Optical Manufacturing

Integrated automation promises improved planar lightwave circuits

BY RAY CISNEROS AND GUY SHECHTER

Automation will make production of fiberoptic components more cost-effective. The author argues that the development of a system that combines automated polishing and inspection capabilities will benefit makers of PLCs.

The rapid proliferation of planar lightwave circuits in a wide variety of dense wavelength division multiplexing (DWDM) solutions places a premium on automating every aspect of the manufacturing process. Planar lightwave circuits (PLCs) already offer a breadth of solutions for DWDM applications, such as arrayed waveguide gratings (AWGs) for multiplexers and demultiplexers, electronic variable attenuators, modulators, splitters, couplers, and semiconductor optical amplifiers.

The polishing process is one step in the manufacturing process that would benefit from an automated solution. The current approach makes use of manual techniques that result in poor production yield, low throughputs, and inadequate process controls. Given the market potential for PLCs, such problems will soon make the current production approach cost prohibitive. At peak periods, for example, a manual approach in a high-volume production facility means employing hundreds of operators just for polishing. An automated system with all the key process capabilities integrated onto a single platform would be an ideal solution.

FIGURE 1. An automated solution for polishing, cleaning, and inspection of planar lightwave circuits and v-grooves includes process technology, servo-motion control, high-performance video metrology, and software.

Current limitations

Dense WDM solutions based on planar technology have brought two components to the polishing process that pose challenges: the PLC itself and the mating input/output v-groove fiber array. Because of the variation in materials, composites, shapes, and sizes, process control and optimization are difficult to accomplish manually. Surface quality at the waveguide feature or fiber core is critical for optimum insertion and return loss performance. High planarity and angle control is essential for mating planar devices in subsequent micro-assembly steps, such as an AWG coupled to a v-groove fiber array. Waveguide or v-groove fiber-core step height is critical for optical photonic coupling.

The current manual approach to polishing PLCs requires several bench-top polishers, manual cleaners, and an optical microscope. Two to three highly skilled operators divide the workload and hundreds of manual manipulations are required to produce one part. Manual methods have limited flexibility and always run the risk of human error. Additionally, manual transport from point to point is one of the biggest causes of defects or part damage. Although 100% visual inspection of the polished surface is required, an operator makes a subjective pass/fail call.

Planar lightwave circuits and v-groove arrays are sensitive to process variables because of their form factor and the materials involved, such as a wafer-thin silicon-based AWG, or the composite material effect, such as a multichannel fiber array. Some AWG devices have reached up to 100 mm wide, and some v-grooves are up to 48 channels.

An integrated solution

The most effective solution for polishing PLCs and v-grooves is to preclude any manual operation and integrate and automate the entire process flow. One automated polishing solu-

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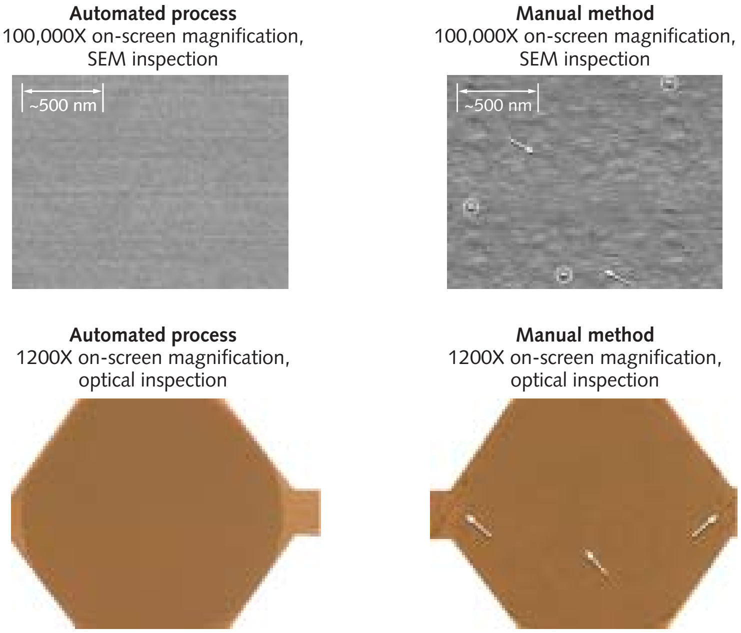

FIGURE 2. Automated polishing provides superior surface finish for a silica waveguide multichannel arrayed waveguide grating (top left) compared to manual polishing (top right). Similarly, for a SMF fiber in a v-groove notch the finish provided by the automated process has fewer surface defects (bottom left) than that possible with manual polishing (bottom right).

tion integrates the process technology, motion control, high-performance video metrology, automation software, and precision tooling on a single platform (see Fig 1). In this case the platform is of modular architecture designed for process flexibility, clean-room factory automation, and high productivity. All process elements—polishing, cleaning and optical inspection—are integrated on the platform.

Controlling process parameters is the most critical aspect of polishing PLCs and v-grooves. An integrated approach controls and monitors all process parameters independently at each process station, including polishing disk speed, applied polishing force, polishing pattern, device carrier rigidity, and consumables management. The typical process recipe for PLCs and v-grooves can be accomplished in three to four polishing steps, with contact or noncontact cleaning techniques between steps. The ability of an automated system to finely control all process parameters and seamlessly route the product from station to station on an integrated platform produces superior surface quality results compared to the alternative manual methods (see Fig. 2).

Unlike other fiber-based optical components, PLCs and v-groove arrays have a larger effective footprint. We have determined that 300-mm polishing disks with less than 5-µm run-out are the ideal polishing disk technology. The larger polishing disk easily accommodates large PLCs and v-groove arrays in batch mode. The larger disk size also allows a motion pattern of the polishing head during processing. The low run-out ensures accurate device-angle formation and mitigates surface defects, such as edge rounding and chipping.

Factory automation and clean-room readiness are increasingly important requirements in polishing PLCs and v-grooves. Many PLC manufacturers suffer the ineffective situation of polishing outside the clean-room walls because of the contamination risk posed by open bench-top polishing units. An automated system should offer a closed process chamber environment to mitigate contamination, and also should receive and return clean and dry parts so there is no manual handling of wet or contaminated parts.

For full automation a system-control software platform is also required. Such a system would allow all process recipes, system events, machine status, and results to be easily managed. A system that is network ready for remote updating and data management is also necessary for real end-to-end factory automation. True distributed computing also must exist, such as the ability to drive the polishing pattern while monitoring consumable rates, or micropositioning the device carrier while driving the image-processing algorithms during inspection (see Fig. 3).

A unique attribute of PLCs and v-grooves is their variability in materials and form factors. Critical to managing this is tooling that ensures high throughput and rapid changeover from batch to batch. The ideal solution is off-line loading and unloading of device carriers so no effective impact on throughput occurs and precision alignment/end-point fixturing is allowed. When switch-

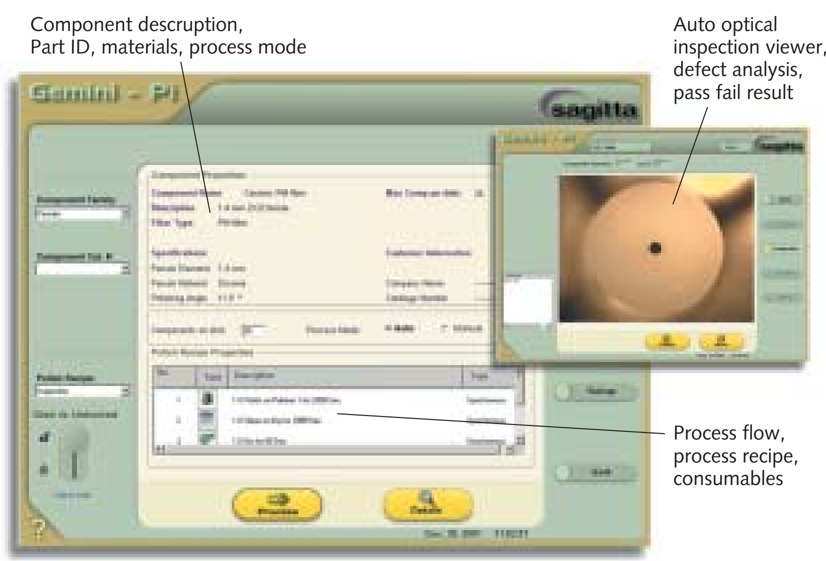

FIGURE 3. A user-friendly graphical user interface manages the process and system control software as well as data management for an automated polishing system. This screen image from the Sagitta Gemini system shows the operating menu and the optical inspection viewer during image processing for defect analysis.

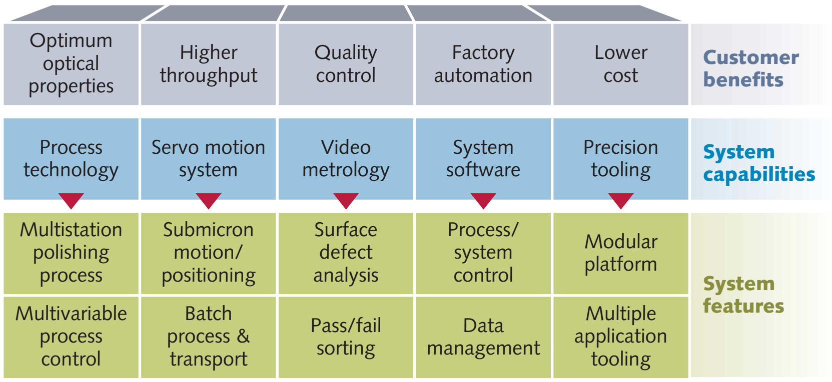

FIGURE 4. An automated polishing process system offers benefits for customers through a variety of system capabilities and features.

ing from processing AWGs to v-grooves or vice versa, for example, no change to the platform should occur; only the carrier specific to the device is prepared off-line and then dropped into the loading bay. Additionally, bar coding of carriers to automatically upload the appropriate process recipe is necessary. This prevents operator error and can handshake to a factory-floor materials requirement planning (MRP) system.

Quality and cost controls

Before adding subsequent value to the end product, optical inspection of the surface quality is performed following final polishing. The ideal automated solution, therefore, should contain a high-performance video metrology station for final quality inspection. This means the system must contain on-board imaging software for defect analysis and pass/fail recognition. The imaging software must be teachable so it can recognize submicron surface irregularities such as scratches, pits, and particles. The software should also be programmable to measure defect severity and region-to-region severity thresholds.

Vibration isolation and servo-motion control are also required to accomplish accurate defect analyses. The imaging station will require active vibration damping to isolate the effect of the in-line process stations. The servo-motion platform will require submicron *x-y* motion for accurate positioning.

The cost savings of an integrated platform are hard to ignore. A manual method today for polishing a typical large AWG can be as slow as two parts per hour. By comparison, the throughput on an automated system can be an order of magnitude greater. In addition, an integrated system reduces training time from weeks to hours and the process is unattended, so labor costs are a fraction.

There are also hidden management expenses. The cost advantage of managing an automated line of systems vs. a pool of craftspeople is significant. Process and quality control measures are hard to control in a manual operation, whereas an automated system is taught and programmed. An integrated automation solution scales, whereas a manual process carries a high inefficiency penalty as production grows (see Fig. 4).

Next-generation demands

The system discussed here is flexible enough to accommodate future trends and needs related to high-performance polishing and inspection of components. Some new or enhanced capabilities of interest and already undergoing evaluation include angle-measurement capabilities, interferometric measuring tools, long-lasting media technology, and auto carrier loading/unloading. The final design will ultimately be driven by customer product requirements, but component manufacturers should be aware that a robust and versatile automation platform enables the best solution for time-to-volume demands. OM

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