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The Authority in Authentication

GOVERNMENT & IDENTITY

Scaling Nano-Optic Security: Industrialization and the Evolution of PICO secure™

LESSONS LEARNED IN INDUSTRIALIZATION OF NANOSCALE OPTO-PHOTONIC DEVICES

Authentix nano optic technology platform leverages nanostructures and proprietary algorithms to form overt features with unprecedented structural color, movement, and visual depth. This new technology development by Authentix represents an emerging era in the frontline protection of currency and identity documents replacing aging, decades old solutions that have down streamed into commercial markets and becoming commoditized. This article explores new developments in Authentix' sub-wavelength nano-optic platform and lessons learned in industrializing this technology for mass manufacturing both novel and cutting-edge security features for banknotes and government identity documents.

Surface plasmon-based optical variable devices (SP-OVDs) represent a revolutionary advancement in nano-optic based security features enable new dynamic opto-photonic elements. These devices exploit the unique properties of surface plasmon polaritons (SPPs) at metal-dielectric interfaces to create angle dependent or independent, and wavelength-dependent optical responses that are next to impossible to duplicate or counterfeit without extensive investment and little-known proprietary manufacturing processes.

The next generation of photonic based OVDS are:

- Flexible, allowing multiple effects in a single feature or origination
- Durable with an ultra thin form-factor, often 10 to 15 times less profile depth than micro-optic OVDs
- Compatible with virtually all substrates and formats
- Extremely high barriers to entry to reproduce or copy

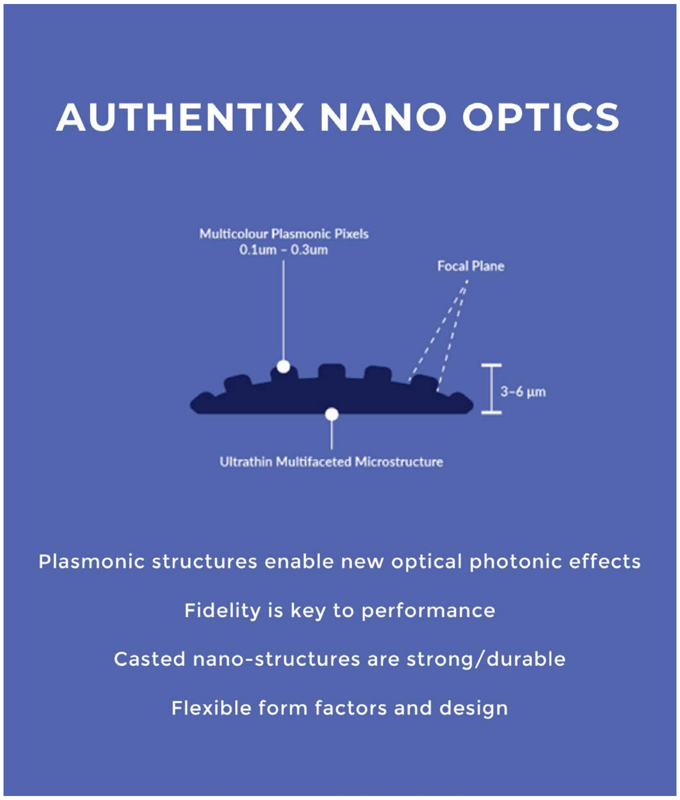


Figure 1: Nano Optic Platform features

This patented development in Nano Optics enables enhanced optical photonic effects and the beginning of a radically new optical security technology platform. Security features can be embedded, effects can be overlayed, and true multiple colors can be displayed due to flexible form factors and design without the use of inks, dyes, or layered lenses. Additionally, these casted nanostructures are strong and durable. Photonic based OVDS offer new developments like mixing colors, color shifts, switches, and programmable 3D animation capability using plasmonic pixels to facilitate a brand-new way to captivate attention and offer intuitive authentication.

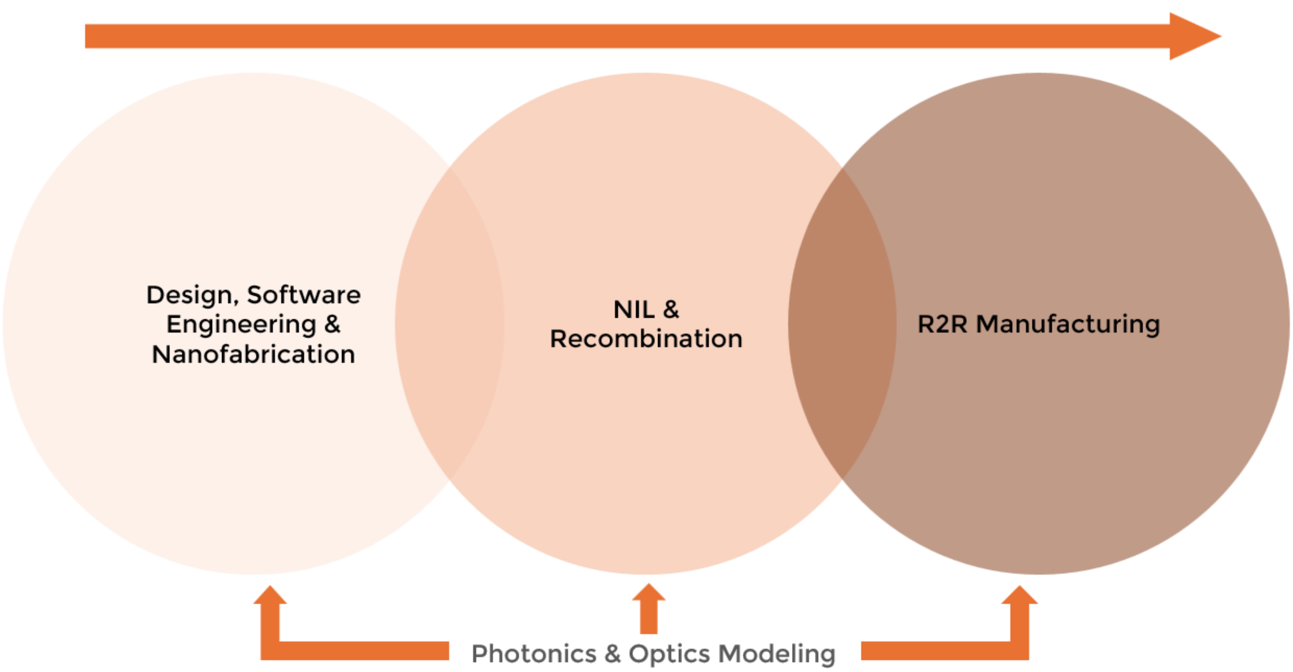
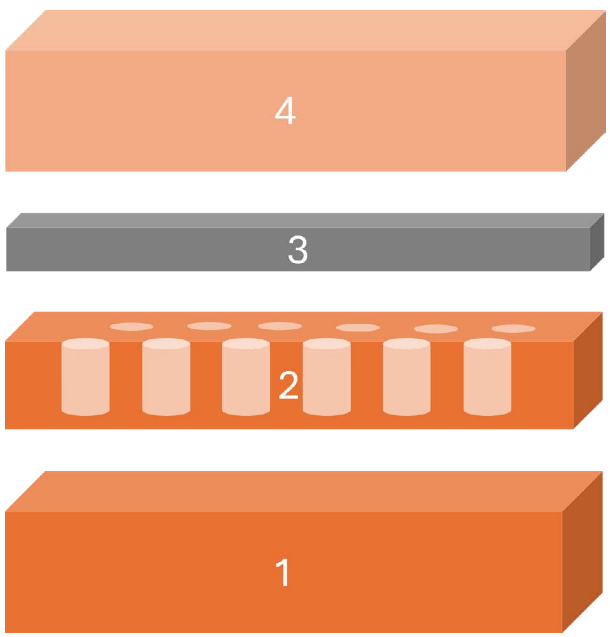


Figure 2: Product Manufacturing Flow

These new optically variable features have been achieved through improvements in photonic modelling to increase surface plasmonic resonance efficiency and software optimization. Authentix has employed advanced metrology techniques to precisely measure the fidelity of each plasmonic nanostructure during every step of the process from origination through to the final manufactured device to generate originations which offset the natural loss of fidelity normally expected in the process.

DEFINING A PLASMONIC OVD PLATFORM

Four primary material factors are required to make high fidelity plasmonic colors:



- 4. Encapsulating material (e.g. Adhesive)
- 3. Materials: thin-film coating (e.g. Aluminum)
- 2. Nanostructure geometry (e.g. 100nm diameter hole w/ 200nm pitch)
- 1. Embossing material (e.g. UV resin)

Figure 3: Four material factors for designing metamaterials

All four material factors must be controlled during the nanofabrication process to be within nanometer precision to achieve high quality, consistent structural colors - every process step involved impacts nanostructure fidelity. Hence, compensations are carefully made in originations for known fidelity restrictions in every downstream processes. Each OVD produced requires a unique set of process parameters to achieve high fidelity and high throughput. Specific UV curable resin selection, precise viscosity, carrier web resin thickness, web speed, UV power, and web cooling are among the most important parameters that are considered through the process steps: Origination on Si > Ni Master > Soft Master > Recombination > Ni Master > Ni Working Shim > Embossed Product.

Figure 4: Nano-fabrication scientists set up Authentix EBL system inside a Class-100 cleanroom

Complexity is further increased with plasmonic nanostructures where the embossing material and metal/di-electric interface of the coatings are crucial parts of the optical design. Authentix aluminum based plasmonic structures require high purity, high density metal depositions within a tolerance of +/- 5nm. If the deposition is too thin, metals resistivity will restrict free electrons on the surface from interacting with correct number of photons leading to darker, lower saturated plasmonic colors.

If the deposition is too thick, metal will migrate into the structural space reducing photonic absorption and reflection will be increased at the cost of wider bandwidth and increased noise effectively leading to plasmonic colors that are brighter but lower in contrast and less saturated. Moreover, this level of precise accuracy must be repeated over hundreds of rolls per year, equating to trillions of images, where each can contain trillions of nanostructures. Operators must monitor real time data collection on optical densities via sensitive optical measurement equipment positioned across the web to interpolate thickness of the metal and adjust for any variable deviations.

In summary, without maintaining an extremely controlled and measured process, nanostructures can change from the origination to the final embossed product. This predictable change must be understood and designed from the outset. Authentix has scaled this process to industrial scale manufacturing capacity to fully understand and predict exactly how this change occurs, what factors are controllable, and developed custom EBL processes, UV recombination and R2R UV casting lines that compensate for this.

Further, the in-depth knowledge and proprietary processes involved also ensures this technology is highly resistant to counterfeiting as any attempt to copy the final OVD end-product will not allow the needed fidelity which result in poor-quality images and colors that are clear and obvious. The requisite knowledge of origination structures cannot be gained by reverse engineering of the end-product as many of the interim steps in the process flow are not only trade secrets but also require extensive experience and knowledge of the art only gained through years of research.

Figure 5: PICO secure™ Identity Card

OPTO-PHOTONIC OVD PLATFORM

Surface plasmon polaritons are electromagnetic excitations that propagate along metal-dielectric interfaces, arising from the coupling between photons and collective electron oscillations in metals. What this means is a plasmonic OVD creates an optical effect using photonic based physics. Plasmonic absorption is an application of engineered quantum tunnelling – a field of study that recently won the Nobel Prize in Physics - where wavelengths of light resonate with the nanostructured surface of a metal and photons are captured and “tunneled’ through smaller than light cavities. Light which traverses the sub-wavelength cavities can either be transmitted through it or absorbed into the material effectively destroying it. The exceptional sensitivity of plasmon resonances to local dielectric environment, geometry, and excitation conditions makes them ideal candidates for creating optical variable devices with unique security features.

Combining low profile micro-domes with photonic SPR nanostructures, Authentix has constructed bridge technology towards fully photonic, and eventually quantum optical OVDs. Nanostructures can be formed along the 3D contour of a micro-structure. Combining micro- and nanostructures augments optical effects of both controlling the light at all scales; including macro, micro and nano. Unique effects are now created where the sum is greater than the parts. E.g., Plasmonic pixels + microstructures = 3D moving displays or image switching devices.

Step 1
Design plasmonic colour subpixels

Step 2
Map to microscale pixels

Step 3
3D multi-colour OVD

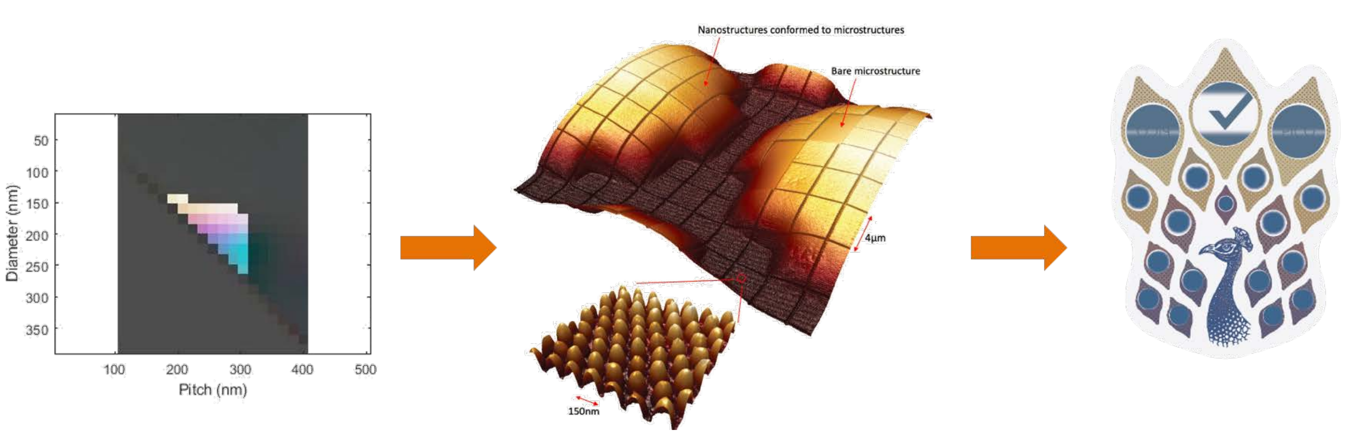


Figure 6: The merging of micro and nanostructures

THE FUTURE OF EMBEDDED ID DOCUMENT SECURITY

Traditional and aging OVD technologies used in many identity documents today, such as holograms and diffractive optical elements, rely primarily on diffraction and interference effects. While effective, these technologies have become increasingly vulnerable to counterfeiting due to advances in fabrication techniques now becoming more widely available.

Surface plasmon-based OVDs offer several advantages including extreme sensitivity to fabrication parameters, complex multi-parameter dependencies, and the ability to create effects that are fundamentally impossible to properly replicate without precise nanoscale control.

Authentix teams has now successfully integrated nano-optic plasmonic structures into polycarbonate material as well, having unlocked a new class of overt, intuitive, and tamper-resistant security for national ID cards and passports. This is a major advancement in document security, marking a technical and material science breakthrough.

The integration leverages the inherent thinness and stability of the nano-structured film, enabling:

- Durable, tamper-evident embedding during lamination
- Window integration with effects visible from both sides
- Laser personalization compatibility for enhanced document-level trust

This level of integration ensures the feature is not surface-applied or added post-production, but bonded into the core of the document, delivering true security-by-design. It provides high public engagement and enhances any document theme with highly customizable, intuitive authentication effects

Figure 7: PICO secure™ OVD

This significant advancement is an innovation for embedded document security as it provides document designers and issuing authorities with a brand-new tool to combine aesthetics, intuitive verification, and embedded security into one cohesive experience. Authentix has employed advanced metrology techniques to precisely measure the fidelity of each plasmonic nanostructure during every step of the process from origination through to the final manufactured device and to generate originations which included programmed compensation for known losses during the end-to-end process.

This new OVD is highly resistant to counterfeiting and represents an optical security achievement - undoubtedly reflecting creativity, design and application innovation, reinforcing optical security well into the future. It brings together overt authentication, personalisation, and polycarbonate durability in a way that has never been achieved - paving the way for a new generation of secure, user-friendly identity documents.

CONCLUSION

Industrialized Deep Sub-Wavelength Plasmonic OVDs have opened the doorway for other potential metamaterial-based nanostructures such as meta-lenses, emerging trends in optical document security, and the integration of digital security features.

Creating these nanotechnological devices requires a nano-optic manufacturing platform capable of reproducing billions of devices for a single customer year over year, where every device is effectively the same. The proprietary Authentix process and technology platform is the first of its kind to achieve such scale and high-capacity volume. The growing demand for advanced security features in currency and identification documents has driven significant research into plasmonic OVDs where Authentix leads the market and is blazing this new trail.

Contact one of Authentix OVD experts today to **request samples** to learn more about using this Nano Optic technology for your next security document, passport or national identity card.

Published on: October 27 2025

The first nano-optic, plasmonic OVD offering always-on-structural color and movement.

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