Ten Steps to Effective Opto Package Prototypes

The 10 steps described in this article lay an effective groundwork for prototyping optical packages. No single step is unimportant, and careful attention to the process will save time and money when the design moves into volume production.

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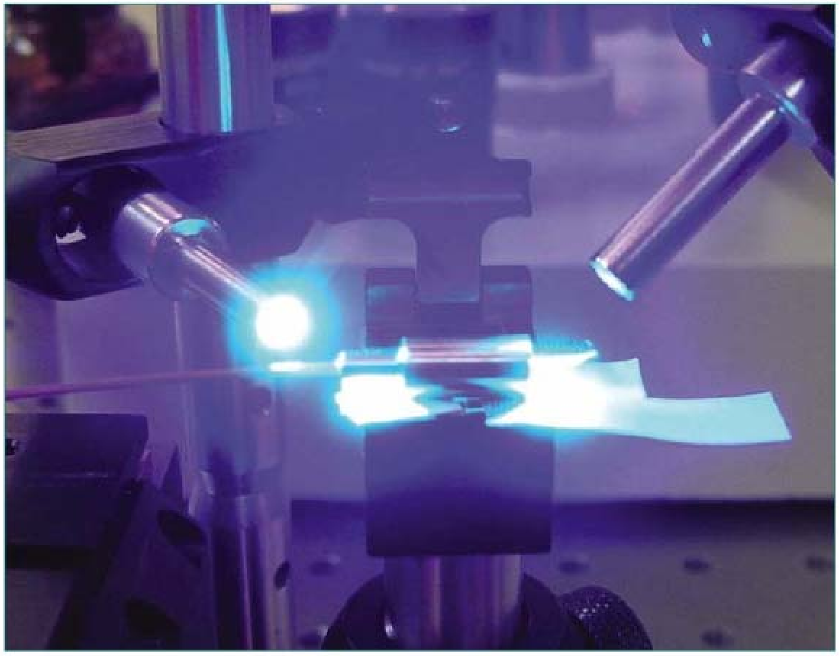


UV curing of epoxies forms a low stress, high-accuracy bond for a rapid prototype as well as some production applications.

There are many phrases that we learned at, and in some cases over, our parents' knees. Only with experience do we come to truly value those expressions. When reflecting on my experience with optoelectronics prototyping there are two phrases that quickly come to mind: the first is "measure twice, cut once," and the second is "third time's the charm."

The first phrase, "measure twice, cut once," is easy to visualize and reminds us that once we actually begin the assembly process, any changes that we make after we "cut metal," so to speak, are going to create an enormous amount of additional work and, more importantly, add cost to the project.

The second phrase, "the third time's the charm," represents insight gained through a large number of optoelectronic product prototyping efforts.

When developing a product, no matter how hard or how carefully you work, it will require three iterations to get it right. This represents an empirical rule, of course, but one that almost always holds true.

Linked

Product design and prototyping in an iterative fashion are inextricably linked with one another in the product development lifecycle. Attempts to eliminate this repetitive aspect and move directly into production will inevitably lead to performance, manufacturing, and cost issues.

Optoelectronic product development is especially sensitive to this iterative link between design and prototyping. This is, in part, due to the high-frequency nature of both the electronic and optical signals that lead to tight tolerancing in the design, as well as the lack of standardization. Prototyping, therefore, cannot be discussed without considering the design.

In this paper we will discuss 10 important aspects of—and the expected results for—prototyping.

Ten Steps

This will include the steps of the design process (measure twice, cut once). In addition, we will go through the steps of the prototyping process and discuss the relationship of the choices that are made to downstream product development (third time's the charm).

For the purpose of this discussion, these are listed as ten steps.

Steps 1-4 review important considerations to keep in mind during the project planning and design phase. Steps 5-6 are considerations to be looked at when the prototype effort begins, and steps 7-10 are focused on making sure much is learned from the prototype phase of your project.

1 ***Understand and define the purpose for your product prototyping:*** It seems obvious, but the first and most important consideration for prototyping is to determine what you are trying to accomplish.

Generally, prototyping activities fall into one of two categories: proof of concept or product development.

Proof of concept efforts are generally undertaken with an eye on short term

The finished prototype can be inserted into the system for proof of concept before the final system design is done.

costs and turn-around time. Proof-of-concept efforts will not lead to the lowest cost or best performance for a device once the concept has been demonstrated another design and development effort will be needed to create a product well-suited to the marketplace.

Choices

Some of the choices guiding the design for a proof-of-concept effort will be the availability of parts and components.

Lead times for some components can vary from four to twelve weeks and making the correct choice can reduce this cycle time significantly.

For a product development prototype, the timeframe can be any where from three months to nine months, again depending on turn-around time for custom parts.

For instance, when designing an optical interface for carrying or combining light, you may elect to employ standard, off-the-shelf lenses initially.

This option will allow you to immediately begin assembling the product, but may not lead to optimal coupling efficiency or the lowest cost on a per-part basis.

You may also consider custom plastic optics. However, the choice of custom plastic optics will have a higher NRE and a longer time to delivery, but a lower piece-part cost. Should the product move into high-volume production, custom optics would be the preferred direction.

2 ***Understand the iterative nature of the prototyping process.*** The key reason for this revolves around the high-frequency aspect of both light and the electrical frequencies used.

Low-frequency electrical signals can follow virtually any kind of metal trace—either straight or winding. Higher-frequency electrical signals will interact with their surrounding medium and this additional complexity must be taken into account during the design phase.

Light is transmitted in two ways: via free space or through fibers. Free space requires a series of bulk optical elements that cannot be moved or physically altered (say by thermal expansion/contraction) or the signal will diminish.

Light Transmission

There are systems that make use of material media such as optical fibers or wave guides for handling the transmission of light.

In the best cases, the models used in the design phase are just highly complex approximations of the actual behavior of the system.

In these systems, total internal reflection is used to capture the light and transmit it with minimal loss. However, unlike metal traces, fibers are severely limited in their ability to be bent or twisted. Even within waveguides there still remains the issue of coupling the light in and out of the waveguide.

Additionally, in optics the movement of components as they expand when heated up and condense when cooled down is much less problematic than in the two-dimensional electronics space.

Such movements and the transmission limitations of light create greater emphasis on thermal and mechanical considerations in optoelectronic devices compared to electronics.

Any movement that interrupts the light signal may degrade the functionality of the entire device. Therefore, the design and manufacturing considerations of the components and the entire device must be viewed as a whole.

Complex Approximations

In the best cases, the models used in the design phase are just highly complex approximations of the actual behavior of the system. These approximations rely on the initial accuracy of our underlying assumptions.

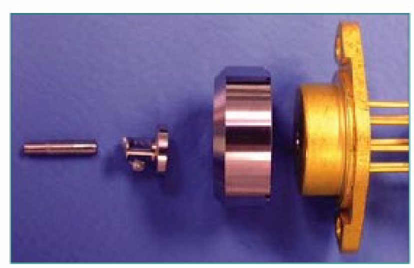
First, build measurements must be made on the system and then fed back into the models to correct for mistakes in the underlying assumptions or tweaks that need to be made to the model.

Once the model and field measurements are in agreement, then the build can move forward.

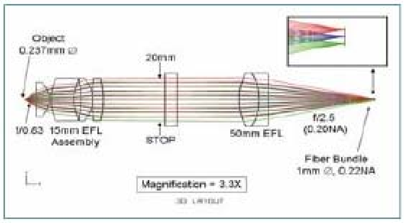
3 ***Define and detail the critical aspects of your product.*** Detailing the tradeoffs that are available in your product is of extreme importance. For instance, will the device have to operate at a specific temperature or in a temperature range?

Is the output power to be held fixed, or does it need to be above a minimal threshold?

When defining the operating parameters and specifications for your product, make sure that when there is room for



Precision parts from reliable vendors speed up the successful alignment of fiber to laser when welding prototype parts.



The optical model provides the basis for iterative designs, interface requirements and the mechanical support system.

variance, acknowledge it. If the requirements are more constrained, then by all means indicate that.

One such example of failure to consider real-world consequences can be seen in the telecom industry. During the bubble as volumes rose, companies tried to automate the hand assembly of their products.

If products were switched from a hand assembly line to an automated one, and the tolerances of the incoming parts were not in specification, the output of the automated line would fall to zero.

Frequently, components were designed into systems, but to tolerances that manufacturing or material buyers could not purchase. This did not present a problem while the devices were hand assembled, since every single assembly could be adjusted by hand. However, a machine cannot do this and instead the yield declines to zero.

4 ***Collect and disseminate all relevant information in writing.*** The reality of a product prototyping effort is that from start to finish there will be numerous hands touching the effort.

In addition, all those involved will want to bring something from their own experience to contribute to the project. Some of these experiences may be valuable and some may not.

When outsourcing a design or prototype effort, it is essential that communication of all information be done in writing. This ensures that the communi-

The packaging world exists at the crossroads for many different types of fabrication. The electronics chip manufacturing world, for instance, is defined in terms of metric units, while the board fabrication and board assembly world is defined in English units.

I have, on more than one occasion, seen parts fabricated incorrectly when 10 mils were interpreted as 250 microns. The fact that engineers working in these crossroad technological areas use the term metric *mils* to mean 25 *microns* may create a dangerous situation.

5 ***Choose well-controlled processes.*** When considering what processes to use for assemblies, always choose those that the fabricator has the most experience with and can demonstrate process specifications indicating these processes are well controlled.

In a perfect world, when your prototype rolls off the line for the first time and functions as expected, it is ready to move out into the market. In the real world, the product may not perform as expected.

To move forward with the debug process, it is desirable for there to be as few variables as possible. This is a problem frequently encountered for proof-of-concept efforts.

Customers in a hurry to get evidence of the workability of a design will use processes that would not be acceptable for the manufacturing solution that will be used later on.

This presents a problem during the debug of the device design, as it will not be known if the design is flawed or if the new process is not yielding the desired result. Always introduce only one new change as a time.

If a new process must be used then try it first on an existing product design whose behavior is well understood.

6 ***Understand the relationship of***

Customers will frequently attempt to cut corners by seeking to get their prototype manufactured as cheaply as possible and then transfer the design to a different manufacturing line for production. This puts us back into the same situation as previously described.

In choosing different sites or locations, we may be running on different tool sets and using different processes. It is worth the time and money to find a location that can offer the prototyping service along with the manufacturing under one roof.

Then, when you are ready to transition to manufacturing, it is unlikely that you will experience glitches due to tooling or processes that are incompatible with those used during the prototyping phase.

7 ***For complex systems, consider modular, testable sub-units.***

When we finally reach the assembly stage of prototyping, testing is vital. All of the underlying assumptions must be validated, and this information needs to be fed back to our models.

Again, in a perfect world where our prototype rolls off the assembly line ready for use, there are no issues.

However, when there are problems making the assembly easier to test, being able to focus the failure analysis effort more narrowly is extremely important to in order to quickly and easily find a solution.

Simplifying the assembly operation into smaller testable sub-units makes interpreting and understanding the results that much easier. It also allows the sub-units to be built and tested independent of one another. This is especially important as ordering times for the components for the various subsystems may vary significantly.

8 ***Testing must exercise all product features.*** I have heard it said many times that testing is frequently more a measure of itself than it is of the product.

Easy access to production facilities promotes concurrent engineering and rapid prototyping.

it exercises all aspects of the product. Failure to do so will lead to unpredictable results in the field.

In the design and fabrication of complex IC chips, for example, it is impossible in a reasonable amount of time to exercise all of the different aspects of the chip.

Algorithms are designed to exercise the circuits one at a time and in various combinations to look for higher-level errors. In this instance, clock handling could lead to a problem, but is only seen when certain circuits in the chip are exercised at the same time.

Similar problems can arise for optoelectronics systems. For example, with high-powered die you want to look for the behavior of the die over time to determine if a power fall-off is occurring.

With high-powered laser die you also need to inspect for secondary effects. These may effects may include out-gassed organics interacting with the laser, decomposing, and subsequently interacting with the optics of the system, leading to a degradation of the system behavior.

9 ***Prototype design needs to be testable for process-line evaluation.*** Prototype lines are low-volume, high-mix lines accommodating many types of processes and products.

This fact makes the inclusion of features designed into the product to measure the stability of the assembly process extremely valuable.

Consider the die placement process as an example. In die placement, alignment marks are always included on both the substrate and the die to enable the automated visual alignment system.

Including features that allow you to measure the process while doing the assembly can offer insight into any failures that occur or performance hits found in the product.

10 ***Iterate results back to design.*** The third time's the charm. You are back at the beginning, and now the entire group of test results must be must fed back into the models.

This activity will enable you to validate and adjust your assumptions for the real world of assembly. It is ideal to make a second run with these measured results fed back into the design with no other changes to the system.

After the second run is made, the models reliably predict system behavior and good, underlying assumptions can be built on real-world data. You can now return to the models and modify the design to optimize device performance.

In addition, the process data acquired from measurements on the prototype will be invaluable during the inevitable debug phase. It will help you to understand, in the unlikely event that the device is not performing, whether you should focus efforts on the design or on the processes used. The amount of time saved here can be enormous.

Conclusion

While most people think of prototyping as a physical event, all of its important aspects are mental. I have described some of the important considerations to bear in mind to be successful at prototyping and product development.

Remember that prototyping is not a one shot effort; getting it right will require more than one trip thorough the process.

Dr. Magill is Avo Photonic's chief technology officer with more than 15 years experience in the electronics and optoelectronics industry. Prior to his current post, he managed groups in advanced packaging, standardization, and automation for JDSU, following its acquisition of Optical Process Automation in 2001.

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