

THE ULTIMATE GUIDE to High-Speed 3D Printing WITH CONTINUOUS TECHNOLOGY

The Ultimate Guide to 3D Printing with High Speed Continuous Technology

Continuous 3D printing is a newer approach to DLP printing in which the build plate moves constantly in the Z direction – allowing light to cure photosensitive polymers without interruption to produce a final part.

In this paper, you will learn more about these technical considerations for continuous 3D printing:

- Beyond speed, what are the benefits of continuous 3D printing?
- What is a dead zone and why does it matter?
- Why is accuracy more challenged on a continuous 3D printer than with traditional DLP or SLA technologies?
- Is surface finish really always better on a continuous 3D printer?

The Promise of Continuous Printing

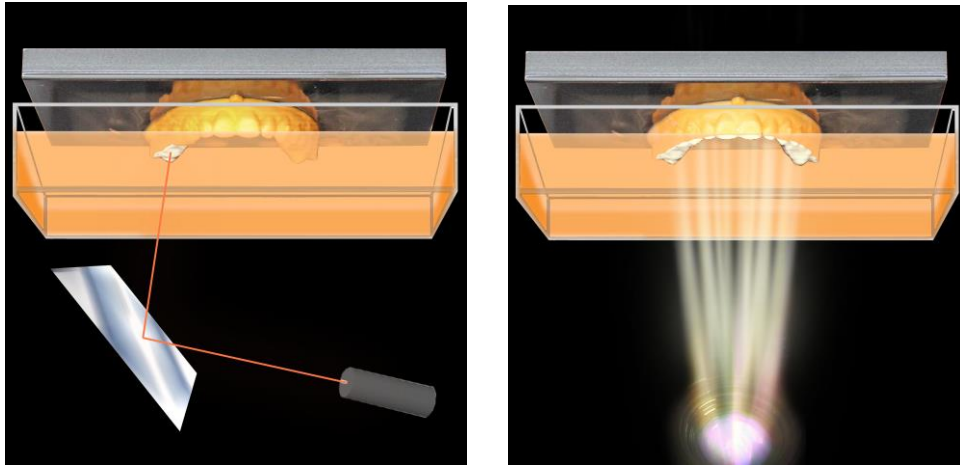
Since its inception, 3D printing has had one large and aching Achilles heel: speed.

One of the earliest methods of 3D printing, stereolithography (SLA) painstakingly draws out parts in photosensitive polymer with a fine laser beam, layer by layer. Even with software advancements and years of development, it's a slower process.

In 2002, when Digital Light Processing (DLP) first came to market¹, it represented a significant leap in print speeds that allowed 3D printing's first deployment in mass customized production.

While exposing a whole layer of resin at a time with an HD projector was much faster, however, the process still required printing one exposure section at a time. That meant pauses in between exposures for peeling and repositioning the build platform, often in 1-200 micron exposure layers.

¹ EnvisionTEC commercialized the first DLP 3D printers in 2002.



SLA (shown left) literally draws a part in resin with a laser beam, a time-consuming process. DLP (shown right) works faster because it doesn't have to draw every single line and can cure an entire layer in one exposure. Still, the build platform must move up and down, repositioning itself for every layer, usually in 1-200 micron increments.

The idea of DLP printing continuously in the Z axis, then, without pausing for each exposure layer, is a natural and exciting evolution of 3D printing technology – one that holds the theoretical promise of many benefits.

In addition to speed, for example, advancing a print job continuously in the Z axis theoretically allows for isotropic properties, or consistent part properties in all directions. This is especially important in the Z direction because prior 3D printing methods, while not all of the same quality, have tended to have stronger X-Y strength, but less in Z. This has caused 3D printer users to strategically orient their objects in the build envelope for optimal strength in certain axes or enhance final material properties with post-curing strategies. Theoretically, then, parts printed continuously are more similar to injection molded parts that don't have clear weak points between layers and are consistent throughout with a smooth surface finish.

What's more, 3D printing at high speeds allows for the processing of chemistries that were previously not possible, such as dual-cure materials with a short pot life. This includes polyurethane-type materials and other chemistries with strong functional characteristics.

Bridging the gap from theory to reality, though, isn't so simple.

Continuous printing comes with inherent accuracy challenges, as each X-Y layer isn't as tightly controlled throughout the build process, as it is with advanced DLP, where the repositioning of the build tray tightly controls the accuracy of the Z-layer height during a build and ensures a tightly controlled exposure layer. In continuous printing, then, light “bleeds” through the build envelope in inconsistent ways that can impede part accuracy, especially with certain materials, such as transparent materials².

Understanding Starts in the Dead Zone

What is the dead zone and why is it so important in continuous 3D printing?

A dead zone in 3D printing was first observed at EnvisionTEC by Chief Technology Officer Sasha Shkolnick in about 2003 — just one year after the company commercialized the first DLP printer and one year before the company launched its Vanquish 3D printer.

The Vanquish 3D printer, launched in 2004, had a unique design among the company's market-leading DLP printers at that time, *including a build platform that moved continuously.*

EnvisionTEC's original Vanquish 3D Printer featured a continuous moving build plate and a projector overhead. This led EnvisionTEC to discover, understand and compensate for the dead zone.



² Read more about how certain materials affect part accuracy in “Understanding 3D Printer Accuracy: Cutting Through the Smoke and Mirrors.” Read at www.envisiontec.com/accuracy

While developing and using this printer, Shkolnik observed that a thin top layer of material in the machine never seemed to cure or harden, even when directly exposed to light.

“I noticed the part was always forming only a little below the surface, but never on the surface,” Shkolnik recalled. “We even had trouble with our most reactive material at that time, R5. We would expose it so much sometimes, you could even see it smoking, but the top layer still wouldn’t cure.”

Unlike the company’s Perfactory printers, in which the projector was located below the vat of photopolymer, the Vanquish was a top-down style DLP printer, with the projector situated above the vat of photopolymer. And the top of the vat was always exposed to open air or oxygen.

Oxygen, as it turns out, inhibits polymerization and that small area where oxygen and the photopolymer comingled on the surface is called the dead zone. In order to build successfully while also building continuously, then, the projector light had to transfer successfully through the dead zone.

While this was initially viewed as a nuisance, it was also eventually viewed as a potential asset and EnvisionTEC filed on Nov. 15, 2006 for a patent on continuous 3D printing³.

When continuous DLP printing in the inverse direction – as EnvisionTEC’s Perfactory model line did at the time, and still does today – a dead zone could strategically be used as a no-stick zone, where parts no longer had to be peeled from the material tray in between exposure layers.

Essentially, this approach allowed for 3D printing in free space.

While that was an exciting idea, the concept also presented other challenges, especially in 2006, prior to widespread availability of modern LEDs. For example,

³ Shkolnik, Alexandr, inventor; Continuous generative process for producing a three-dimensional object. US patent 7892474 B2. Feb. 22, 2011.

the light intensity had to be strong enough to penetrate the dead zone and still convey enough light, or energy, to the resin behind the dead zone to build parts accurately and quickly as the build platform advanced at more rapid speeds. Essentially, the light had to cure material faster to move the build platform faster.

Continuous printing also required innovative methods to prevent an oxygen layer from creating a balloon of air at the bottom of the build tray, which could also distort part accuracy, a problem that continues to vex other continuous 3D printers to this day.

Compensating for the Dome Effect

3D printing is a complex enough undertaking that requires understanding of mechanical systems, chemical reactions and physics. But by deliberately adding oxygen to the process to create a dead zone on which to 3D print, an inevitable bubble of trouble was created.

In today's continuous 3D printing systems, oxygen is typically added below a thin rectangular piece of oxygen-permeable film that covers the entire build area. That film allows just enough oxygen to penetrate to create a dead zone on which to free-print.

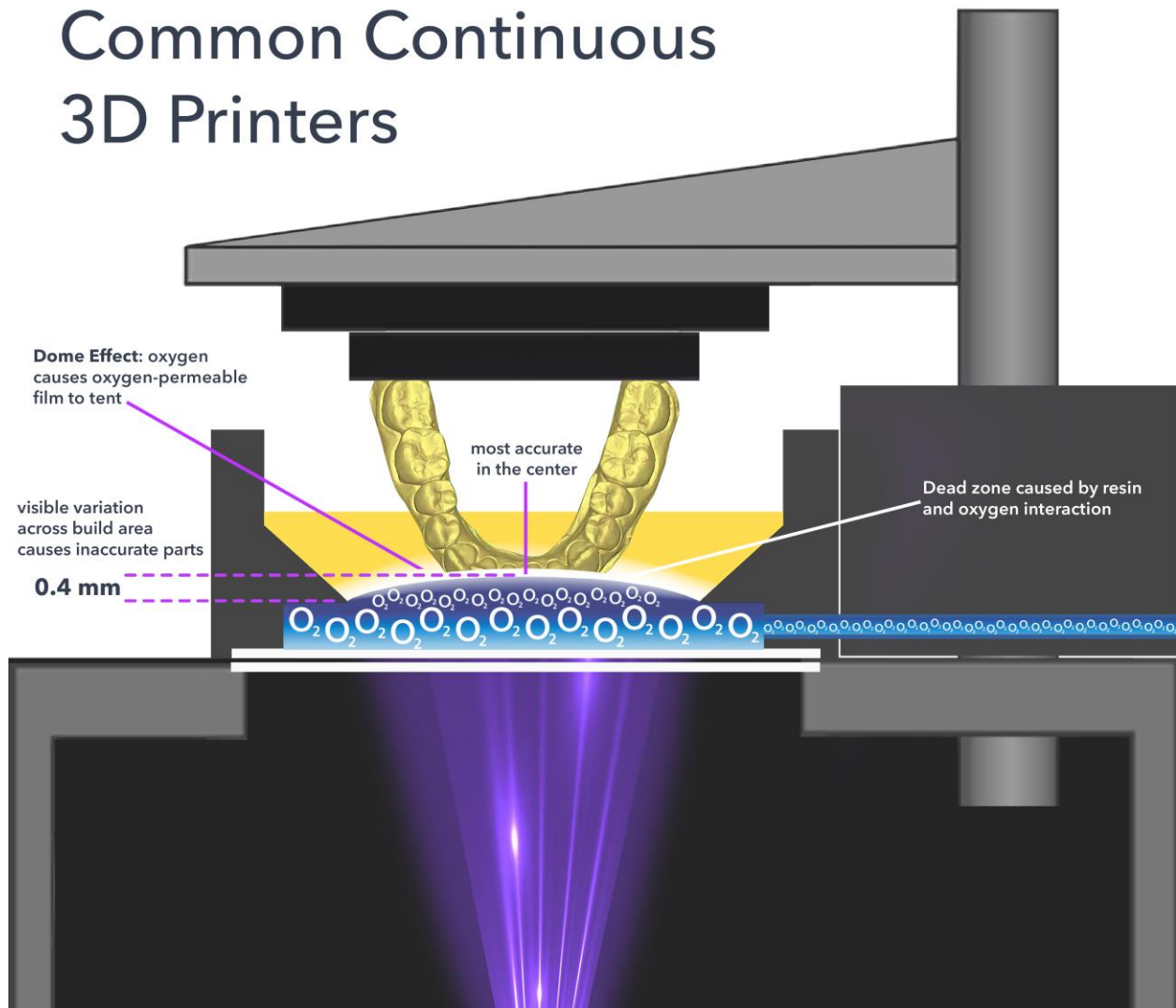
But adding oxygen below the film inevitably causes the film to tent, or rise more in the center than at the outer edges. That means the film is slightly domed, and the dead zone is also domed. This, in turn, means parts are no longer being 3D printed on a flat surface, even in free space.

This dome effect significantly impedes accuracy.

At EnvisionTEC, where continuous 3D printing has been under development for more than a decade, a patent-pending material tray was invented to correct for this dome effect and to evenly control the pressure of oxygen across the entire build tray. This ensures a flat and even dead zone and build surface for continuous 3D printing.

One of the most important requirements for accurate 3D printing is a flat and parallel build surface across the entire build envelope.

Common Continuous 3D Printers



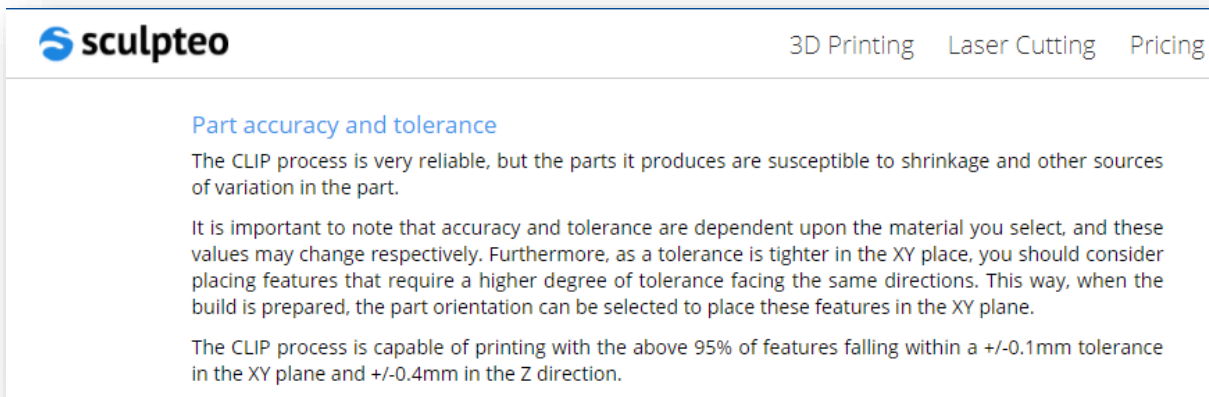
The importance of this simple requirement was covered in detail in the white paper, “3D Printing 101: Stay Flat and Parallel.”⁴ Commitment to the basic premise of parallelism across the build area is one of the key reasons EnvisionTEC machines are consistently known for best-in-class accuracy across its lineup.

A side effect of not correcting this dome effect is that it also creates a plunger-like effect within the build area so as the build plate moves continuously up in Z, it’s also pulling resin upward in the vertical direction unevenly in the build area. To release

⁴ “3D Printing 101: Stay Flat and Parallel,” by EnvisionTEC, 2017.
www.EnvisionTEC.com/3Dprinting101

this plunger-like pressure, some continuous 3D printer makers have begun to stop the continuous motion in one direction and must move the platform down slightly before advancing it up again. This replicates the common up-and-down motion that is used in DLP and slows down the process.

In effect, this means they are no longer continuously printing, but simply DLP printing on a curved dead zone, adding negligible speed improvements to the building process. This back-and-forth build motion can also add layer lines to the final printed part, meaning that not all continuous 3D printers truly deliver truly smooth surface. It could also jeopardize the promised isotropic properties of the part.



The screenshot shows the Sculpteo website header with the logo on the left and navigation links for "3D Printing", "Laser Cutting", and "Pricing" on the right. Below the header, there is a section titled "Part accuracy and tolerance" in blue. The text in this section states: "The CLIP process is very reliable, but the parts it produces are susceptible to shrinkage and other sources of variation in the part." It then explains that accuracy and tolerance are dependent on the material selected and that tighter tolerances in the XY plane require features facing the same directions. Finally, it notes that the CLIP process is capable of printing with 95% of features falling within a +/-0.1mm tolerance in the XY plane and +/-0.4mm in the Z direction.

The French service bureau Sculpteo reports tolerance levels from Carbon's CLIP process on its website, as shown above. An XY tolerance of 0.1 mm equates to 100 μm . For a good dental crown fit, a tolerance of 50 μm is required. Meanwhile, Sculpteo reports that the CLIP process results in a tolerance of +/- 0.4 mm (400 μm) in the Z direction, a level at which Z layer thickness could compromise final XY part accuracy and bite registrations.

Conclusion

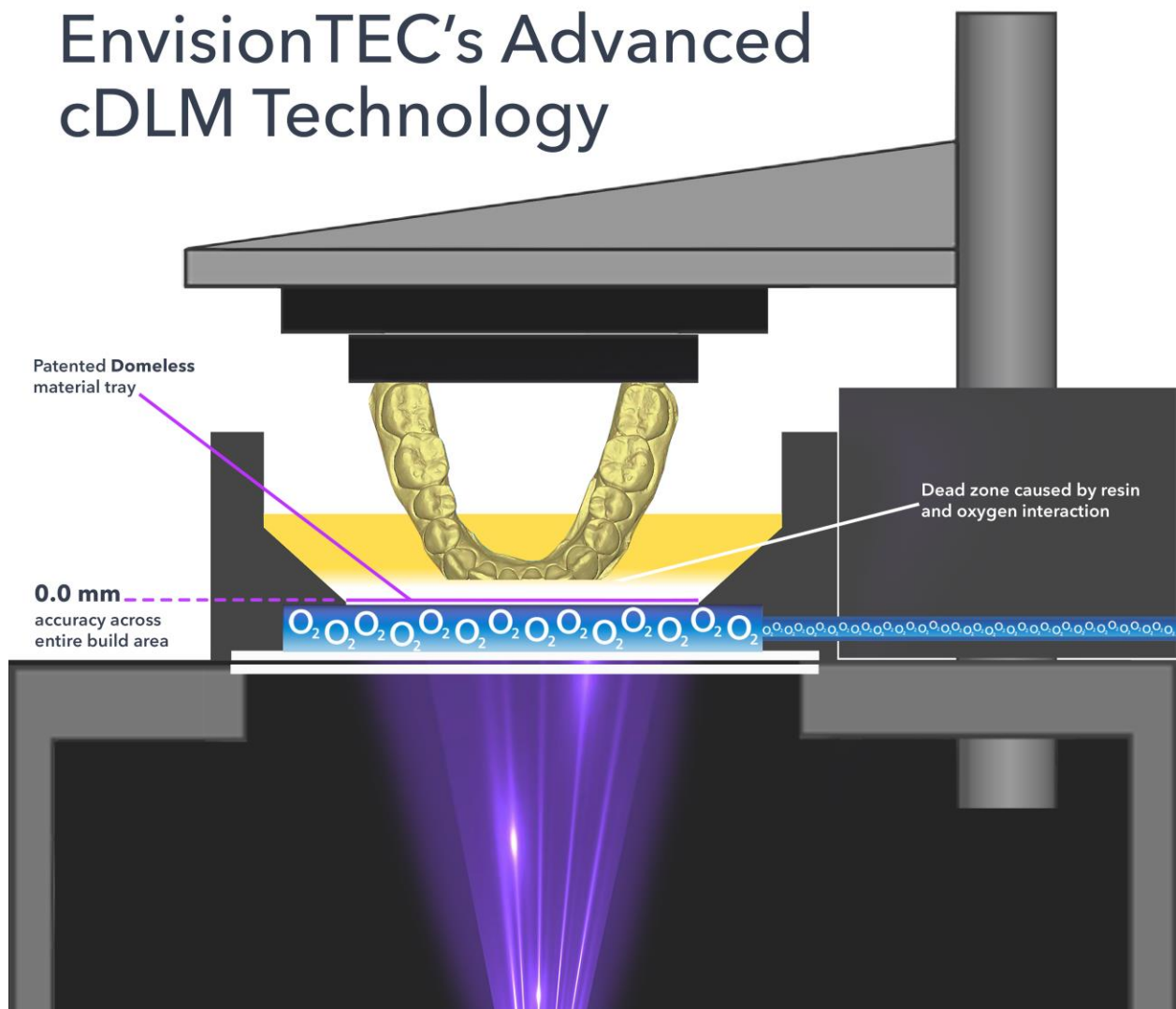
While speed is a long-desired goal in 3D printing, one must consider how much accuracy is compromised to increase throughput and gain other benefits.

As oxygen is added to the 3D printing process below an oxygen-permeable film to create a desired dead zone, the film naturally tents or creates a dome. This dome

causes inaccuracies across the build area, measured at 0.4 mm in the Z direction, in some continuous 3D printers. This means parts tend to be more accurate in the center of the build tray and increasingly less accurate as a part extends away from the centerpoint.

At EnvisionTEC, where continuous 3D printing was invented prior to the launch of the Vanquish 3D printer, in 2004, a patented material tray was invented to correct for doming. This allows for consistent printing across the entire build tray in a completely continuous build process.

EnvisionTEC's Advanced cDLM Technology



The Vida cDLM – The Fastest, Most Accurate Continuous 3D Printer

SPECIFICATIONS

Build Envelope
145 x 81 x 100 mm |
5.7 x 3.2 x 3.94 in.

XY Resolution
76 μ m | 0.003 in.

Z Resolution*
25 to 150 μ m |
0.001 to 0.06 in.

Full-Service Warranty | Free
phone assist, parts and more

CHECK IT OUT!

The cDLM also comes in three
other sizes and resolutions:

- Micro cDLM
- Vida HD cDLM
- Vida UHD cDLM

More at EnvisionTEC.com/speed

