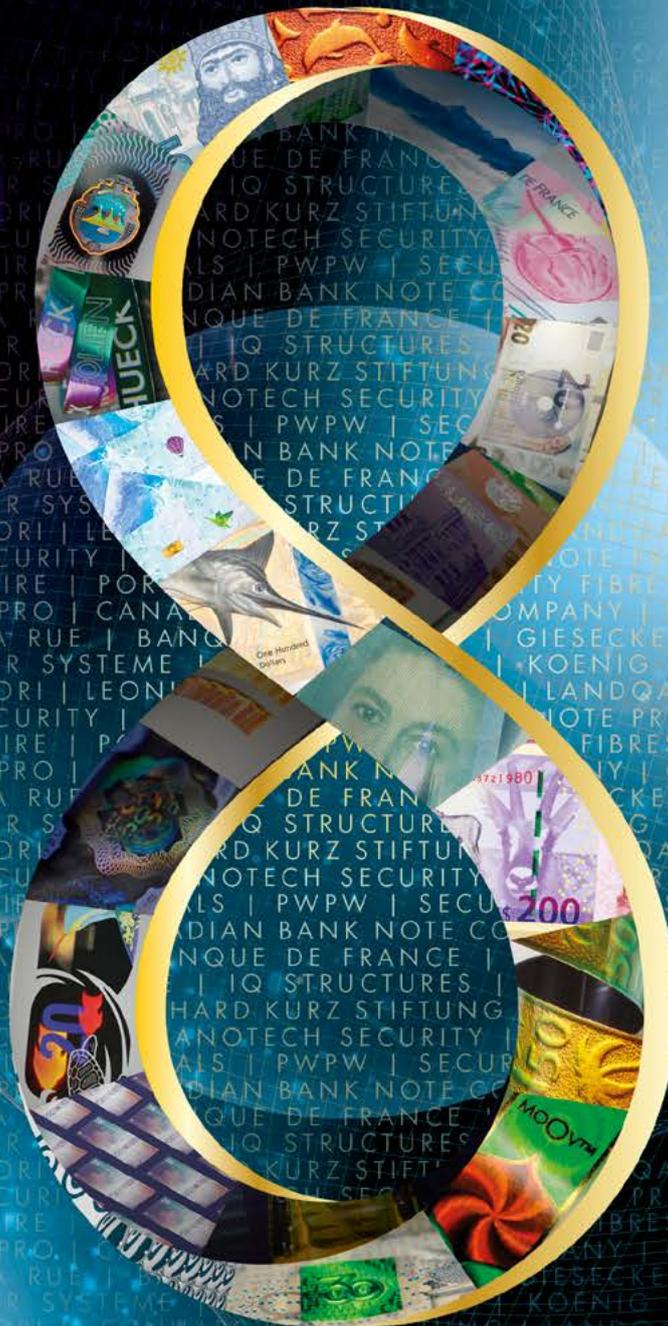


BANKNOTE TECHNOLOGY REPORT

B T R

ISSUE

08.22



Created by

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BANKNOTE
INDUSTRY NEWS

www.banknote-industry-news.com



NANOTECH SECURITY

INVESTING IN INNOVATION

BRINGING KOLOUROPTIK®
TECHNOLOGY TO MARKET

Investing in Innovation — Bringing KolourOptik® Technology to Market

NANOTECH SECURITY

Over the course of the global pandemic, individuals around the world have adapted to change, discovered new passions, and invested time and attention to the development of new skills. Nanotech Security Corp. (Nanotech) has also experienced significant growth and investment over the past two years – most notably, through a change of ownership and a focused attention towards bringing its award-winning KolourOptik® nano-optic display technology to market.

In October 2021, Meta Materials Inc. (META®), a developer of advanced functional materials and nanocomposites, acquired Nanotech. META designs, develops, and manufactures high-performance, functional materials and intelligent surfaces that are scalable, sustainable, and efficient. Along with this acquisition came META's strong commitment to Nanotech's banknote security portfolio as well as significant investment into furthering manufacturing capability to deliver the innovative KolourOptik technology to market, now part of META's product portfolio.

When first introduced, the patented KolourOptik technology platform was intended to demonstrate scientific advancements in and promote opportunities for plasmonic, pixel-based, full-parallax, multi-colour OVDs (optically variable devices). Since then, Nanotech's, and now META's, R&D and production engineering teams have added a new gear; to not only continue technological development of the science, but also to master production-grade recombination and roll-to-roll (R2R) casting with the precision and quality required to maintain nano-scale fidelity.

KOLOUROPTIK® TECHNOLOGY PRIMER

META's KolourOptik technology combines sub-wavelength nanostructures and microstructures to create modern overt security features with unique and customizable visual effects. The pure plasmonic colour pixels are patterned on ultra-thin microstructures to create the thinnest security stripes and threads that are nearly impossible to replicate.

KolourOptik was developed based on a comprehensive understanding of how human eyes have evolved to see and perceive objects, specifically stereoscopic depth, and movement. By combining movement, three-dimensional depth, and multiple colours, KolourOptik delivers uniquely interactive and intuitive visual effects that are easy to authenticate.

As has been well documented, human visual processing to authenticate a banknote occurs in less than 300 milliseconds. It has been further demonstrated that exposure to 3D depth features for as little as 100 milliseconds is adequate for the brain to confirm authenticity. (J Raymond et al, '3D Micro-Optics Enable Fast Banknote Authentication by Non-Expert Users', Optical Document Security

Conference 2020, S5P2, San Francisco USA). KolourOptik technology leverages this foundation of multi-layered depth to deliver engaging movement across a wide range of recognizable colours and shapes for quick and intuitive recognition.

FROM PLATFORM TO PRODUCT

To date, bringing KolourOptik technology from research and development through to manufacturing has proven challenging due to the complexity and advanced material science of surface plasmon resonance nanostructures. To this end, META has invested in developing a new nanoimprint lithography (NIL) workflow, as shown below, comprised of 10 key stages, each with proprietary processes and intellectual property, to deliver its KolourOptik Stripe banknote security product in 2022.

While complex, META's NIL workflow is robust and aligned to its three brand pillars:

- Speed of Discovery
- Breakthrough Performance
- Manufacturing at Scale

META Nanoimprint Lithography Workflow



SPEED OF DISCOVERY

KolourOptik technology starts with design and simulation via a proprietary graphics engine that renders 3D layer art inputs into hundreds of individual 2D perspective images to create a full parallax display. The optics engine maps 2D perspectives onto the surface of a 3D faceted microstructure. Each group of microstructure surfaces that point to the same spatial direction will display content of one of the 2D perspectives.

The image above illustrates the resulting, precisely micro-engineered surface pattern with interleaved nano-scale structures, which combine hundreds of 2D perspective images into a full 3D colour display. In this example, sets of multi-coloured concentric rings shift in all directions as the user changes the viewing angle by tilting the note.

Through rapid design, simulation, and prototyping, META's proprietary graphics

engine enables its R&D team to accurately model exactly how the KolourOptik effects will behave and appear under a variety of lighting conditions. This helps to ensure the desired depth and movement effects are produced prior to any production in physical form, thereby optimizing use of EBL (e-beam lithography) origination time and resources.

Once a design is approved, both the microstructures and nanostructures are originated to the exact specifications required. META is the only Canadian company that owns and operates a 100kV class EBL system. Operating out of a Class 100 (ISO 5) cleanroom facility, the META R&D team is well equipped to develop continuous advancements in the precise execution of proprietary process steps.

Electroforming is the last origination step in Stage 2 of META's workflow which produces a hard nickel duplication master from an EBL patterned silicon wafer. Proprietary process timing and handoff between development, soft bake, seed layer sputtering, and electroforming have been developed and matured to avoid unwanted effects that deteriorate the final master shim quality. Multiple phases of precise electroforming are required to obtain a nickel shim with appropriate thickness, while preserving the all-important fidelity of the nanostructures.

A team of scientists and technicians oversees separation, trimming, and chemical cleaning of the initial nickel shim. Soft masters are fabricated by a UV casting system and then used as the masters for the auto-recombination production process.

BREAKTHROUGH PERFORMANCE

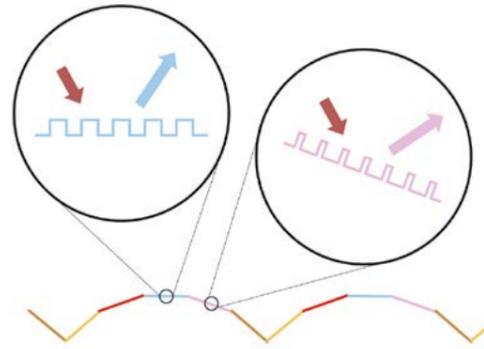
In addition to modeling movement and depth, META's proprietary physics engine is also used to generate a full palette of stable, structural colours. Sub-wavelength nanostructures precisely control how light is reflected at the sub-pixel scale. With pixels of less than 40µm, big data processing algorithms intermix physical and graphic data into a proprietary digital format for EBL origination.

As shown below, specific nanostructure patterns and periodicity control the exact wavelength of light reflected to the eye. This enables a wide range of colours that can be used in KolourOptik security feature design to either contrast or complement a banknote design, with always-on performance across a wide viewing angle.

One of the key benefits of KolourOptik technology is the ultra-thin form factor that can be surface applied with existing, industry-leading application machinery, across a variety of banknote substrates. META has developed innovative EBL-based grey scale lithography to produce 40µm diameter microstructure domes, each patterned with 4µm edge facets. In Stage 2 a second EBL write forms plasmonic pixels onto each 4µm facet. The result is an ultra-thin, single-layer, metalized nanostructure with a total height of only 5µm – 10µm, or roughly 1/10 the thickness of competing lenticular technologies.

META is also driving breakthrough performance in environmental sustainability. The development and qualification of its water-based lift-off process for

Plasmonic Colour Physics Engine



demetallization delivers a sustainable-friendly solution by avoiding the introduction of unwanted materials and harsh chemicals. This lift-off process also produces higher accuracy with cleaner edges than many alternative demetallization options.

MANUFACTURING AT SCALE

Leveraging the company's decades of experience manufacturing and supplying LumaChrome™, one of the industry's leading colour-shifting optical thin films, META's highly secure manufacturing facility in Thurso, Quebec houses proprietary production equipment that reliably produces nanocomposites in wide-web format, at high-speed and large quantity. Capacity at this manufacturing facility, a company owned building situated on 11 acres of land, is currently in excess of seven million square meters per year. META plans to double capacity to 15 million square meters over the next 1-2 years, with the first phase of expansion already underway.

Over the past few years, considerable time and effort invested have yielded incredible gains towards achieving

commercial manufacturability. Industrial foil production is accomplished through ultra high-resolution replication at the nanometer scale. Within Stage 5 of the NIL workflow, a transparent soft master is repeated many times, maintaining the precise fidelity required to preserve nano-optic colours and visual effects. These advancements in manufacturing have led to the development and announcement of META'S KolourOptik Stripe, illustrated below.

At every opportunity META has strived to simplify the production of its foil and deliver a sustainable solution that relies upon robust high-throughput materials. The company's lens-less, full-parallax colour display is created with 4µm high 'flat' optics, reducing the construction to a single-layer of metalized nanostructures, constructed with non-rare earth materials. Similarly, the large palette of structural, plasmonic colours is created without the use of inks or dyes, simplifying the manufacturing process and supply chain variables.

META remains committed to the advancement of banknote industry security through advanced, functional metamaterials, as demonstrated by its KolourOptik Stripe, expected to launch in 2022. Central Banks and industry partners can contact the META Sales Team to request samples or for further information.

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