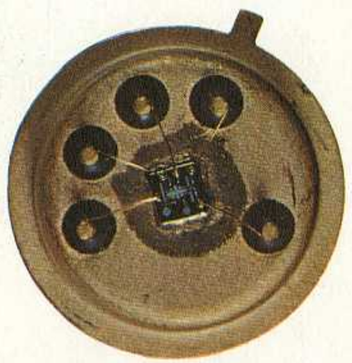
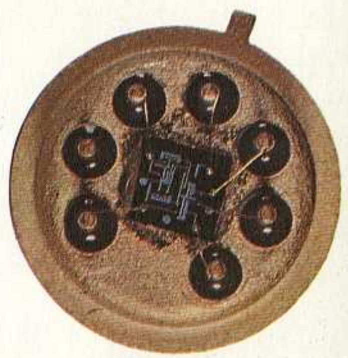
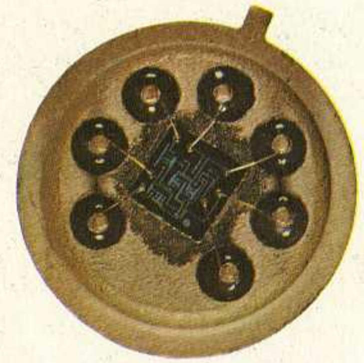
THE INSIDE STORY ON FAIRCHILD MICROLOGIC

ROBERT K. WAITS





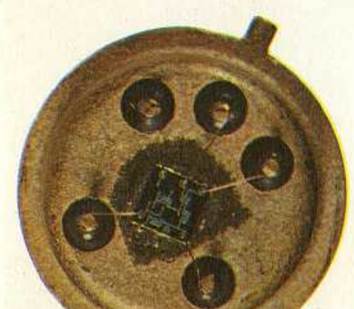

ACTUAL SIZE

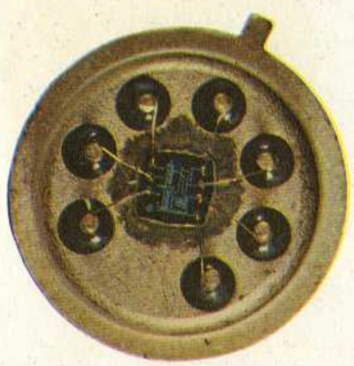


Micrologic elements are a compatible set of miniature logic circuit blocks, each built into a single, monolithic chip of silicon about 1/16 inch square. Micrologic circuits are a modified form of DCTL — direct-coupled transistor logic. DCTL was chosen for five reasons: (1) fewest number of components, (2) fewest kinds of components, (3) non-critical component values, (4) low power consumption, and (5) low supply voltage.

This family of functional elements can be used to fabricate a low cost, highly reliable computer logic section using no other components. They will operate at 1 mc (50 nsec stage delay) clock rates over a temperature range of —50 C° to +125° C.

This brochure will guide you through the manufacture of a typical Micrologic element — the Half-Shift Register — from the crystal to final inspection. The story is told for just one reason: it demonstrates Fairchild's production capabilities in the field of integrated circuitry.





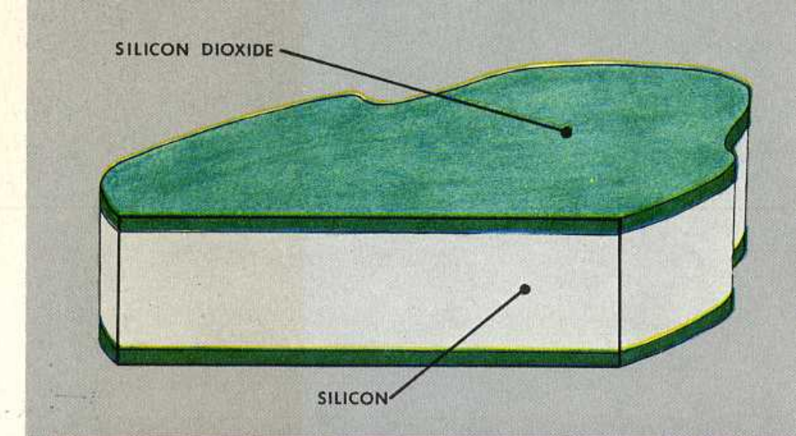
THE INSIDE STORY ON FAIRCHILD MICROLOGIC

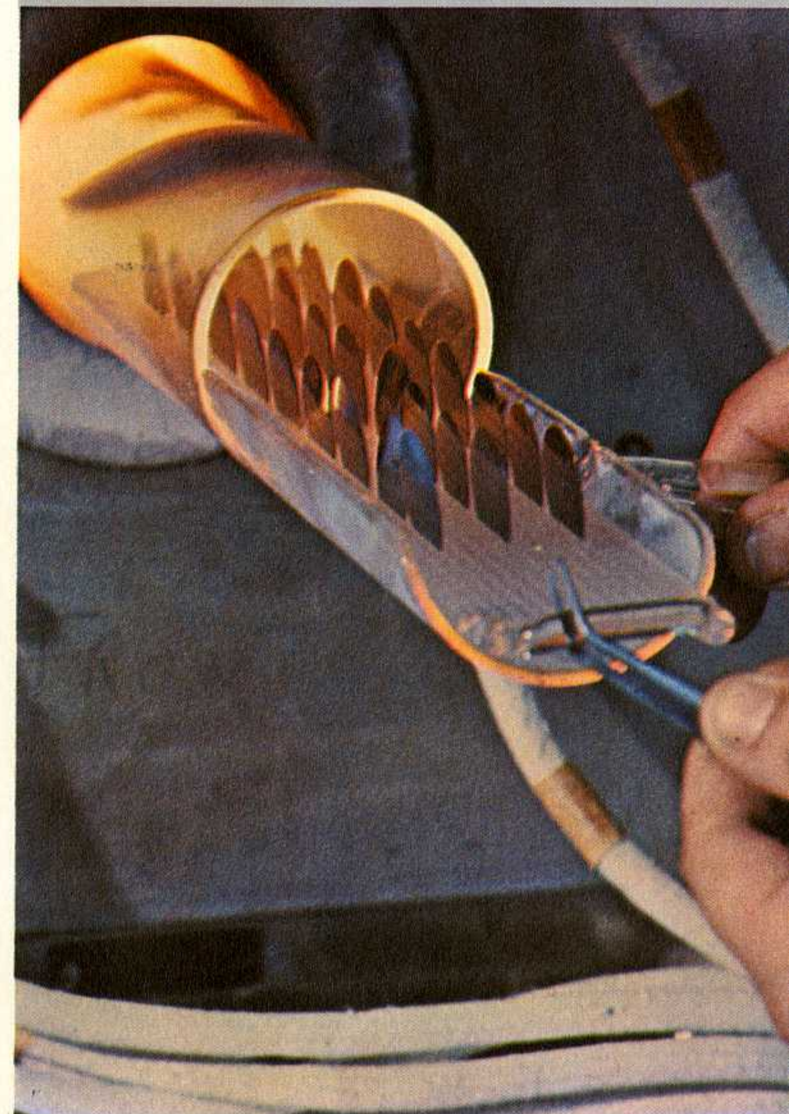
CRYSTAL GROWING

The starting material for Micrologic elements is the same high-purity silicon which is grown by Fairchild and used in its transistor production. The crystals are carefully selected for low dislocation and imperfection counts of the crystalline structure. The silicon crystals are grown by the Czochralski method: a small perfect seed crystal is lowered into molten silicon, and slowly pulled out to form a crystal about six inches long and one inch in diameter. For Micrologic, the crystal is grown with a phosphorus impurity to make it n-type.

CUTTING AND LAPPING

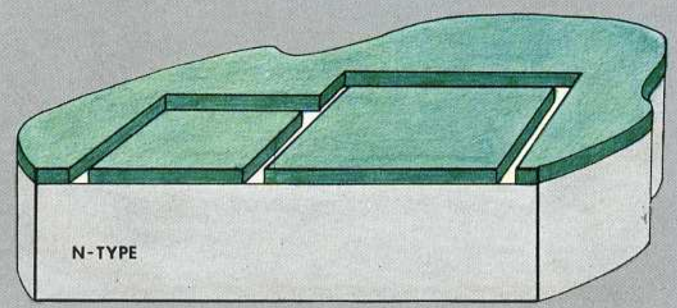
The crystal is sawed into wafers approximately eight thousandths (.008) of an inch thick, using a diamond saw. Each wafer is then lapped flat automatically, using very fine grit abrasive. A chemical etching results in a final thickness of about three thousandths inch (.003), and a smooth shiny surface. These steps are the same as those used in the preparation of Fairchild Planar transistor wafers.

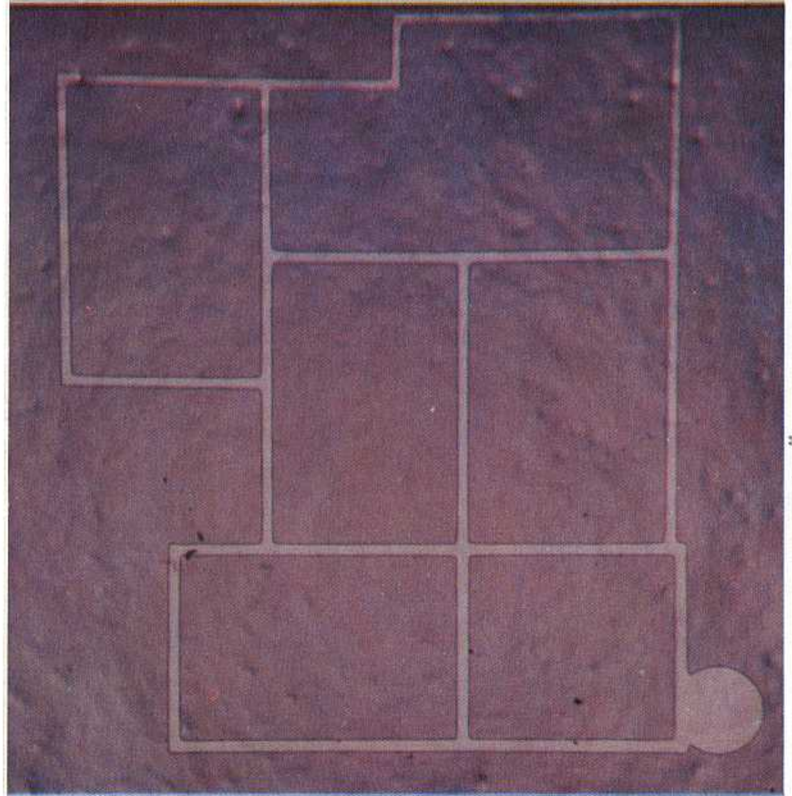




OXIDE GROWTH

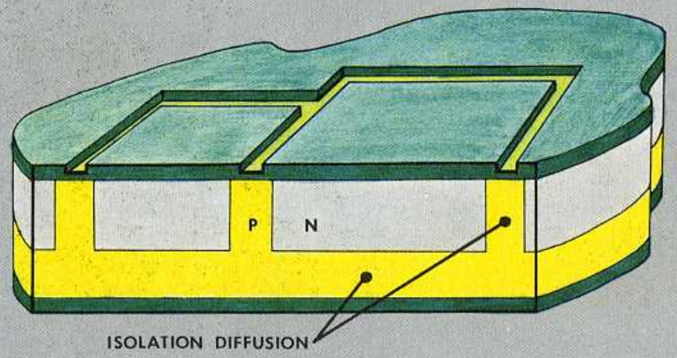
Many wafers of silicon — representing thousands of potential Micrologic elements — are placed into a furnace containing an oxidizing atmosphere at 1200° C. Oxygen penetrates the crystal lattice at the surface of the wafer and combines chemically with these surface silicon atoms to form the inert, stable compound SiO_2 (silicon dioxide). Through this process, standard at Fairchild, the silicon wafers are virtually encapsulated and the surfaces are passivated. This one step — the beginning of the planar process — is the key to reliability and production economy.

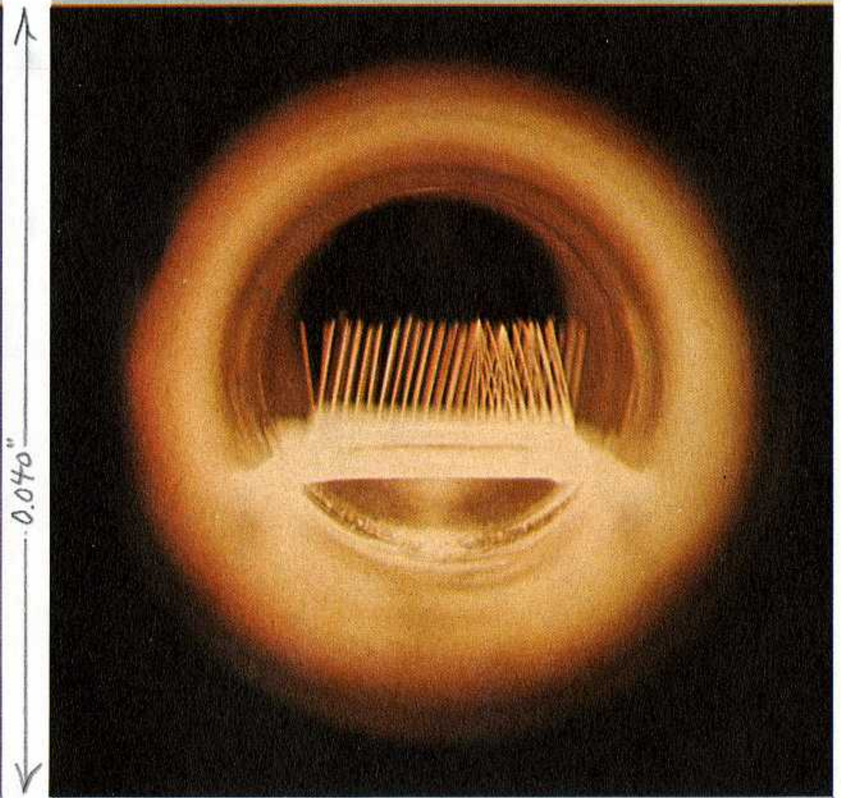




ISOLATION MASKING

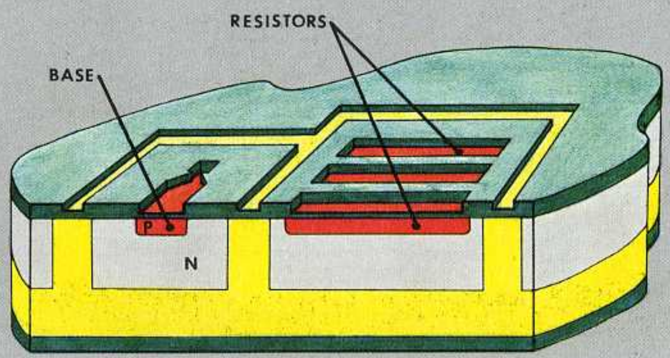
The following steps are performed in order to isolate electrically the individual transistors and resistors from one another. The wafers are coated with a photosensitive material in a darkroom. This material is exposed to light through a high-resolution mask. The portions not exposed are soluble and are easily removed by a solvent rinse. Then, an etch is used to dissolve the silicon dioxide from the areas not protected by the film of photosensitive material. In this way, a thin band, or "windows" surrounding the transistor areas, are photo-engraved through the protective silicon dioxide.

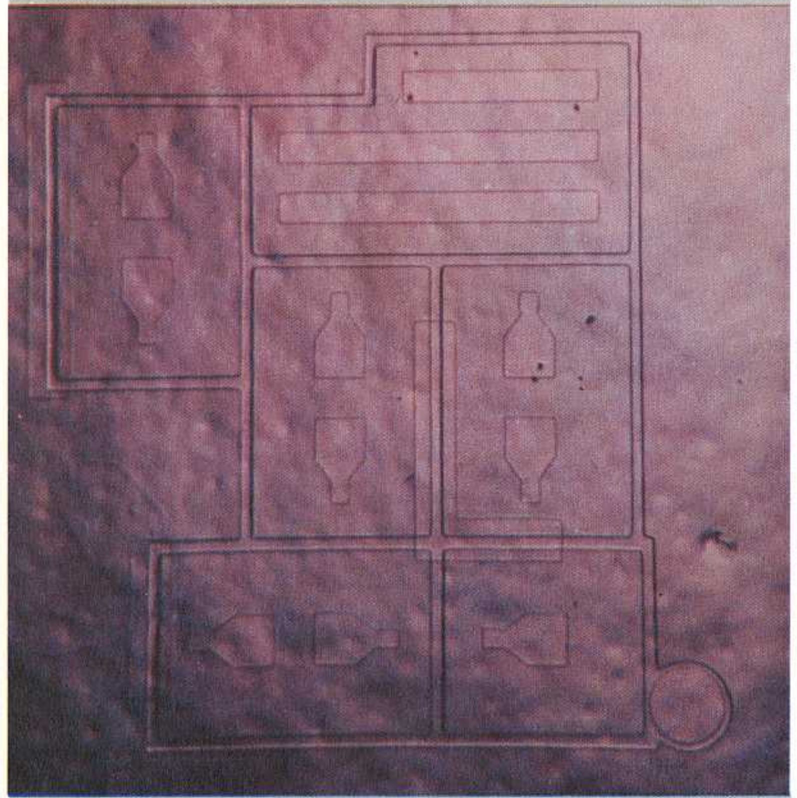




ISOLATION DIFFUSION

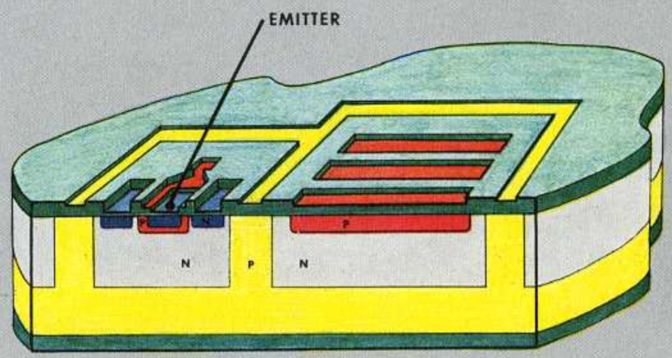
The wafers are placed into a special, high-temperature furnace where the atmosphere contains boron in a gaseous state. The boron impurity diffuses into the surface of the silicon wafer only where it has been exposed by the preceding photo-engraving steps. Even at elevated temperatures the silicon dioxide protects the underlying silicon from the dopants. The temperature is then raised to 1300°C; oxygen is introduced, and the boron impurity diffuses simultaneously from both sides of the wafer to meet in the middle, leaving pockets of the original n-type material which will become the collector regions of the transistors. These regions are separated from one another by the presence of the diffused isolation. In areas where the original silicon dioxide was etched away, a new layer is formed by surface oxidation during the diffusion.

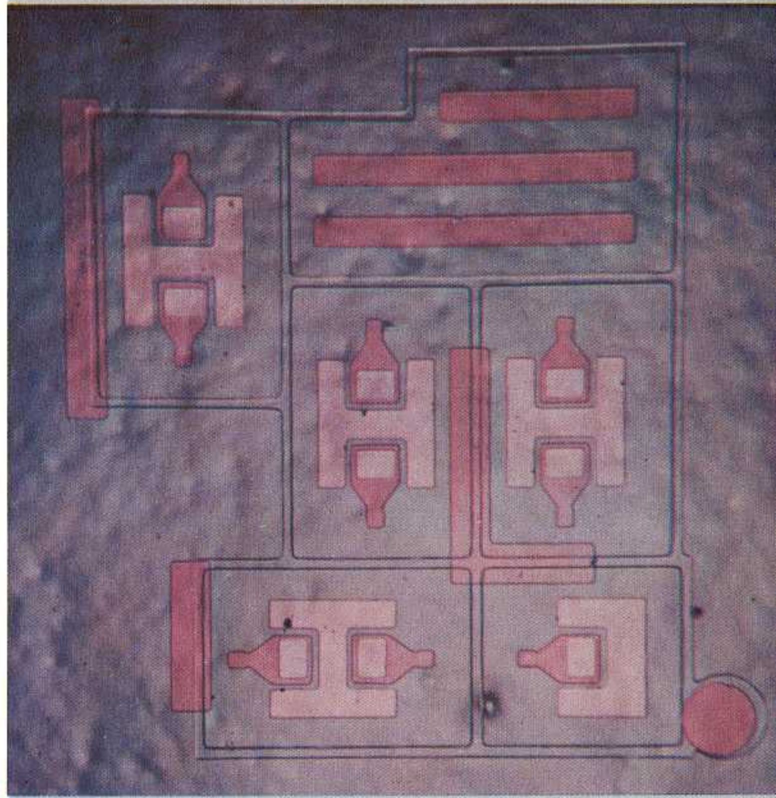




MASKING AND BASE DIFFUSION

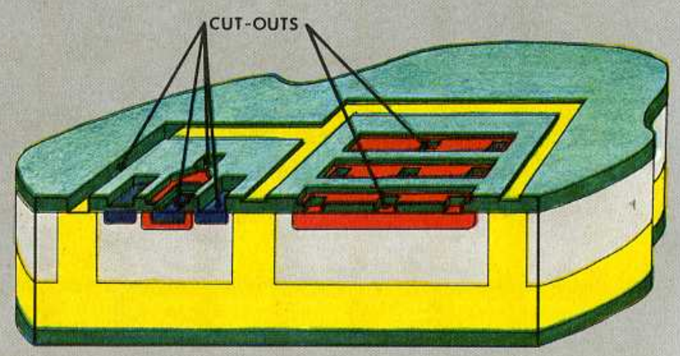
The wafer is again masked and etched for the simultaneous diffusion of the base region and resistors. Once again boron is used as the diffusing impurity in this high-temperature diffusion. The base region is diffused into the n-type starting material to form the collector-base diode of each transistor as well as all the resistors in the circuit. As the diffusion progresses, the oxygen atmosphere in the furnace re-oxidizes the cutout portions of the wafer surface and seals them against contamination or injury. As the diffusion progresses downward into the wafer, it also proceeds laterally, diffusing into the silicon covered by the original protective oxide. The doping level of the base of the Micrologic transistor is very similar to that of standard Fairchild Planar transistors. The resistivity of the diffused area is thus a convenient value for use in the diffused resistors.

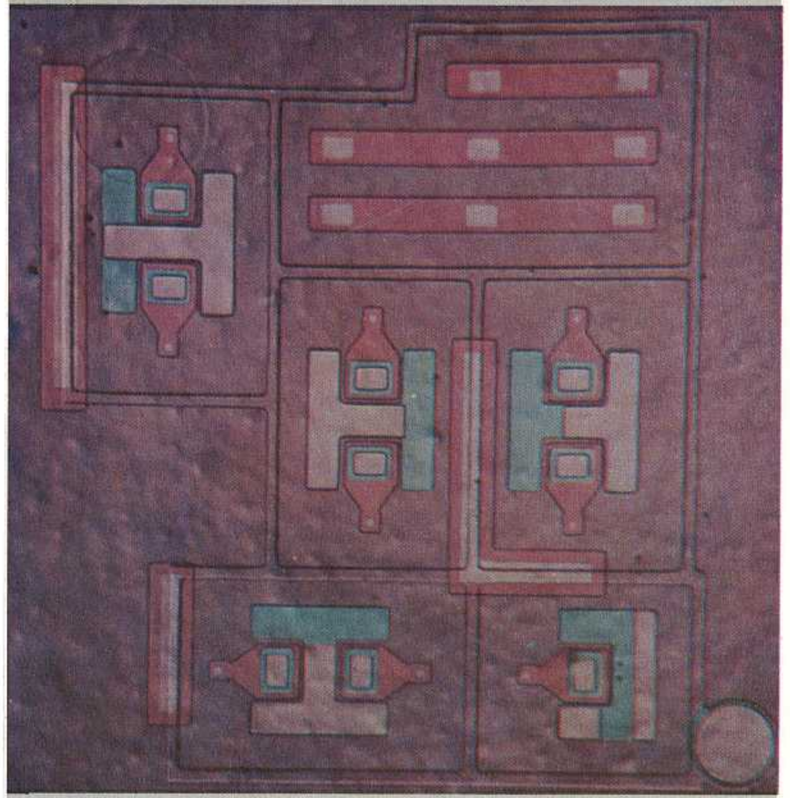




EMITTER MASKING AND DIFFUSION

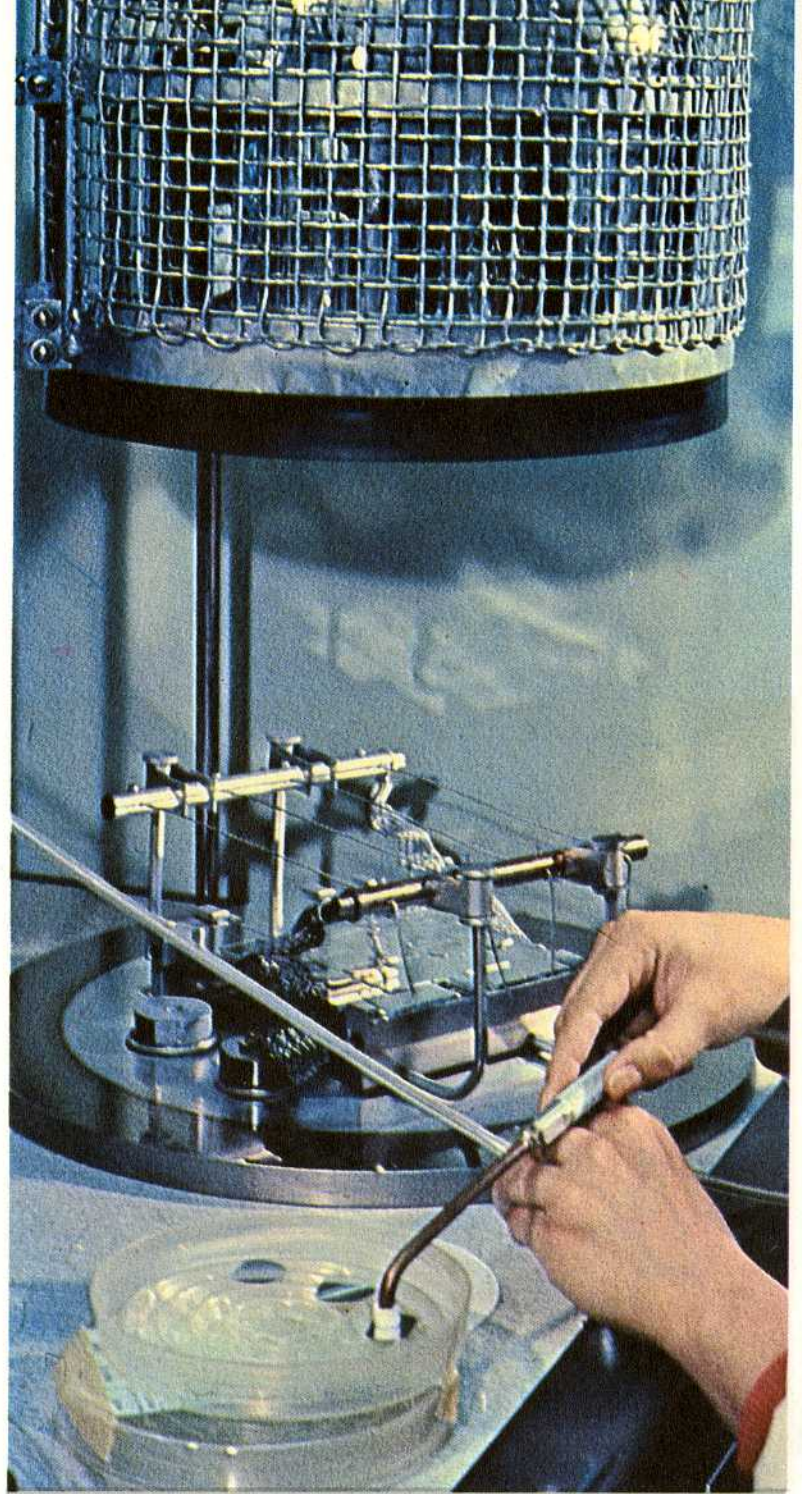
Another precisely indexed masking step is performed to remove oxide for the emitter diffusion and for the top-side collector contacts. In another high-temperature step, phosphorus — an n-type impurity — is deposited on the surface. Diffusion then takes place at about 1200°C. Again silicon dioxide forms as the diffusion progresses, covering the photo-engraved area and sealing the surface. Side diffusion carries the junction underneath the protective layer. Notice that in each case the diffused region ends underneath an oxide which existed previously. This oxide permanently protects the actual junctions of the device against exposure to the outside environment.





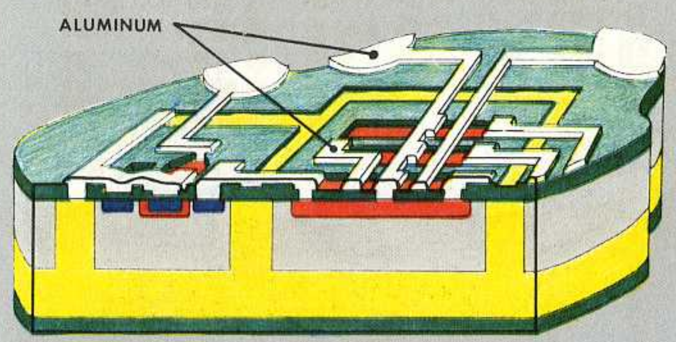
EXPOSURE OF CONTACT AREAS FOR INTERCONNECTIONS

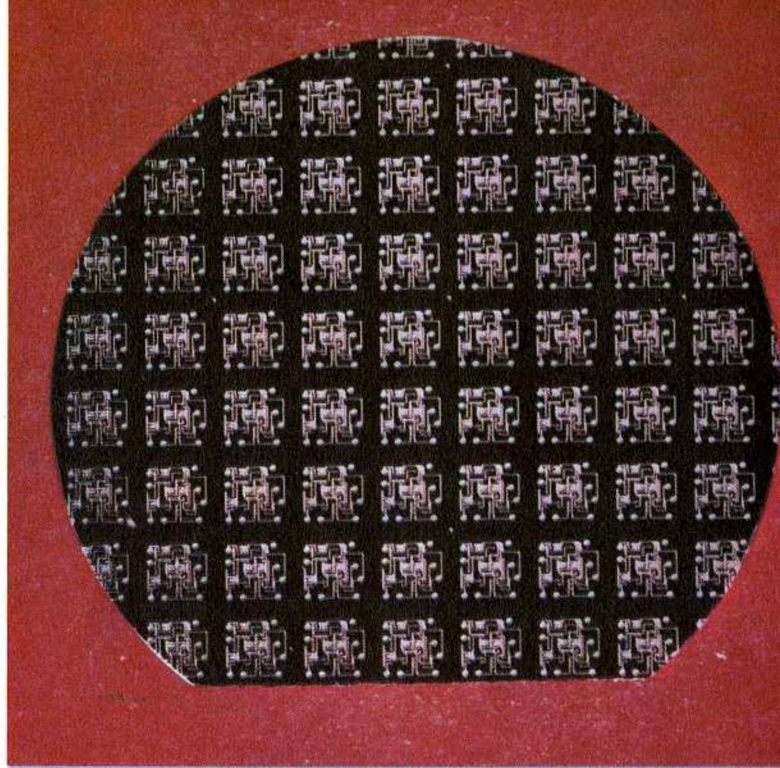
At this point the transistors and resistors of the Micrologic circuit are completed. They must now be connected together into the desired logic circuit. This is done by evaporating metal interconnections onto the surface of the silicon wafer. Before this can be done, however, a hole must be photo-engraved over the appropriate regions of the devices so that the evaporated metal can make contact. This is done in a masking step similar to the others.

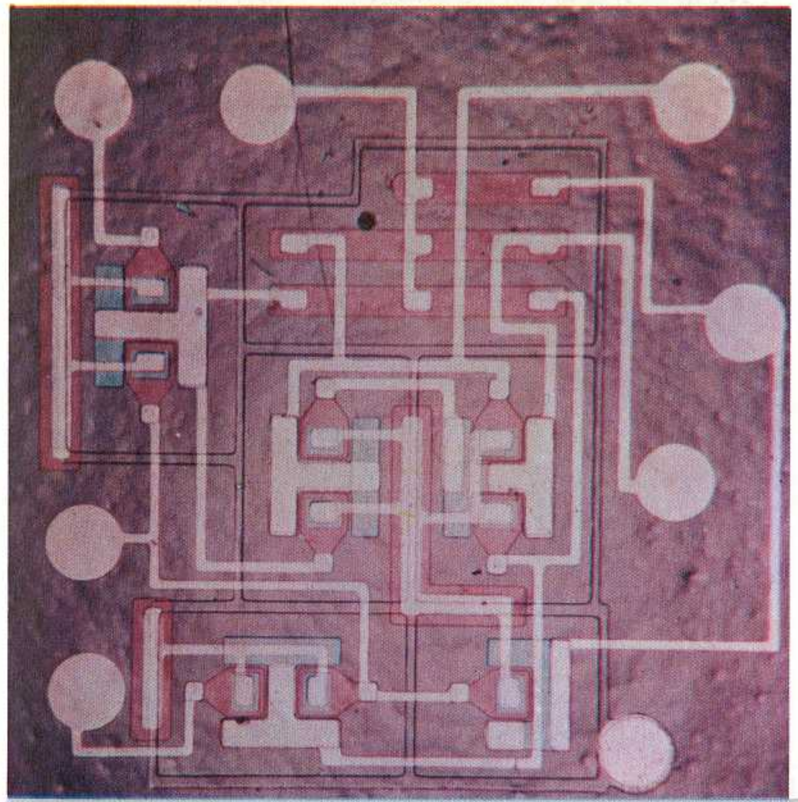


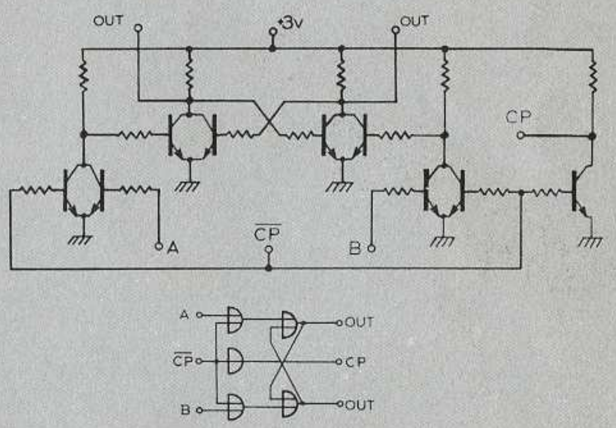
METALIZATION

The wafers are now placed into a vacuum chamber. Under high vacuum, aluminum is heated and boiled from a hot tungsten filament. This evaporated metal deposits in a thin, even coat over the entire wafer surface. Many wafers, comprising hundreds of Micrologic units, may be processed at one time in this fashion.









METAL INTERCONNECTIONS

In another precise photo-engraving step, the aluminum layer is masked and selectively etched to leave a pattern of interconnections between transistor and resistor elements in the logic circuit. The Micrologic Half-Shift Register wafer is now complete electrically and needs only to be cut into individual circuits and packaged. Up to this point, all operations have been done on many wafers at a time. The elimination of the handling of each device separately is a major factor in the reduction of production costs. This batch processing also increases the reliability and compatibility of the devices.

Compare the electrical schematic to the color photomicrograph of the finished element. Notice the flip-flop section in the center of the picture, with the metal interconnections from the collector of one side to the base of the other. The collectors of each gate may be seen connected to the base of each flip-flop. All connections to the outside — inputs, outputs, power supply and ground — are brought out to the periphery of the element as large, circular aluminum pads, for easy, reliable connections. The power supply pad on the device may be traced to the center-tap on the 1200 ohm resistor, and from there through 600 ohms to each collector. All emitters have been tied to the isolation, which acts as the common ground.

FAIRCHILD
SEMICONDUCTOR

FRANCHISED STOCKING DISTRIBUTORS/REPRESENTATIVES

Alabama
GODDARD, INC.
43 Traylor Island
Huntsville, Alabama
539-7385

Arizona
G. S. MARSHALL COMPANY
A Division of Marshall Industries
30 Pima Plaza
Scottsdale, Arizona
WHitney 6-5521

California
HAMILTON ELECTRO SALES
11965 Santa Monica Boulevard
Los Angeles 25, California
BRadshaw 2-9154 TWX: WLA 6637-U

DENNY-HAMILTON ELECTRONICS
P. O. Box 7457
2196 Cable Street
San Diego 7, California
ACademy 4-3451 TWX: SD 6537-U

WEATHERBIE INDUSTRIAL ELECTRONICS, INC.
333 Prevost Street
San Jose 26, California
CYpress 7-9550

G. S. MARSHALL COMPANY
A Division of Marshall Industries
2065 Huntington Drive
San Marino, California
SYcamore 5-4304
TWX: PA SA CAL 7797-U

G. S. MARSHALL COMPANY
A Division of Marshall Industries
4410 Kearney Mesa Rd.
San Diego 11, California
BRowning 8-6350

G. S. MARSHALL COMPANY
A Division of Marshall Industries
801 Woodside Rd., Suite 9
Redwood City, California
EMerson 6-8214

Colorado
WARD TERRY & COMPANY
Electronics Parts Division
90 Rio Grande Ave.
P. O. Box 869
Denver 1, Colorado
AMherst 6-3181 TWX: DN 979-U

HYER ELECTRONICS
3385 S. Bannock, Suite B-12
Englewood, Colorado
761-0754 FAX: FGL

Connecticut
CRAMER ELECTRONICS
60 Connolly Parkway
Hamden 4, Connecticut
AT 8-3581

Florida
GODDARD, INC.
1309-11 North Dixie
W. Palm Beach, Florida
TEmple 3-5701

SCHWEBER ELECTRONICS
333 New Haven Avenue
Melbourne, Florida
PArkway 3-4461

Illinois
SEMICONDUCTOR SPECIALISTS, INC.
5706 W. North Avenue
Chicago 39, Illinois
NAtional 2-8860

MAGNUSON ASSOCIATES
Magnuson Electronics, Inc.
5639 W. Fullerton Avenue
Chicago 39, Illinois
NA 2-6322 TWX: CGO-913

Iowa
ENGINEERING SERVICES COMPANY
160-29th Street, N.E.
Cedar Rapids, Iowa
EM 5-6182 TWX: CR 6194-U

Kansas
ENGINEERING SERVICES COMPANY
247 South Pinecrest
Wichita, Kansas
MUrray 3-3751

Maryland
SCHWEBER ELECTRONICS
Silver Spring Division
8605 Cameron Street
Silver Spring, Maryland
JUniper 5-7023 TWX: SSPG 494

ANGUS-SLOANE ASSOCIATES, INC.
880 Bonifant St., Rm. 101
Silver Spring, Maryland
588-1821

VALLEY ELECTRONICS, INC.
1735 East Joppa Road
Towson, Maryland
VAlley 5-7820 TWX: TOWS 564

Massachusetts
CRAMER ELECTRONICS, INC.
811 Boylston Street, Rm. 101
Boston 16, Massachusetts
CO 7-4700

L. L. SCHLEY COMPANY
70 Coolidge Hill Road
Watertown, Massachusetts
WA 6-0235 TWX: W TWN 863

Minnesota
MAGNUSON ASSOCIATES
Magnuson Electronics, Inc.
13159 W. Maynard Drive
St. Paul, Minnesota
MI 6-7943

Missouri
ENGINEERING SERVICES COMPANY
4550 Main Street
Kansas City, Missouri
PL 3-7227 TWX: KC 379-U

ENGINEERING SERVICES COMPANY
6717 Vernon Avenue
St. Louis 30, Missouri
PArkview 6-2233 TWX: SL 793-U

New Jersey
ANGUS-SLOANE ASSOCIATES, INC.
13 East Main Street
Moorestown, New Jersey
BElmont 5-1900 TWX: MRTN 1050

New Mexico
HYER ELECTRONICS
1411 Broadway, N.E.
Springer Transfer Complex
Albuquerque, New Mexico
243-3664

New York
STANDARD ELECTRONICS, INC.
1501 Main Street
Buffalo 9, New York
TT 3-5000 TWX: BU 392

SCHWEBER ELECTRONICS
60 Herricks Road
Mineola, Long Island, New York
Pioneer 6-6520 TWX: G CY NY 580-U

DART SALES
P. O. Box 67
East Molloy Road
Syracuse 11, New York
GI 6-1642 TWX: SS 353

New York (cont.)
STATEWIDE ELECTRONICS SUPPLY CO., INC.
Pickard Drive
East Syracuse, New York
GLenview 4-3227

B. B. TAYLOR CORPORATION
Taylor Electronics Corporation
2270 Grand Avenue
Baldwin, L. I., New York
BAldwin 3-8000 TWX: FR PT NY 1676

Ohio
SHERIDAN ASSOCIATES, INC.
Roselawn Center Building
P. O. Box 37646
Cincinnati 37, Ohio
631-2460 TWX: CI 406

Pennsylvania
PHILA ELECTRONICS, INC.
1225 Vine Street
Philadelphia 7, Pennsylvania
LOcust 8-7444

Rhode Island
CRAMER ELECTRONICS, INC.
80 Broadway
Newport, Rhode Island

Texas
NORVELL ASSOCIATES
3603 Lemmon Avenue
Dallas 19, Texas
LAkeside 6-7861 TWX: DL 1082-U

NORVELL ASSOCIATES
112 Meyerland Plaza
Houston 35, Texas
MOhawk 5-0558

Washington
SAMUEL N. STROUM CO., INC.
621 Michigan Street
Seattle 4, Washington
PArkway 3-7310 TWX: SE 403-U

ALMAC ELECTRONICS CORPORATION
6301 Maynard Avenue, South
Seattle 4, Washington
PArkway 3-7310 TWX: SE 403-U

Canada
LAKE ENGINEERING CO., LTD.
123 Manville Road
Scarborough, Ontario, Canada
PLymouth 7-3253

FAIRCHILD SEMICONDUCTOR SALES OFFICES

Sherman Oaks, California
14921 Ventura Boulevard
OLeander 5-6058
TWX: VNYS 5546

Oak Park, Illinois
6957 W. North Ave.
VIllage 8-5985
TWX: OAK PARK 2820

Garden City, L. I., New York
600 Old Country Road
Pioneer 1-4470
TWX: GCY NY 5391

Minneapolis, Minnesota
6220 Oliver Avenue, South
UNion 6-4300

Detroit 19, Michigan
20187 Houghton
KEnwood 8-3158

Orlando, Florida
618 E. South St., Suite 21
CHerry 1-2596
TWX: OR 7217

Jenkintown, Pennsylvania
100 Old York Road
TUrner 6-6623
TWX: Jenkintown PA 1056

Washington 6, D. C.
Suite 809, Cafritz Bldg.
1625 Eye St., N.W.
NAtional 8-2590
TWX: WA 756

Syracuse, New York
731 James Street, Rm. 304
GRanite 2-3391
TWX: SS 94

Bedford, Massachusetts
Colonial Building
36 North Street
274-8450
TWX: LEX MAS 643

Palo Alto, California
378 Cambridge Ave., Suite M
DAvenport 1-8780
TWX: PAL AL 135

San Diego, California
3354 Felton Drive
JUniper 3-5100

Englewood, Colorado
3385 South Bannock
Suite B-12
761-1735

MAIN PLANT—DIODES
4300 Redwood Highway
San Rafael, California
GReenfield 9-8000—TWX: S RF 26

MAIN PLANT—TRANSISTORS
545 Whisman Road
Mountain View, California
YOrkshire 8-8161
TWX: Mtn View Cal 853

Lithographed in U.S.A.