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Since 1985, the Naval Ocean Systems Center has been identifying and developing needed technology for flexible manufacturing of hybrid microelectronic assemblies. Specific projects have been accomplished through contracts with manufacturing companies, equipment suppliers, and joint efforts with other government agencies. The resulting technology has been shared through semi-annual meetings with government, industry, and academic representatives who form an ad hoc advisory panel. More than 70 major technical capabilities have been identified for which new development is needed. Several of these developments have been completed and are being shared with industry.

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INTEGRATED AUTOMATION FOR MANUFACTURING OF ELECTRONIC ASSEMBLIES

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ABSTRACT

Since 1985, the Naval Ocean Systems Center has been identifying and developing needed technology for flexible manufacturing of hybrid microelectronic assemblies. Specific projects have been accomplished through contracts with manufacturing companies, equipment suppliers, and joint efforts with other government agencies. The resulting technology has been shared through semi-annual meetings with government, industry, and academic representatives who form an ad hoc advisory panel. More than 70 major technical capabilities have been identified for which new development is needed. Several of these developments have been completed and are being shared with industry.

INTRODUCTION

Since 1985, the Naval Ocean Systems Center (NOSC) has been identifying and developing needed technology for flexible manufacturing (large and small lot sizes) of hybrid microelectronic assemblies. Specific projects have been accomplished through contracts with manufacturing companies, equipment suppliers, and joint efforts with other government agencies.

Since 1986, more than 70 major technical capabilities for which new development is needed have been identified. Under Navy contract, three developments (Distributed Architecture Computer System, Standardized Hybrid Carrier, and Automated Storage Retrieval System) were completed, while three others (Improved Lead Bond Machine, Automated Epoxy Dispensing, and Automated Substrate Attach) have since been developed and marketed by private industry. The resulting technology has been shared through semi-annual meetings with government, industry, and academic representatives who form an ad hoc advisory panel.

During 1988, NOSC worked closely with the Air Force on a joint effort to develop a Universal Robotic Work Cell. Out of that effort came a conveyor mounted robotic handler which featured an alternative version of the Standard Hybrid Carrier and performed both laser scribing of the hybrid and ink jet marking of the sealed package. In a related effort, a prototype of an Automated Diagnostic System was developed. This system consisted of an 8 probe test fixture for hybrid diagnostics, driven by a cell controller which was fully integrated with the factory host computer system.

In 1989, the focus became computer integrated manufacturing. Two initial capabilities were developed. One was a method to direct download a computer aided design file to a pick and place robot and the other was a low cost method to automatically upload and analyze electrical test data. Next, a joint effort was started with the National Institute of Standards and Technology (NIST) to develop a standardized file transfer format. During the next two years, this format will be used to develop generic, open architecture computer aided engineering tools for the automatic exchange of information between design and manufacturing. Other capabilities will be developed to fully use this standard.

The major programs under which these projects were accomplished are called the Integrated Facility for Automated Hybrid Microcircuit Manufacturing (IFAHMM), the Air Force Precision Guided Munitions Industrial Modernization Incentives Program (PGM/IMIP), and the Microelectronics Computer Integrated Manufacturing (MicroCIM) Program.

IFAHMM

In December 1985, a contract was awarded to Teledyne Microelectronics to initiate development of a factory of the future for the manufacture of hybrid microelectronic assemblies. Teledyne is a major manufacturer of hybrid microcircuits for the Department of Defense and is also a major supplier to the medical industry of hybrid components for pacemakers.

Teledyne started their efforts by first modeling the methods currently in use for making hybrids. They then surveyed the industry to determine where the problems were and what technology was available to solve those problems. Their findings were summarized in a list of 15 proposed technology developments which could enable the industry to realize significant enhancements in hybrid manufacturing (1). Those enabling technologies which had the greatest benefit were selected for development.

Distributed Architecture Computer System

At the heart of all modern factories is a centralized computer system with databases and functional controls distributed throughout the plant and connected via an integrated network. Hybrid microelectronics manufacturers have been reluctant to risk profits on the procurement and development of such a computer system which would be not only costly to develop but also costly to maintain. Computer equipment suppliers have been reluctant to spend research and development funds on systems for an uncertain market (2).

Through an agreement reached with IBM, Teledyne served as a beta site for the computer system development. IBM provided development funds and the Navy funded the implementation and engineering support at Teledyne. The result is the Distributed Automation Edition (DAE), currently being marketed by IBM. DAE runs on an IBM AS400 host system and shop floor control is provided by IBM Model 7552 cell controllers. Networking was originally performed using the Manufacturing Automation Protocol used by General Motors but was later replaced with a Token Ring network.

Additional software was developed by the University of California at Los Angeles. This software addressed specific areas of the hybrid facility such as wirebonder control as well as generic capabilities for work in process tracking and automatic storage and retrieval of kitting materials. Teledyne has subsequently modified this for industry release under the product name of "Factory Manager/2".

Standardized Hybrid Carrier

In order to automate handling of the small 2" x 2" hybrid, the hybrid needed to be enclosed by a carrier frame which could be moved from workstation to workstation. The carrier would protect the delicate hybrid from contamination and damage and would be of standard construction so that a minimum amount of reconfiguration would be needed. The carrier material had to be helium non-absorbent for leak testing during final packaging and the surface area of the carrier had to accommodate a bar code.

Teledyne designed a plastic frame that was injection molded around the hybrid case. Inexpensive molds are available up to a 5" x 5" size. A suitable material for leak testing was not found, so the carrier is designed such that the plastic is not exposed to helium during the test.

The carrier has facilitated work in process tracking and eliminated much of the damage previously attributed to handling. However, Teledyne has not yet implemented an automated handling and distribution system.

Automated Storage Retrieval System

Teledyne purchased a carousel storage system from White Carousels, Inc., of Kenilworth NJ, and modified the software to permit integration with a centralized computer system. All storage containers on the carousel are bar coded and all incoming parts are bar coded prior to placement in the storage containers. In the planning department, all parts and materials needed at kitting are listed and entered into the central database. This information is automatically downloaded to the carousel, in accordance with a pre-programmed production schedule. At the carousel, an operator must still remove parts from their containers and place them into a kitting basket. Both the containers and the individual parts are passed by bar code readers for inventory control.

Other IFAHMM Developments

The initial factory modeling at Teledyne was done by BDM International using the Air Force Integrated Computer Aided Manufacturing Definition (IDEF) method (3,4). These models have been reviewed by representatives of hybrid manufacturers at Raytheon, Westinghouse, Hughes, and CTS. While the Information Model (IDEF1) has always proven to be company specific, the Functional Model (IDEF0) has demonstrated a 90% correlation with other hybrid manufacturing facilities and is considered a basic requirement for the determination of production cost drivers (5).

In another effort, Teledyne worked with Teledyne TAC, a supplier of hybrid manufacturing equipment, to develop an automatic substrate attach machine using pre-formed thermoplastic pads as a replacement for epoxy. Although the adhesive is significantly more uniform, failures in shear testing have delayed incorporation into military standards for hybrid manufacturing.

All of the Teledyne/IFAHMM developments were shown in an End-of-Contract demonstration. As of 1990, Teledyne was continuing to demonstrate these products to interested companies. An extensive set of documentation on the Teledyne efforts is available from NOSC. This includes a thoroughly descriptive Final Report (6), from which the foregoing has been extracted.

PGM/IMIP

A development effort at Hughes Aircraft Company, Microelectronics Division, in Newport Beach CA, was undertaken in 1987 with joint funding from the Navy and the Air Force. This was part of an Industrial Modernization Incentives Program and specifically focused on the production line for the Precision Guided Munitions contract. The two primary developments were for a Universal Robotic Work Cell (URWC) and for an Automated Diagnostic System.

Universal Robotic Work Cell

It was originally planned to develop a material handling system which has a universal interface to any shop floor workstation, however, only two interfaces were developed as part of this project. Those interfaces were for the Laser Scriber workstation and the Ink Jet Symbolizer workstation.

The robot is from Intelledex and the software operating system is QNX. A PC is used as the Cell Manager. The Cell Manager interfaces with the company host computer (Stratus), the robot, and each workstation. The architecture of the Cell Manager consists of a Network server, and several Link Drivers.

Material handling is performed by a transport system, consisting of a robotic arm and a barcode reader attached to a carrier basket which itself is mounted on a conveyor belt. The robotic arm picks up cassettes from a loading station located next to the conveyor belt and places them into the carrier basket. The cassette has a barcode which is read as the cassette is placed in the basket. A cassette contains carriers which hold the hybrid substrates.

The carriers are designed to fit most of the standard hybrid sizes. Hughes reviewed the Teledyne design, but considered it not rugged enough for robotic handling. In addition, Hughes desired a carrier which opened up so that the hybrid could be removed, such as during inspection, then replaced afterward back into the carrier. Hughes designed a snap-fit carrier that used composite materials. The material had the extra benefit of not out-gassing helium, so the carrier could be immersed with the hybrid during leak testing.

After loading, the transport system moves down the conveyor to the first workstation, Laser Scribe. There, the arm removes a carrier from the basket and places the carrier into position at the workstation for processing. The workstation secures the carrier and lases a barcode pattern on the substrate. The robot arm then retrieves the substrate carrier, passing the newly scribed barcode pass the barcode reader. When all carriers have been processed, the transport system moves to the next workstation.

Automated Diagnostic System

One of the continuing needs in the manufacture of electronic components is one for automated and integrated diagnostics. Hughes Newport Beach, working with the Micromanipulator Company in Carson City NV, developed a prototype 8-probe system that interfaces with a centralized host computer for both downloading of the parametric and test data, and uploading of the test results. This system allows the rework technician to quickly access data regarding part failure, perform automatically a series of tests to gather specific performance information, then automatically perform the necessary analysis to isolate the cause of the failure.

The interface with the host computer system provides the technician with electronic forms of information, thus eliminating paperwork and the accompanying delays in distributing that paperwork.

Wirebonder Enhancements

Hughes Newport Beach worked in conjunction with Hughes Industrial Products Division in Carlsbad CA, and Gonzaga University in Spokane, to modify the Hughes Model 2460 Wirebonder for direct downloading from a centralized database. Hughes provided a microprocessor interface and operating software was developed by Gonzaga. Accuracy requirements for bonding still necessitate considerable set-up time so the direct downloading feature is not yet cost effective.

MICROCIM

In August 1989, NOSC awarded contracts to the Raytheon Company, in Quincy MA, and to the CTS Corporation, in West Lafayette IN, for the development of methods to implement computer integrated manufacturing technology into the hybrid microelectronics industry. This effort is known as the Microelectronics Computer Integrated Manufacturing (MicroCIM) Program.

The improvements in automated equipment have greatly benefited the electronics industry by increasing throughput with faster performance, increasing yields through consistent high quality performance, and by reducing production costs overall. However, there is rarely any integration of this automated equipment and there is significant labor required for the manual transfer of information between machines. Because of the chance of error being introduced by the manual transfer, additional costs are incurred to check for errors and to make the necessary corrections. The purpose of MicroCIM is to show the benefits of integrating these "islands of automation".

CAD Downloading

In 1990, Raytheon and CTS each developed some preliminary software for system integration. The Raytheon efforts permitted a computer aided design (CAD) file to be downloaded to a computer aided machine (CAM) on the assembly floor. The CAD system used at Raytheon is Mentor-Graphics. The CAM system was a pick and place robot. Hybrid circuit designs are stored in the Mentor-Graphics machine and have file names which carry a "dxf" extension. A conversion program, written by Raytheon and called CADTOPP, translates the "dxf" file into a format called "comma separated value (CSV)". CSV is a generic data format which is easily read either manually or by machine. The CSV file is stored on a diskette which is carried to the pick and place machine and inserted into the robot's front end processor. A Raytheon software program called "SUBWRITE" then translates the CSV file into subroutines recognized by the robot. Setup time has been reduced by about one minute for each die used on the substrate.

Electrical Test Data Collection

CTS developed software to upload test data into a centralized database for analysis. The overall task was straight-forward but was constrained by the conditions that system cost be low, software interfaces must be generic, and commercially available components had to be used. The intent was to facilitate duplication of this capability by small manufacturers.

The result was a test data collection system, with automatic analysis, for a cost of about $100,000. Hewlett Packard test equipment are each connected to a terminal server which, through an ethernet card, access a local area network. An analysis package is continually running on a workstation in engineering and automatically sends a warning when operating controls are about to be exceeded. The limits for operation are easily changed as needed. The terminal servers, ethernet cards, and network software are low cost, commonly available items. The analysis package is for statistical process control and is available from ATA. Manipulation of the analysis software is done using specially designed operator interface screens which are generic to any hybrid microelectronics manufacturing facility. These interfaces were developed using X-Windows and Motif, which are also low cost, commercially available components.

Since all data is stored on electronic media, paperwork is reduced and analysis is now performed by computer. Fault trends are now recognized instantaneously versus the former 30 minutes using manual methods and failure analysis has been reduced from hours to minutes.

CURRENT EFFORTS

There are currently three other projects underway. One is an Automated Substrate Production Cell at Raytheon. Another is a Manufacturing Data Collection and Analysis project being performed by CTS. The third, and most complex, is the CAD to CAM project being developed in association with NIST with subtasking to Raytheon and CTS.

Automated Substrate Production Cell

The Automated Substrate Production Cell is planned as an integration of several pieces of equipment in the substrate fabrication area. All equipment will be under one cell controller which interfaces with the factory host computer system. In the Cell, an automatic loader will place blank substrates on a conveyor belt which will carry the substrates under a laser scriber for bar coding. The conveyor will then carry the blank substrates under a screening machine which will print an electrical trace pattern on the substrates. The substrates next will be carried to a drying furnace and then automatically inspected for defects by a machine vision system.

Production parameters for any part are downloaded from a centralized database to the cell controller. The cell controller will alarm and stop the production run when test parameters in the machine vision system are exceeded. For routine defects, the controller will send the defective parts to rework where optics will automatically be positioned and focused over the defect to assist the technician. During operation, the statistics gathered by the machine vision system are continually analyzed and uploaded to Engineering for production adjustments.

Goals for this effort include reductions in direct labor, scrap material and rework, and increases in cell capacity and yield. As of September, 1991, a preliminary design has been reviewed and accepted.

Manufacturing Data Collection and Analysis

The Electrical Test Data Collection project served to demonstrate the concept for a low cost approach to factory integration. The next step is to expand that concept. CTS is planning to add other test stations onto their data collection and analysis network. The analysis software will be modified to show specific correlation between the types of defects and the probable process steps which caused the defects. A Design of Experiments effort will help determine which parameters at each process are the most effective to control. Personnel from the Advanced Microelectronics Facility at the Naval Avionics Center are assisting in the identification of the process parameters.

CAD to CAM

As part of a broad based effort to standardize the manner in which information is electronically transferred from design to manufacturing, NOSC is working with the National Institute for Standards and Technology (NIST) to develop an Applications Protocol, in accordance with MIL-D-28000 (7), for Hybrid Microelectronic Assemblies. This work incorporates guidance from the international committee on The Standard for the Exchange of Product Model Data (STEP), and the national committees for the Initial Graphics Exchange Specification (IGES) and the Product Data Exchange using STEP (PDES) (8).

The Protocol has three main elements. One is an activity model which describes the processes used to manufacture a hybrid. The second main element is the information model which relates all data needed for design, manufacturing, test, and documentation to the relevant activities. As of October 1991, these two models have been completed and are being reviewed by IGES/PDES national committee. The third element is an interpretive model which specifies the format into which data elements from specific sources can be mapped.

NIST is the lead agency for the Application Protocol. Raytheon has helped to define the data elements required for manufacturing and CTS has defined those required for design.

CTS will further assist by developing translators to implement the interpretive model. One translator will move data out of a CAD machine and into a centralized database. There, the data can be manipulated and used as needed. CTS will also develop a second translator to move data from a centralized database into a CAD machine. The format for the translation will be IGES.

Raytheon will be developing other software tools to assist in the manipulation of the data contained within the centralized database. This will include the ability to download subsets of the data to specific shop floor machines, the ability to upload parametric data from the shop floor machines, the ability to verify translated files for completeness, and the ability for multiple access of a common set of data while still maintaining configuration control of that data.

All of the work performed during 1990, and the plans for future efforts, are contained in the CTS and Raytheon Phase I Final Reports (9,10).

CONCLUSIONS

The developments undertaken by NOSC are intended to enhance the technical capabilities of the American electronics manufacturing industry. While new manufacturing technology is an important first step, dissemination of that technology to industry and implementation by industry are keys to realizing our intent. Therefore, NOSC continues to sponsor ad hoc advisory panel meetings and has a continuing involvement with industry groups such as the IGES/PDES subcommittee on electronics. In addition, NOSC has taken a leadership role in the development of Navy sponsored Industrial Modernization Incentives Programs to help companies implement new technology as it becomes available.

While these described MicroCIM efforts will conclude at the end of 1992, there are many technology challenges that have yet to be addressed. NOSC has assembled a five-year MicroCIM plan to meet these challenges and has submitted it to the Office of the Assistant Secretary of the Navy for review. For further information on that plan, or on any of the projects presented here, contact T. Joseph Sampite', Naval Ocean Systems Center, Code 936, San Diego CA, 92152-5000 or telephone (619) 553-3265.

REFERENCES

(1) Integrated Facility for Automated Hybrid Microcircuit Manufacturing (IFAHMM), Conceptual TO-BE Factory of the Future Strategic Planning Methodology (SPM) Analysis Results; Naval Ocean Systems Center Technical Document 1368, October 1988.

(2) Manufacturing Technology: Cornerstone of a Renewed Defense Industrial Base; Commission on Engineering and Technical Systems, 1987.

(3) Integrated Facility for Automated Hybrid Microcircuit Manufacturing (IFAHMM), IDEF0 AS-IS Model; Naval Ocean Systems Center Technical Document 1365, October 1988.

(4) Integrated Facility for Automated Hybrid Microcircuit Manufacturing (IFAHMM), IDEF1 AS-IS Model; Naval Ocean Systems Center Technical Document 1366, October 1988.

(5) Lessons Learned in Hybrid Microelectronics ManTech Program-to-Program Technology Transfers; Sanders B. Cox, BDM International; MTAG/IMIP '90 Proceedings.

(6) Integrated Facility for Automated Hybrid Microcircuit Manufacturing (IFAHMM), Final Report; Naval Ocean Systems Center Technical Document 1694, December 1989.

(7) MIL-D-28000, Digital Representation for Communication of Product Data: IGES Application Subsets; December 22, 1987.

(8) IGES/PDES Organization Reference Manual, July 1991.

(9) Microelectronics Computer Integrated Manufacturing (MicroCIM) Technology Development Final Report; CTS Corporation; March 14, 1991.

(10) Microelectronics Computer-Aided Manufacturing (MICROCIM), Phase I Final Report; Raytheon Company; April 26, 1991.