

BIBLIOGRAPHY

Books

Ericson, Emmanuel E., and Seefeld, Kermit. Teaching the Industrial Arts. Peoria, Illinois: Chas. A. Bennett Co., 1960.

Fierer, John E., and Lindbeck, John R. Industrial Arts Education. Washington, D. C.: The Center for Applied Research in Education, Inc., 1964.

Miller, Rex, and Smalley, Lee H. Selected Readings in Industrial Arts. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1963.

Olson, Delmar W. Industrial Arts and Technology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

_______________. Technology and Industrial Arts. Columbus, Ohio: Epsilon Pi Tau, Inc., 1957.

Susskind, Charles (ed.). The Encyclopedia of Electronics. New York: Rheinhold Publishing Corporation, 1962.

Wilber, Gordon O. Industrial Arts in General Education. 2nd ed. revised. Scranton, Pennsylvania: International Textbook Co., 1954.

Articles

Friese, Jon T. "Analysis of Course-of-Study Material for Industrial Arts," Industrial Arts and Vocational Education, Vol. 42, No. 9, (September, 1953), pp. 208-211.

Hammond, Robert G. "Determining Content in Industrial Arts," Industrial Arts and Vocational Education, Vol. 50, No. 10, (May, 1961), pp. 24-25.

Karnes, M. Ray. "Improving Industrial Arts Education: Some Dimensions of the Problem," Industrial Arts Teacher, May-June, 1960, p. 19.

Unpublished Material

Stadt, Ronald W. "A Method of Selecting Content for Lending Intelligibility to Industry: A Critque and a Proposal." Unpublished Doctor's Dissertation, University of Illinois, 1962.

Bell Telephone Magazine. Vols. 42-44., 1963-1965.

Electronic Engineering. Vols. 35-37., 1963-1965.

Electronic Industries. Vols. 22-24., 1963-1965.

Electronics. Vols. 36-38., 1963-1965.

Electronics World. Vols. 69-74., 1963-1965.

QST. Vols. 47-49., 1963-1965.

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