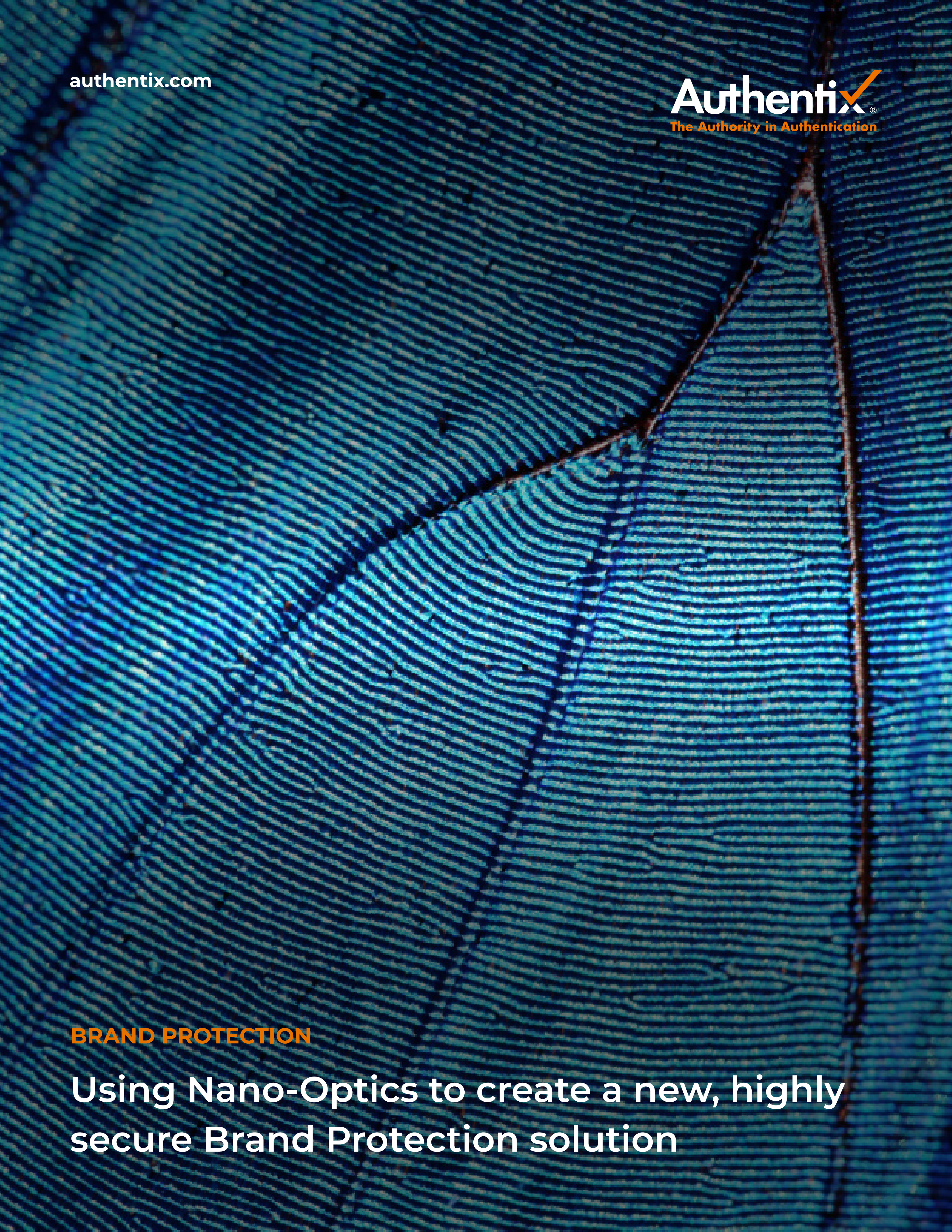


authentix.com

Authentix®
The Authority in Authentication

BRAND PROTECTION

Using Nano-Optics to create a new, highly secure Brand Protection solution

OVERVIEW

Authentix's nano-optic display technology employs subwavelength nano-scale diffractive structures and proprietary algorithms to enable high impact visual designs, product authentication, and brand protection. The technology enables visual effects that include RGB true color (24 bit), high-contrast movement, on/off, on/invisible effects, and image switches; all enabled using diffraction efficiencies approaching the theoretical maximum. Viewing angles up to 180 degrees and pixel resolutions up to 12,700 ppi have also been demonstrated. Electron beam lithography-based origination coupled with Authentix's proprietary software algorithms result in an authentication solution that redefines the standard for holographic images. The features are compatible with current high-volume brand protection production, yields, and durability standards.

INTRODUCTION & BACKGROUND

Given that brand protection solutions using holographic technology have become outdated and easily counterfeited, Authentix saw an opportunity to develop a new advanced optical variable device (OVD) platform with a new technology that was significantly more difficult to reproduce than a hologram. Authentix leveraged industry leading research to create stunning structural colors through the interaction and manipulation of natural light with an array of nano-structures. The company envisioned a platform that would create a new paradigm shift in the technological advancement of physical brand protection features.

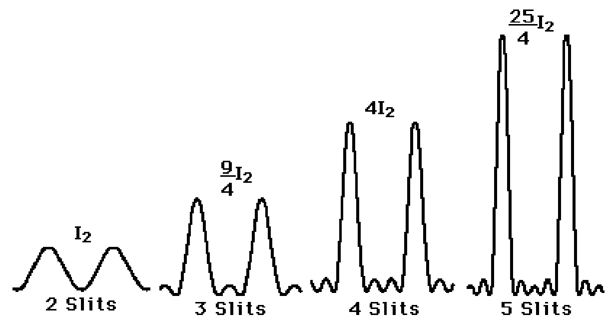
This paper explores Authentix's diffractive OVD technology based on nano-scale structures and their exceptional diffractive visual characteristics. **This new technique for originating OVDs creates distinctive, highly visible colors that are much more discernible than current holographic micro-scale grating-based structures, especially in low-light environments.**

Current state-of-the-art overt brand protection features found on most products rely on diffraction based OVDs, which are largely holographic in nature. OVDs are traditionally considered to be difficult to produce because they are replicated from a master holographic shim that requires expensive, technologically advanced equipment. However, extensive use of holograms has lowered the cost of these specialized tools, compromising the security of these features in recent times. Diffraction gratings in the micrometer scale, which form most surface relief holographic features, are limited by small viewing angles and poor color definition, as the grating diffracts all wavelengths of light within a few degrees of viewing. Legacy holograms offer a partial solution to this problem by providing high optical efficiency and good definition of single colors however, they are more costly to produce, require thicker materials to be effective, and are limited to very small viewing angles making large images difficult to see.

The ideal brand protection OVD possesses multifaceted features that require complex processing to manufacture and produce an intuitive and simple message to the authenticator. Incorporating multiple effects into a single OVD is desirable as it greatly increases the complexity to counterfeit the feature.

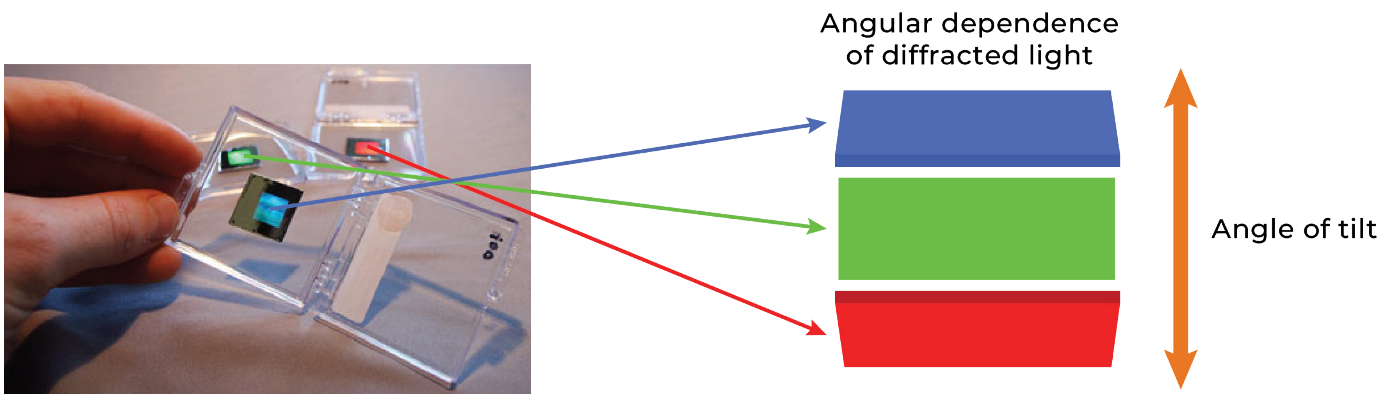
DIFFRACTIVE NANO-OPTIC TECHNOLOGY

Nano-optic diffractive structures are separated by a distance (the periodicity, or pitch) roughly on the same scale as a wavelength of light (~400nm to 700nm). These nanostructures split (diffract) different light waves into specific directions which depend on the periodic spacing. The intensity of the light waves reflected is related to the density and shape of these diffractive structures. Generally, the smaller the periodicity (the denser) the structures are, the higher the intensity of light. The relationship of diffractive structure size and periodicity to intensity is illustrated by the Fraunhofer Diffraction equation: intensity is proportional to the square of the amplitude – the more slits per area, the greater the intensity.



Fraunhofer Diffraction Intensity

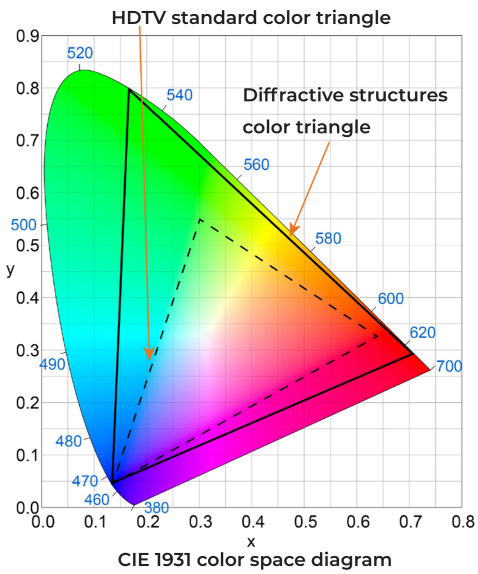
Diffractive colors are bright, pure RGB colors with high intensity, but are also highly dependent. This angular dependence means that viewing a particular diffractive color image requires positioning the image under a given light source and tilting it until the designed angle of diffraction (viewing) is found.



DIFFRACTIVE NANO-OPTIC TECHNOLOGY

Diffractive structures can be blazed or non-blazed. Blazed structures provide the highest theoretical diffraction intensity for a specific wavelength of light at a specific “blazing angle”. However, their nano-scale geometry is difficult to originate at large scales, and mass production of such structures requires a high fidelity process such as roll-to-roll UV casting that is still relatively uncommon in the holographic industry. Despite the complex origination and production challenges, Authentix has established and patented a process to produce the ultimate diffractive technology.

Authentix’s blazed diffractive nano-structures exhibit true RGB colors for hyper-photorealistic image reproduction. They are high intensity, angular dependent, accessing the full RGB spectrum. True RGB means a wider and more flexible color triangle in the CIE 1931 color space diagram compared to active displays and other known diffractive technologies (see below). While this capability provides the platform with hyper-realistic image reproduction, it introduces design challenges. Images designed on current computer display technologies may appear different than the final output, for example, a slight over saturation in Photoshop may translate into a gross over saturation in the final image due to the ultra-high diffractive efficiency.



Authentix’s diffractive RGB CIE color triangle vs. HDTV capability (left).
Example of an actual Authentix OVD demonstrating true color image (right).

Nano-scale structures provide additional advances with respect to resolution. The lower bound of resolution in diffractive technology is determined by the size of a color sub-pixel, red, green and blue, and should not be smaller than 2um x 2um. Below this limit, additional diffractive properties may be introduced to the image and induce unwanted rainbowing effects. The upper limit is mostly set by the resolution the human eye can detect, which for static images is approximately 40-50um, with most individuals not noticing pixels smaller than 80um.

Despite a large number of recent emerging technologies, superimposing multiple advanced features typically increases the thickness of the OVD and/or the number of materials required. This naturally leads to an increase in manufacturing complexity causing lower yield and higher cost. Authentix's nanographic display technology transcends the aforementioned issues by imposing a number of novel combinatory features beyond typical single-function designs. At the most fundamental level, the sub-wavelength dimension of nano-scale structures enables high-intensity diffractive colors by leveraging maximum density and engineering blazing angles optimized for each wavelength of color. The resulting pattern resolutions of up to 254,000 dpi (~100nm "dots"), while yielding potential pixel image resolutions as high as 12,700 ppi (2 pixels per micron). A single nano-scale layer of pixels cast or embossed into a substrate can be arranged to produce multiple overt effects such as movement, "ON/OFF" RGB image transitions, image switches, and ultra-high definition true color artwork.

Authentix Blazed Grating Nanostructures

Engineering diffraction of light at the micro to sub-micron scale

FEATURES	BENEFITS
High intensity, angular dependent, accessing the full RGB spectrum	Blazed nanostructures provide the highest diffraction intensity for your brand labels
Splits white light into individual wavelengths → different colors	Difficult to reproduce → No starting point for counterfeiters
Intensity and color is related to the density and geometry. More dense smaller spacing = more intensity	Perform better → brightest colors and effects for brand authentication
Structures typically coated with Aluminum (shiny material for reflection). Can also be transparent when coated with HRI materials like ZnO, ZnS, TiO2	More animation frames → Heightened customer engagement

Nano-scale structures provide additional advances with respect to resolution. The Core to supporting the design and layout of nanographic OVDs, Authentix developed proprietary software that utilizes advanced optical modeling for rapid simulation. Authentix's OVD images showcase intense high-definition artwork, capturing deep colors including skin-tones via RGB-based true color mixing and fluid motion effects.

See example in the figures below.

Nano-scale diffraction structures provide much larger viewing angles as the spread of the first order diffractive vectors is larger, and therefore better color definition for OVD features may be realized. This translates directly into a user experience which is both unique and more intuitive to perform. The fabrication of such small geometries poses many challenges, as the diffraction limit of light constrains standard photolithography to sizes larger than half of the wavelength of light in the visible spectrum (200nm to 400nm), which is much larger than Authentix's nano-structures (~100nm – 200nm). Deep-UV systems face many barriers to produce the 100nm to 200nm geometries required, with projection and immersion lithography being too costly and impractical for brand protection OVD applications. A new class of direct-write based lithographic systems, such as electron-beam lithography (EBL), provide a method for constructing structures well below the diffraction limit, as small as 8nm or less[1, 2]. For OVD applications, these systems can be used to create originations or master shims for reproduction of nickel shim tooling and recombination necessary to manufacture these gratings at high volumes in the same manner as traditional surface relief holograms. Proper handling, substrate preparation, and subsequent processing of materials to be patterned in an EBL require specialized clean-room facilities and supporting equipment.

1 Leech P., "Pattern Replication in Polypropylene Films by Hot Embossing," Microelectronic Engineering 85 (2008) 181–186.

2 Wilhelmi O., et al. "Rapid Prototyping of Nanostructure Materials with a Focused Ion Beam," Jpn J. Appl Phys. Vol. 47, No. 6 (2008), pp. 5010-5014.

DEVELOPMENT PROCESS OVERVIEW

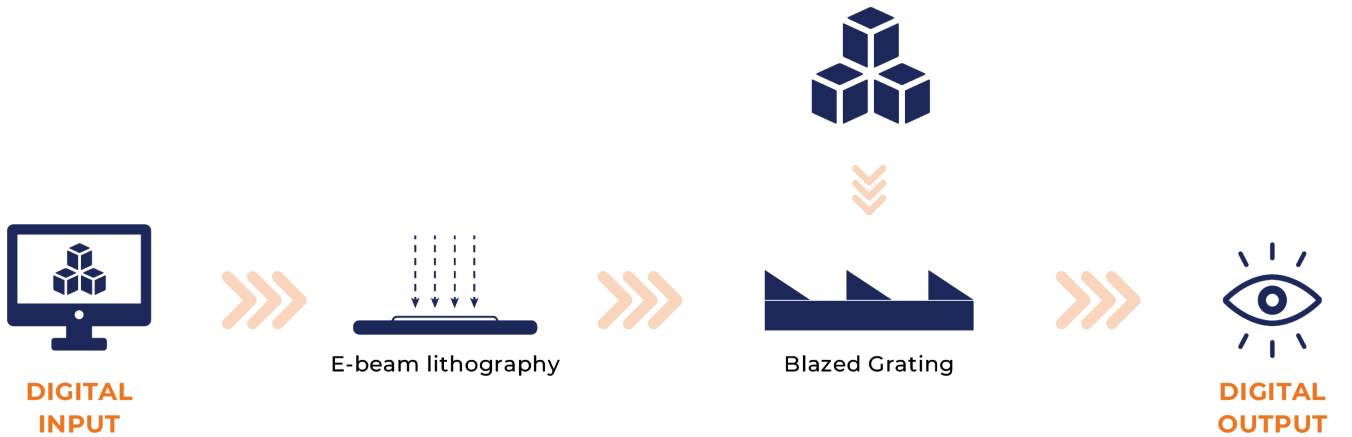
A customer's image concepts are brought to Authentix's engineered graphic design, where an image is optimized for the nanographic display technology. Once an image is finalized, Authentix's proprietary software is used to convert the graphic design files to nanofabrication files that can be used on Authentix's EBL system . The ultra-stable 100kV EBL writes an image pattern anywhere from a few hours (typically) to up to several days, which is then used to fabricate a nickel shim through electroforming. This nickel shim is what is used to emboss or cast the final product.

01	02	03	04
ENGINEERED GRAPHIC DESIGN	**PROPRIETARY SOFTWARE**	**NANOFABRICATION**	**PRODUCTION**
Image and/or motion graphic development	Unique software used for each LiveOptik feature Convert graphic design files to nanofabrication files	Si-microfabrication processes Electron beam lithography Nickel electroforming	Recombination UV casting R&R UV casting Soft thermal embossing

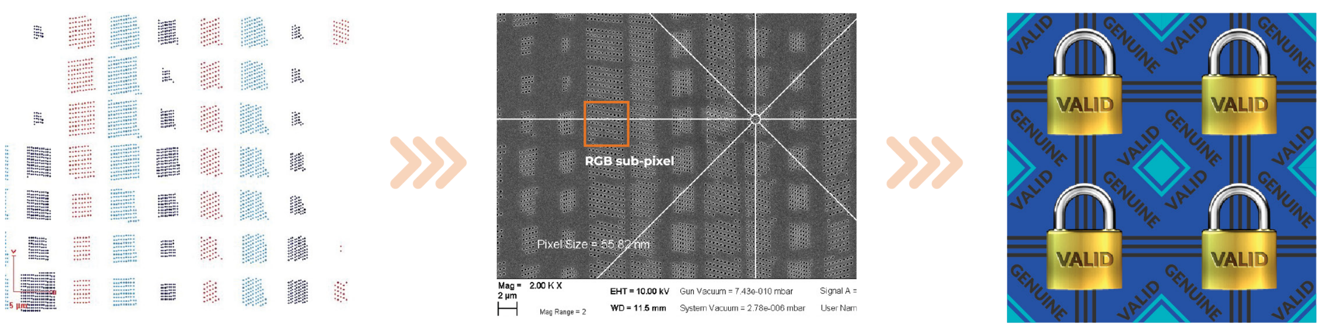
Authentix's Production Process

AUTHENTIX PROPRIETARY SOFTWARE

Authentix's proprietary software is unique for each display technology. The software is used to convert a graphic design file (e.g. AI, After Effects, PS files, etc.) to nanofabrication files (e.g. GDSII) that can be read by Authentix's EBL system. One major differentiator of Authentix's software is the retention of all of the digital information in the graphic or animation outputted to the physical structural color display device (the final product image). Every bit of data in each pixel of the image or animation is represented as a physical nano-structure on the final origination for your brand.



Integration of Authentix proprietary software



GDSII CAD File | Originated Nano-Optic Structures | Originated Image

Complete retention of digital information in the production of the final image

NANOFABRICATION OF AUTHENTIX ORIGINATIONS/MASTER SHIMS

01 EBL design file conversion

02 EBL write onto silicon wafer

03 Process silicon wafer for deposition

04 Seed layer deposition

05 Nickel electroforming

06 Wafer and shim separation and cleaning

EBL fabrication flow processing steps for Authentix master shim originations

Nanofabrication techniques have been widely used in the semi-conductor industry for the last three decades to produce high volume and relatively low-cost devices. This industry uses wafer level manufacturing techniques to achieve uniform micro and nano-structures, such as transistors, integrated circuites, sensors etc. However, the tools designed for this process flow are primarily suited to silicon wafer handling and are not ideal as the throughput is not nearly adequate for rollto-roll patterning of substrates. Furthermore, fabricating sub-wavelength features below the diffraction limit using opticalbased techniques has proven very costly and limited to replication of the same shapes over and over[3]. For these reasons non-optical fabrication methods are required for the production of Authentix OVDs. Non-optical manufacturing tools such as EBL and focused-ion beam lithography can be employed to create sub-wavelength structures in nearly any shape and pitch on wafer scale substrates. While these tools are not high-throughput systems suitable for the volumes required by the OVD industry, they can be used to create master shims for the subsequent high-volume manufacturing of nanographic features. Authentix has created a new process for producing masters suitable for use in existing high-volume roll-to-roll thermal embossing or UV casting manufacturing processes.

Nanofabrication files are converted to EBL CAD files and the EBL system writes an image pattern onto a silicon wafer. This takes all the digital information contained in the nanofabrication files and constructs it into physical nano-structures on the wafer surface. The silicon wafer is processed to prepare it for the deposition of a seed layer. At this stage the structural color display device has been yielded. Once the seed layer is deposited, the wafer undergoes nickel electroforming. The electroforming is done to transfer the device into a form (a nickel shim) that is suitably robust to survive casting/embossing of the final product (stripe, patch, label). The nickel shim (the master) is then separated and cleaned. It is now ready to cast or emboss the image onto a substrate.

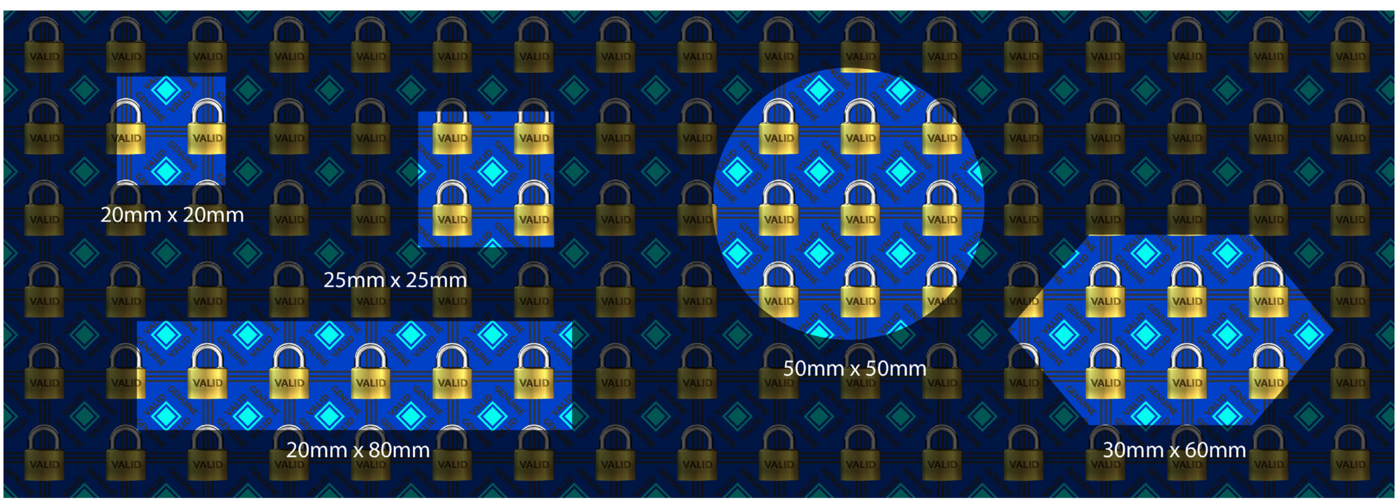
3 Wiley B.J., Qin D., and Xia Y., "Nanofabrication at High Throughput and Low Cost," ACS Nano 2010 4 (7), 3554-3559.

LiveOptik®

LiveOptik® is a proprietary brand protection overt security solution utilizing Authentix's exclusive and patented Nano Optic platform. Authentix's LiveOptik delivers unique, multi-image, on-off and on-invisible visual effects with unmatched bright colors that are easy to validate, making it an exceptional indicator of authenticity.

Using nano spectral features less than one tenth the size of traditional holography or micro-optics, LiveOptik security features can be customized to customers' design and functional preferences to include multi-color, 3D depth, vivid animation, image switching in multiple formats like films and converted labels. Durable across a wide range of material substrates and application processes, including overprinting, high-strength adhesive and/or tamper evident material. LiveOptik delivers a proven solution to combat counterfeiting. Add a sophisticated, attractive brand authentication complement to your existing packaging or product portfolio and protect revenues.

FLEXIBLE FORM FACTOR



OVERT SECURITY LABELS

- Full customization of motion range, 3D depth, color movement, and design
- Multi-color and pure color palettes available
- Can include custom and pictorial image origination
- Flexible formats and additional functionality (e.g. tamper evident)
- Can be layered along with integrated covert features

SUITABLE FOR VARIOUS INDUSTRIES

CONCLUSION

Authentix's technology employs nano-scale diffractive structures to create unique visual effects for brands that include full RGB color, on/off effects, and image switches. Sophisticated algorithms and modeling comprise Authentix's propriety software and ensure that nano-scale structures are deployed in a manner that creates a visual experience characterized by exceptional brightness, enhanced viewing angles, and extreme high definition resolutions that far exceed the limits of human perception. The combination of nano-scale origination and sophisticated algorithms results in a security label solution that is virtually impossible to replicate or reverse-engineer. Given the global increase in counterfeiting goods, brands require new solutions to protect their brand and prove authenticity to their customers. LiveOptik® offers an innovative solution to brands looking for the next generation of physical brand protection.

Please **contact us** to learn more and schedule a meeting with one of our brand protection experts.

North America | Europe | Middle East | Africa | Asia

Innovative Brand Protection Solutions For Total Product Integrity

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