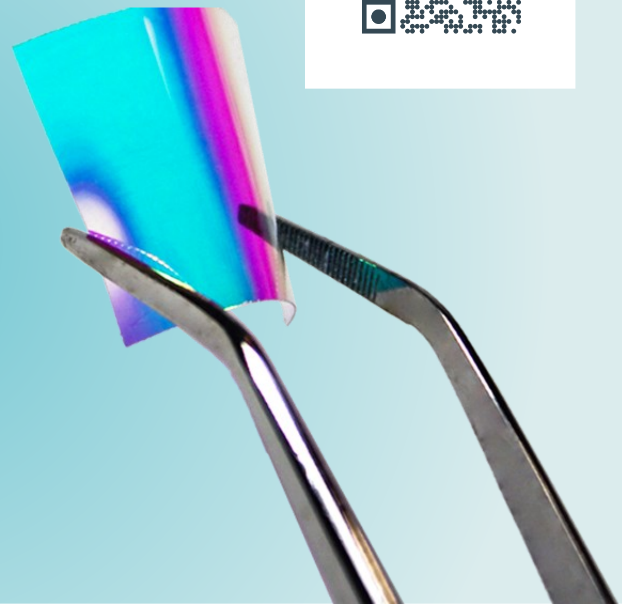
Overview

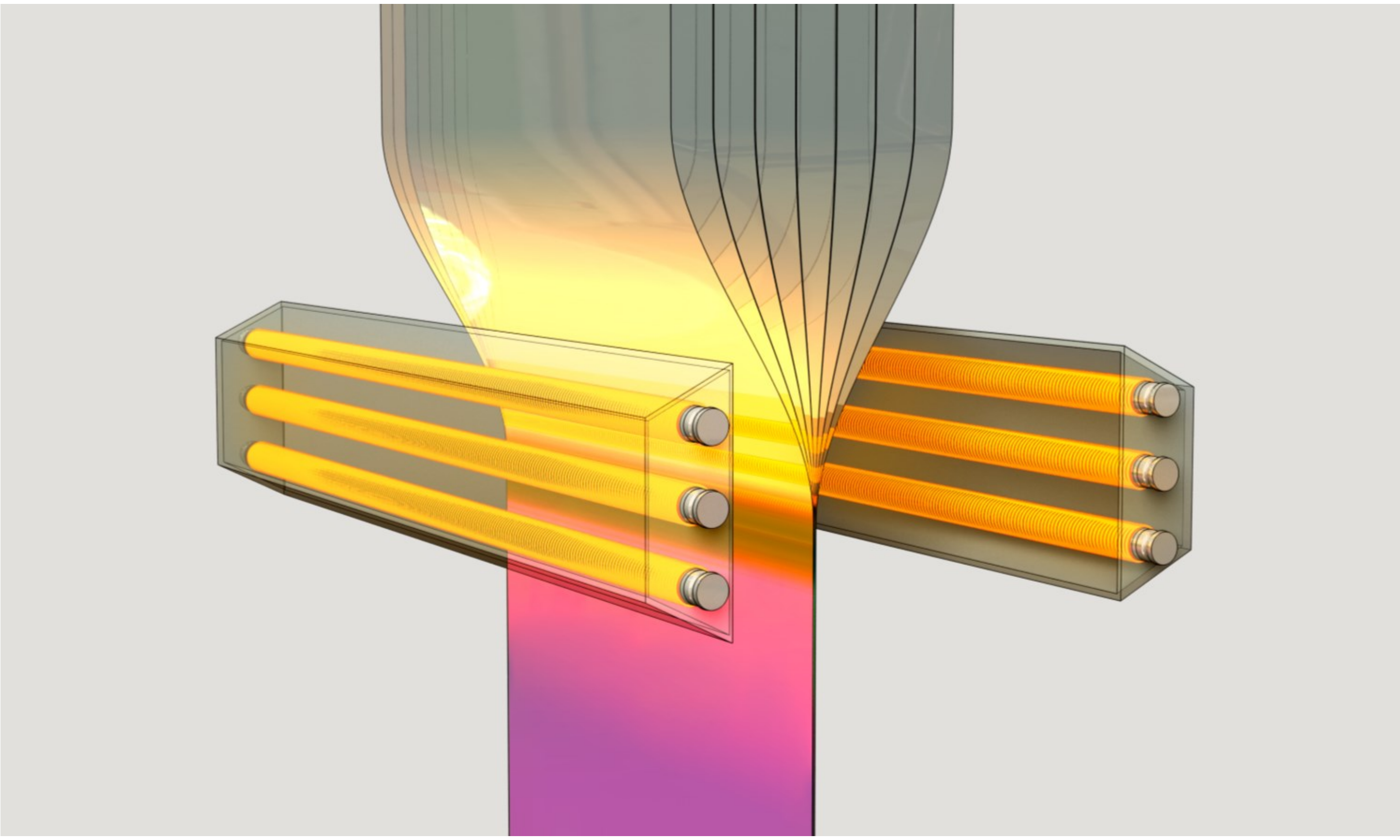
Technology and Applications Overview for Everix Ultra-Thin Optical Filters



One of the most common components in an optical system is the optical filter. These elements transmit certain wavelengths to the sample or detector and absorb or reflect the rest.

They are commonly used in a transmissive geometry to allow specific wavelengths to pass through for clean-up of illumination sources (like LEDs), or for wavelength-selective detection (as in laser-light scattering). They can also be used in a reflective geometry as wavelength-specific mirrors to combine or separate different colors from one another – for instance in laser combining. Although new methods for wavelength selection (like holographic metamaterials and volume Bragg gratings) have appeared on the scene in the last 15 years, traditional interference filters rely on thin, transparent layers of alternating materials. The spectral performance of the filter is determined by the relative thickness of these layers. Traditional filter manufacturers use vacuum coating chambers to prepare each layer, one at a time. Everix is changing this paradigm by preparing all the layers at once using a thermal draw process, explained in more detail below.

In an interference filter, at each layer interface, some fraction of light is transmitted and some is reflected, based on the difference in refractive index of the two materials. This results in wavelength-specific constructive and destructive interference that tunes whether a given spectral band will pass through the filter or be reflected by it. Most interference filters are designed with materials that don't absorb the light; it is either reflected or transmitted. Traditional interference filters have been prepared with vacuum-processes for over sixty years. In contrast, Everix is perfecting a highly-scalable method for the production of high-performance plastic interference filters that uses a technique similar to fiber drawing. A large polymer preform is assembled with layers in the correct proportion. This preform is then heated and pulled (thermally drawn) in one direction to make a long sheet which is spectrally mapped, inspected, and cut into filters. There are many variables to control during the process including heating profile, speed, web tension, etc. Everix has been continually improving this process since 2015 and holds over 30 patents in this area. Other, lower performance but large format polymer filters have also emerged, mostly in the large-area window film and display markets. These polymer sheets are prepared with co-extrusion and also use interference physics to obtain visually appealing reflective surfaces and perform basic functions like IR blocking. Because they are mainly used for aesthetics or with other filter elements, the spectral requirements are much more relaxed when compared with Everix thermally-drawn filters, which are custom-designed to provide the best performance for a given application. Both vacuum-deposited and drawn polymer filters work using the same principle (interference between hundreds of layers), so excellent performance can be achieved with either method.



Compared to established technologies

Substrate-free and very thin

Competing technologies include physical vapor deposition (PVD) and sputtering methods developed decades ago. Vacuum-based thermal evaporation processes were established over 60 years ago using heat from a resistive source to evaporate alternating materials onto glass substrates at extremely low pressures. Filters prepared this way are often composed of delicate materials such as cryolite and zinc sulfide which must be protected with epoxy and a coverslip to avoid degradation and scratching. These early laminated filters were often several mm thick. Advances in PVD technology, including e-beam and ion-assist densification, enabled deposition of harder oxide materials including silica and niobia. Modern methods, developed over the last 15-20 years, utilize sputtering and reactive plasmas to produce very dense and rugged hard oxide films on the surface of the glass substrates. Hard, surface-coated filters are much thinner (typically 1-2 mm) than the original laminated assemblies, but can be susceptible to scratching, chipping and breakage, as well as surface contamination that affects their performance. Everix filters are formed from and embedded in polymer layers that are very thin, somewhat flexible, and less sensitive to chipping and breakage.

Because the filter is not prepared by a deposition process, there is no substrate, so the total filter thickness is typically 0.05 - 0.5 mm.

Table 1. Comparison of vacuum coating and thermal drawing methods

	Everix thermal drawing	**Vacuum Coating**
Scalability	**High** preform size dictates batch size	Medium vacuum chambers have a limited capacity
Energy consumption	**Low** small heating zone for several hours	High up to 70x more to run a sputtering chamber for several days
Spectrum customization	**High** wide to narrow-band designs	**Very high** wide to ultra-narrow band designs with extremely steep edges
Layer uniformity	**High** frictionless viscous flow of materials	**High** large chambers and custom masks and/or substrate rotations are used
Unit cost at high volume	**Low** automation possible	**High** automation impractical
Custom shapes	**Yes** CNC laser cutting	Limited capabilities with low yields
Minimum Thickness	0.05 mm	0.5 mm
Formable for AOI compensation	**Yes**	No
Ruggedness	Sealed edges	Edges prone to chipping
Flexibility	Flexible or rigid	Rigid only
Weight	**Low** made of lightweight polymers	High all glass – roughly twice the mass at a given thickness
Operating/Storage Temp	-40 – 93° C*	-50 – 200° C

* Current product offering – higher temperature offerings are under development

Fast manufacturing process

As described above, vacuum deposition methods deposit the layers one by one on the glass substrate and are very slow (especially sputtering). Each layer is formed one at a time after several passes over the sputtering target and can take several days to complete a complicated design. In contrast, Everix assembles the preform as a monolith and creates filters in a one-step process, going from preform to filters within a few hours. Everix's first product offerings are acrylic-based filters, but the technique is general and can be applied to a large number of meltable amorphous materials. Everix has a number of different materials in the development pipeline that will expand the spectral range and thermal stability of our products.

Scalable process

Another advantage of Everix's process is its scalability. By changing the dimensions of the preform, the lot size can change dramatically. In contrast, vacuum systems are limited by the size of the vacuum chamber, which typically has a capacity of about 1 m^2. Besides the raw filter draw capacity, Everix can also take advantage of other in-line processing methods, including in-line spectral measuring and laser cutting. In contrast, vacuum coated plates must be unloaded before they are spectrally measured. Standard glass-cutting techniques like mechanical cutting (dicing) and core-drilling are typically used, so custom shapes are difficult to achieve with good yield.

Core-drilling, in particular, is a very slow process involving blocking the glass filters between sacrificial layers to reduce edge chipping, followed by cutting with a hole-saw, deblocking and cleaning. Everix, in contrast, uses CNC laser cutting and can cut nearly any shape the customer desires in a fraction of a second. The laser cutter also seals the edges of the filter so there is no delamination of the parts over time. Everix has spent years perfecting the laser-cutting process of their filters to minimize edge effects and produce sealed edges. This manufacturing flexibility intrinsically leads to a very attractive cost structure which supports high volume applications like those listed below.

Flexible and formable for unique optical designs and near-zero angular shift

The ultra-thin form-factor of Everix filters is unique. Because our filters lack a substrate, they are 2-10 times thinner than typical glass-based interference filters. They are also lighter weight, not only because of the thickness, but because they are made primarily of optical-grade acrylic (a much lighter-weight material than glass). The filters can have adhesive-backing added or can be epoxied to other components for unique optical design possibilities. It is well-known that interference filters exhibit a blue spectral shift as a function of angle-of-incidence. Because they are made of thermoplastics, Everix filters can be 3-D formed to reduce or eliminate angle-of-incidence effects on the spectrum. Everix filters are also tolerant to scratches because the interference layers are embedded between thicker acrylic covers. Small scratches in the cover will not affect the overall performance.

Absorptive filter integration

The oldest optical filtering method of all is the absorbance filter. This started out as the “stained glass” used in church windows and decorative arts for thousands of years before being used by scientists and engineers. This was the only option for wavelength selection before the advent of vacuum chambers and interference filters in the first half of the 20th century. Absorbance filters do not exhibit dramatic angle-of-incidence effects and can be successfully used for long-wavelength range blocking, but they are limited by solubility of the chromophore in the matrix and by the availability of suitable chromophores. Many interference filter companies use absorbance filters in conjunction with interference stacks for long-range blocking. Everix partners with a material supplier to provide custom stand-alone, thin absorbance filters and hybrid filters where the absorbing material and the interference stack are drawn together in a single unit. Because it is encapsulated, the polymer absorbance filters do not exhibit degradation, like surface fogging, that is common in many colored glasses.

Applications for ultra-thin, lightweight and unique form-factor filters

Everix provides high-performance optical filters at scale for applications in the consumer market (e.g. AR/VR, wearable health monitoring), miniature and point of care diagnostics (e.g. endoscopes, portable PCR machines), and IoT and other low-cost, lightweight sensors (e.g. disposable food sensors, drone-mounted sensors). Most of our competition does not have the capacity to satisfy these markets. Everix is poised to grow to truly high-volume, low-cost filter production enabling growth in a number of areas.

Drone-based sensing

Drones are being used to perform a diverse number of inspection and mapping applications including crop mapping, infrastructure monitoring (i.e. pipelines), construction mapping, mining, search and rescue and surveillance. Thin, lightweight filters reduce payload to maximize flight time. The ability to curve the filters to maintain excellent performance while increasing the field-of-view (and angle-of-incidence range) is also attractive to these customers.

Wearable and in-vivo health monitors

Everix filters will revolutionize miniaturized health monitoring equipment. The thinness, lightweight and high-volume manufacturing capabilities of this technology will enable a number of new devices. Disposable monitoring patches can incorporate flexible Everix filters that can move with the patient. Smart watches, rings and hearing aids can incorporate miniature Everix filters for blood-pressure and glucose monitoring. Our technology is also compatible with ingestible cameras and endoscopes since our products are biocompatible and can be made inexpensively enough to be disposable. Our ability to produce very thin, biocompatible filters with any shape makes filter integration simple. Mounting tabs and holes can be incorporated directly into the filter.

XR wearable devices

Augmented, virtual and mixed reality devices are the wave of the future. Everix is uniquely poised to provide low-cost filter films that ensure user-privacy by reflecting display wavelengths to the viewer, while reducing or eliminating transmission through the viewing window. This will allow users to fully view and interact with their surroundings while simultaneously seeing a privately displayed overlay. The thinness of the film and high-volume manufacturing will allow for easy integration into new and existing eyewear concepts.

Everix's miniaturization capabilities also come into play in the eye-tracking portion of these devices. We can produce unique form-factor miniature filters that can be integrated into the eyewear frames, etc.

Food safety

Everix filters can be incorporated into freshness-monitoring windows for safe food distribution. We can incorporate optical-grade pressure-sensitive adhesive to the films so they can be adhered to the surface. Everix's unique high-volume manufacturing process will bring costs down for these disposible products while maintaining high performance.

LIDAR

Everix is developing unique capabilities for the LIDAR space. Our filters are already able to reduce or eliminate angle-of-incidence shifts in the visible wavelengths because of our unique form factor. As we develop new materials, we will be able to increase the out-of-band blocking throughout the visible and increase transmission in the NIR bandpass wavelengths that are attractive for automotive applications. The resulting increase in signal-to-noise will enable detection from farther away, increasing the range and safety for these systems.

Summary

The combination of rapid and scalable manufacturing with high optical performance sets Everix apart.

Adding in the ultra-thin form factor, the ability to cut to any size and shape and the formability of the product to reduce or eliminate the angle-of-incidence shift is a winning combination that will enable a wide variety of low-cost, high performance sensing solutions. Contact us today to find out what we can do for you.