Cost-effective packaging is one of the keys to reducing component cost in optoelectronic assembly. Compared to traditional microelectronic packaging, optoelectronics packaging presents new challenges. Materials are different, thermal considerations play a major role, and placement accuracy is critical for electronic information to be transformed efficiently into an optical form.

Packaging accounts for an estimated 60% to 80% of current manufacturing expenses in optoelectronic assembly (see figure 1 on page 28). The assembly of optoelectronic packages has been almost exclusively a manual process because of the complexity and low volumes involved. In the current economy, the industry is placing increasing emphasis on the automation of critical assembly processes to drive down component costs and increase manufacturing yield.

Industrial engineering approaches common in other high-tech industries are largely absent from today’s photonics manufacturing environment, however. These practices include process engineering, design for manufacturing, design for test, standardization, outsourcing, and automation. The aforementioned topics are highly interrelated, and any discussion of automation must include these practices, together with the specific types of materials employed in optoelectronic components.

The first true automation in the optoelectronics industry has come from adapting existing automated die-attach
and wire-bonding equipment to meet the needs of optoelectronic-component manufacturers. The industry has found that the wire-bonding and die-bonding equipment designed for the high-performance hybrid, multi-chip module, and microwave industries can be used as virtual off-the-shelf solutions for automating certain processes in the optoelectronic industry. To be truly effective, however, automation equipment must be refined to meet the specific needs of optoelectronics assembly and packaging.

**Automation nuts and bolts**

Because optoelectronic devices involve both electronic and photonic signals, their fabrication incorporates a plethora of materials. This variety of materials is one of the factors that distinguishes optoelectronic-device assembly from conventional microelectronic assembly. Instead of silicon serving as the common substrate, compound semiconductors such as indium phosphide and gallium arsenide are used. These materials are very fragile and require special handling and thermal management.

Processes for optoelectronic assembly today include many traditional microelectronic assembly processes and a few special processes that include the added complication of fiber alignment and active-component alignment. Implementing a high-yield, fully automated assembly process for optoelectronic packaging requires specialized machine functions such as conversion of instrument electrical readings to other engineering units typically involves additional test system components, such as photodetectors, integrating spheres, fiber-pigtails, etc. Calibration drift anywhere along the signal path can cause erroneous readings and process variations. If this drift goes undiscovered, yield may be affected for days or weeks, depending on quality-assurance methodology.

**Drifting along**

Slow calibration drift is a subtle and insidious source of unreliable instrument readings. Instrument manufacturers usually publish thermal-drift specifications, typically in terms of 90-day and one-year accuracies for a given temperature range. If published specs are not available, it is best to ask the manufacturer to certify thermal drift.

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Calibration should be checked periodically. Since critical production facilities typically have multiple test stands and backup instruments, one simple calibration check is to cross-correlate readings. This involves taking measurements on an identical group of devices under test (DUTs) using different test stands or instruments, or measurements on DUTs from the same production run taken over sufficient time to spot systematic yield differences. In most plants, this should be an ongoing practice in which two production tools running identical processes pass work-in-progress (WIP) to two identical test tools. This allows an engineer to correlate variations to a process or test tool.

**Intermittent false pass/fail results**

It is difficult to detect random or intermittent measurement failures in the form of false “good” readings on bad parts or vice versa. Passing bad parts may eventually increase field returns and warranty costs. Rejecting good parts reduces yield.

Often with instruments that have wide uncertainty bands, production test-tolerance bands are purposely narrowed to avoid passing bad parts. Higher-accuracy instruments may allow wider tolerance bands on production measurements because higher precision provides increased levels of reliability and confidence. This increases yields without increasing the pass rate for bad parts.

**Nuisance failures**

Many optoelectronic component test stands are plagued with frequent instrument lockups that require excessive operator interaction and lower throughput, plus introduce the possibility of transposition errors. Such errors can occur as operators manually sort parts and erroneously record (transpose) data on those parts, resulting in false defect classification.

Recovering a stalled instrument in an automated production environment is time consuming and costly. In addition to restarting the instrument, WIP stock must be rearranged to make sure all DUTs are completely screened. Depending on test system complexity, this task can be complicated and prone to error. Nuisance failures tend to breed operator anxiety, which leads to throughput reductions as proper operation of test equipment is frequently checked. A typical manufacturing response is to increase equipment investment, operator staffing, and maintenance technicians to sustain acceptable throughput, which defeats the purpose of automation. Robust operation with minimal lockups depends on thoroughly testing instrument firmware in the production environment.

By combining novel measurement techniques with proven production test instruments, systems can be developed for high test accuracy, throughput, and component yields. These solutions take advantage of automation features on instruments designed specifically for PC-controlled testing and can be scaled for different levels of automation.

—Paul Meyer, Keithley Instruments Inc.
The past year has been an active one for the Photonics Manufacturing Association Council (PMAC), organized under the IPC-Association Connecting Electronic Industries trade association and launched in early 2002 (see oemagazine, August 2002, page 20). The PMAC has established its steering committee, which formally approved the PMAC mission statement and has begun work on organizing standards and industry trade activities.

High on the list of objectives for 2003 is the formation of a PMAC standards subcommittee that will focus on guiding standards development in concert with other international standards efforts. The Standards Subcommittee charter will be as follows:

- Identify/prioritize key areas requiring standardization (e.g., from roadmaps)
- Explain how standards get created, maintained, etc.
- Publicize relevant standards activity to increase awareness and incite participation and proliferation
- Facilitate development and deployment by providing structure, organization, and publication where possible
- Interface with appropriate bodies in the development, publication, and implementation of standards
- Maintain standards library/Web links to assist membership.

An important milestone in this effort will be the imminent release of a new standardization roadmapping document, “IPC-0040: Optoelectronics Assembly and Packaging Technology,” which is under final ballot and should be issued early this year.

Collaboratively assembled over the past 16 months as a guiding document for standardization, the IPC-0040 document identifies 23 distinct areas that the contributors agreed need serious, immediate standards work. These areas include assembly techniques, fiber handling and management, inspection, and quality and test standards. Additionally, the document references many existing fiber-optic-related standards.

The goal of the IPC-0040 document is to provide a detailed background reference on current fiber-optic manufacturing technology and present a framework and document control structure from which to develop and deploy new standards that don’t fit under any other current standards-development efforts. One such standard, “IPC-3841: Specification for Process Carriers Used to Handle Optical Fibers in Manufacturing,” has already been developed; at this writing it was scheduled for a January release under the new IPC standards document structure. This standard was born of an effort spawned by the 2002 National Electronics Manufacturing Initiative (NEMI) roadmap. It is a prime directive of the PMAC to work collaboratively with other groups and standards bodies wherever possible to accomplish our mission. This is a good example of how such collaboration can work.

The PMAC has recently formed the standards subcommittee and invites volunteers from all sectors of the industry to join in. Formal meetings presenting the IPC-0040 document and tying in other roadmapping and standards efforts are being planned in collaboration with other groups, including NEMI and The Optoelectronics Industry Development Association.

—Randy Heyler, PMAC Steering Committee and Newport Corp.

You can signal your interests in standards participation or find out more about the PMAC by contacting David Bergman at DavidBergman@ipc.org or logging onto the IPC/PMAC website at www.ipc.org/html/fsrelated.htm.
rate (see figure 2). Once the interface is brought up to the proper eutectic temperature, the heating mechanism must maintain that programmed temperature with minimal overshoot. After the required amount of reflow time, the heating mechanism must controllably cool the interface to minimize damage to the laser cavity and to allow the eutectic material to reach metallurgical equilibrium. This equilibrium is reached through simultaneous application of active thermoelectric pulse heating and cooling gases.

**placement accuracy**

Final placement accuracy of the diode laser relative to its submount is vital for the proper transmission of the laser light. p-side-up, edge-emitting diode lasers require a final placement accuracy of ±5 μm (3σ). Proper placement maximizes thermal conduction; improper placement occludes the laser’s emission.

Today’s automated systems can control the accuracy, precision, and repeatability of component placement to within ±5 μm (3σ). For example, placement algorithms can position a die so that any subsequent die is located relative to the most recently placed die. This improves component-to-component positioning accuracy. It also controls the length and position of wire bonds, ensuring the wires are parallel and the same length. These factors are important for high-frequency electrical conductivity.

The extremely tight tolerances, the complexity of the operations, and the tremendous costs of materials and labor involved make automating the optoelectronic manufacturing process desirable. Automation can yield significant cost savings. A component manufacturer demonstrated that one automated eutectic die attach machine could produce the same total output as four manual stations run by 20 operators over multiple shifts. The automated process raised yield by over 50% over the manual process while reducing the footprint in the clean room by 67%. These savings realized a return on investment for the equipment in less than three months.

The downturn in the economy has resulted in a reduced labor force and downsizing. Companies can ill afford the expense of costly repair and rework or the results of low yield. As the demand for optoelectronic components and devices increases, automating the optoelectronic assembly process becomes a very appealing and practical option. **oe**

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**Figure 2** Programmable pulse heating (blue) offers advantages over dumped-energy heating methods (red).