IMAGING JOINS ROBOTICS

IN HYBRID ASSEMBLY

by Michael Chalsen

Tighter tolerances for pick-and-place are answered by new vision-robot marriages

Imagine, if you will, picking randomly orientated electronic components, smaller in size than a grain of pepper, and accurately placing them in the proper orientation on a circuit board that is populated with a multitude of similar components.

Even with the assistance of microscopes and monitors, vacuum pencils and transfer devices, this procedure is laborious, tedious and error prone. Advanced imaging techniques combined with articulate positioning systems have provided the tools needed to develop an automated way of accomplishing this task. The process is of particular interest for the chip-on-board (COB) and hybrid-circuit industries.

Hybrid-circuit and COB technologies have evolved to a significant position in the electronic-package industry because of their high density, high performance and high reliability. As a result of their popularity, a large variety of hybrids in both a batch and high-volume environment are being assembled today. Components (also referred to as die or chips) that vary in size from 0.008" to 0.500" with either complex or simple patterns need to be analyzed, picked and oriented on both printed circuit boards and ceramic-based substrates (Figure 1).

Hybrid assembly manufacturers now are realizing the benefits of placing to tighter tolerances with the proliferation of fully automatic wire bonders and pullers, processes that follow die attachment. Greater placement accuracy results in less downtime in these subsequent steps.

Manual or semiautomatic component placement is still widely practiced in the industry. Through an eyepiece or a monitor, the operator finds the die in a wafflepack tray, determines its orientation and corrects for it before or during final pick-and-place. A semiautomatic tool often is employed to assist in the routine portion of the pick-and-place operation (die movement). In both cases, schematics and maps are needed to help the operator decide the proper position and orientation for placement.

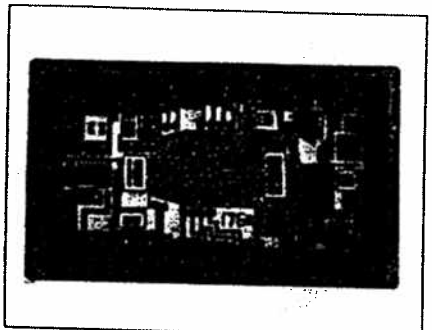

Figure 1.
A hybrid-circuit board.

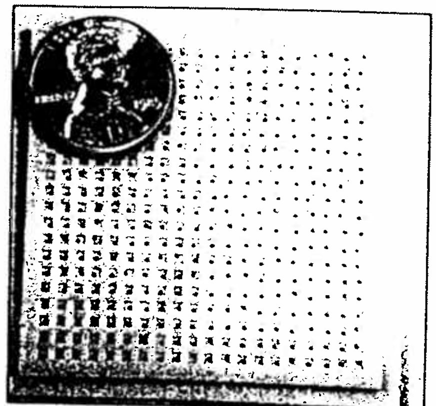

Figure 2.
Components in a wafflepack.

Typically, components are delivered to users in plastic wafflepack trays that do not normally hold parts in a consistent manner from grid to grid. This is the crux of the problem. Even some fully automatic die-attached systems need the die to be preoriented to within ten degrees for successful vision processing. Figure 2 shows components located in wafflepacks.

There are some key factors to be considered with the methods mentioned above. First, placement accuracy and consistency are direct function of human fatigue. Dies that are very symmetrical are particularly prone to misplacement. Second, speed is difficult to control both in new production runs in small-scale batch-oriented production environments where there are frequent changeovers and significant learning curves.

The interplay of human fatigue and speed on product quality, consistency and cost were driving factors for an accurate, vision-based, computer-controlled die attach/COB system.

Design considerations

- Vision Software. The heart of any flexible, automatic die-placement system is the vision software. The algorithms must be generic enough to determine the orientation of a wide variety of components and substrates once they are taught and stored into the system. They must have enough intelligence to account for real shop-floor conditions such as missing die and upside-down die. There are times when more than one part is located in a grid; this too must be detected properly. Finally, multiple sourcing of the same die (i.e., different patterns) will wreak havoc on a system.

- Teaching. Part imaging for the detection of components is based on a database developed by the end user. The routines needed to develop this database must be simple enough for an operator to perform, yet sophisticated enough to detect the almost limitless variations of components. Menu-driven/interactive teach-in routines are the most efficient method and have been utilized throughout.

- Vision system hardware. A fully automated die-placement system requiring advanced digital-image-processing techniques demands state-of-the-art vision hardware. High resolution is essential in resolving the patterns on die into enough detail so that nearly symmetrical parts can be differentiated. A gray-scale-based system is required to better determine edges and features than would a pseudo gray scale or threshold system. It also is less sus-

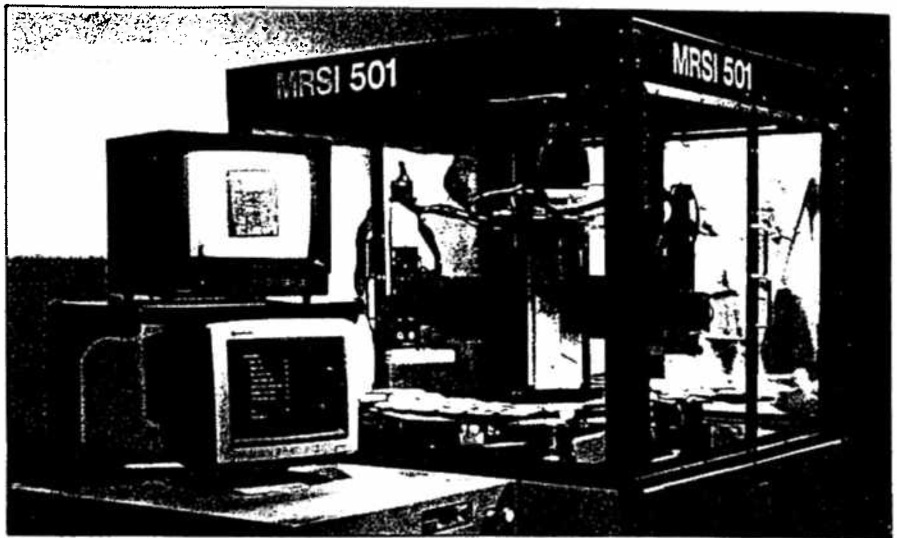

Figure 3.
MRSI's automated die/COB placement system

ceptible to variations in ambient lighting.

Finally, the vision system must be fast. Reduced cycle time from manual operations is one variable that is considered in economic justification of capital equipment.

- Material handling devices. The system must have the following characteristics: precision, a large working area, high speed and the ability to handle a wide range of parts, including those that are as small as 0.008". High resolution in the vertical (Z) axis is needed for two reasons: first, to prevent the crushing of delicate parts such as GaAs die during the picking and second, to accurately control forces during die placement to ensure the proper displacement of epoxy under different size die.

System achievement

To answer die-placement requirements in the hybrid and electro-optical marketplace, Micro Robotics Systems Inc. (MRSI) has developed the MRSI-501, a truly automated die/COB placement system now being used in both commercial and military applications (Figure 3). It offers a high capacity for most assembly requirements and high speed for economics. Placement accuracy of ±0.002" to 0.003" in position and two degrees in angle now is possible. A total of 400-450 die attachments per hour for vision-guided placement of die from wafflepacks and 900 die attachments per hour for direct pick and place (such as from linear feeders) can be maintained while die are being handled under a controlled contact force. This approach can be easily adopted to perform other tasks for delicate parts assembly.

An IBM-PC/AT version is being used as the system's host computer not only because it has been established as an industrial standard, but also for its versatility in real-time control and adaptability to available communication standards. The major workhorse, the MRSI Vision System, is based on a 512 × 512-pixel resolution, 256 gray-scale level vision package.

The Swiss-manufactured Microbo MR-03 cylindrical robot is the handling device that has been configured with five degrees of freedom (Figure 4). The first axis provides a 340-degree rotation of the robot arm. The second axis provides a vertical travel of 5.3", with 0.00015" repeatability. The third axis controls the extension of the robot arm and manipulates the radius from 10" to 17.5". The remaining two axes (six and nine) control the rotation of the vacuum pickup tool on each wrist. The Microbo MR-03 robot was selected for its high-precision, high-speed, unique configuration and for its low maintenance requirements.

Two cameras, one with high and the other with low magnification, are mounted on each of the robot's wrists. The magnifications are optimized to cover a range of part sizes and to provide enough detail within a pattern to resolve and decipher orientations of nearly symmetrical parts. Cameras with extra low or extra high magnifications are optional.

The system is programmed to recognize die that are in any orientation and position within a wafflepack cavity. If any pocket of the wafflepack is empty, the system will detect the condition and move to the next pocket. If the pocket contains a die that is incompatible in size (misplaced or chip outs) or upside-down, it will skip it and process the next pocket. If the pocket contains multiple die, the system will recognize the

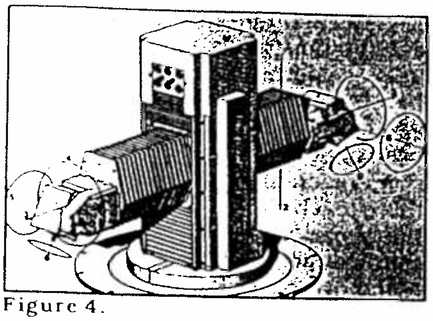

Figure 4.
The Microbo MR-03 handling device

first one when they are visually separable, otherwise it will move on.

The vision system determines the orientation of the die by matching a subset of the pattern that is taught and stored during the teach-in process. Only die that match in pattern (with appropriate tolerances) are picked by the robot. Very common in the industry is multiple sourcing of the same component. With alternate die capability, the system is able to match a pattern with parts from different vendors that are many times visually different. This is done automatically by the system. Subsequent pattern matches will begin with the last successful pattern match type.

The vision system also processes fiducial marks on the PCB or substrates to compensate for any misalignments in feeding or positioning. Once final placement points are recalculated, the system can begin producing product. If there are more than one set of patterns of the substrate (i.e., snapstrate), the system will process each individual pattern accordingly.

Dual vacuum pickup tips (one on each wrist) reduce the overall cycle time by eliminating the time consumed in changing end effectors. It also eliminates the effect that quick-change end effectors have on the precision of the system. The impact is most significant when handling die under 0.015 ".

A compliant vacuum pickup device virtually eliminates damage to small delicate chips including GaAs during picking and placing. It helps increase the tolerance to local unevenness of wafflepacks, substrates and components. Force detection also is built into the head, enabling the user to preselect a placement force for each type of die. This feature helps ensure that epoxy is properly displaced beneath a part prior to baking. In addition, built into the head is a static eliminator that will help discharge any static that may accumulate on the plastic vacuum pickup tip, enabling smooth, precise and static-free pickups. Finally, very accurate vacuum sensors have been

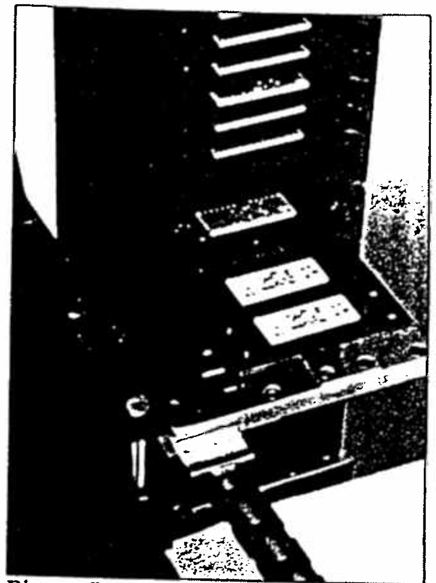

Figure 5.
A flexible substrate feeding device

integrated to detect presence and absence conditions at the pickup tips. A configuration has been implemented that can detect vacuum conditions through a 0.006" diameter through-hole.

The system also can interface with a flexible substrate feeding device (Figure 5). A user can specify trays, magazines or elevators to suit his/her environment. The automatic substrate loading/unloading can provide significant increases in system autonomy.

The production cycle is as follows: Cameras attached to the robot capture an image of the substrate; the new placement locations are calculated; the robot moves the appropriate camera over the wafflepack cavity and captures the image of die; the location and orientation are determined and coordinates are transferred to the robot which then picks the part with the vacuum tip; and finally, the robot places the part with a preselected gram load. The third through sixth steps are then repeated.

Software

The software structure and operation of the system are designed for operators. These menu-driven programs are easy to run and mistakes and/or inadvertent inputs can be corrected with ease.

The software categories are as follows:

- Calibration-verification programs. Calibration programs are not intended to be used by operators. They are employed when add-on components are remounted, which happens rarely. These programs are designed for system engineers or advanced technicians.

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Verification programs can be executed by operators to check the validity of calibration data. They should be checked routinely or when the operator suspects that damage has been inflicted.

- Teach-in programs. There are three teach-in programs: one for die, the second for substrates and the third for wafflepacks. All three are menu driven, vision assisted and designed for ease of use. Information that is gathered in teach-in programs is stored in the data base files. Also, the flow direction in the teach-in process is not absolute. Most of the links are reversible (by simple key strokes) to correct previous misentries. A program that will verify vision recognition of die in a wafflepack is included as well.
- Assembly programs. There are parameters that can be changed in execution to alter speed, visual verification of placements, assembly sequence, etc. In addition, a simulation process that runs through all or part of the placements without picking up or placing components is available so that the operator may verify the assembly process. System default settings are available to simplify data entry.
- Data base management programs. There are a number of data base files used in the system. For each data base file, there is a program to create, inspect and modify the file. These programs are menu driven and easy to use. Certain data is protected against manipulation and other data is protected against extremely inappropriate corrections. These programs are for system data files, die data files, substrate data files and wafflepack data files. The structure of data base files is optimized for large capacity, minimum search time and easy manipulation.

In summary, a system has been designed and successfully implemented to automatically pick and place randomly oriented die quickly and consistently. Advanced vision algorithms provide for robust image processing of a wide variety of components and conditions.

Meet the author

Michael Chalsen is an applications manager at Micro Robotics Systems Inc (MRSI) of Chelmsford, Mass. He has more than eight years' experience in high-precision automation. Three of those years were spent in Digital Equipment's Advance Manufacturing Technology/Storage Systems division. His responsibilities at MRSI include product and operations management, and customer applications and proposal development. He holds a degree in mechanical engineering from the University of Rhode Island and is completing his MBA at Bentley College.