Cost-effective Large-area Roll-to-Plate Imprinting

MORPHOTONICS

Cost-effective mass manufacturing of nano/micron textures is needed to make life-enhancing products commonplace and affordable for consumers. Incorporating such structures via nanoimprinting in higher value-added products like sunlight-readable smartphones, immersive augmented reality glasses, and autonomous-driving-enabling LIDAR sensors will significantly improve our daily lives.

Morphotonics, a Dutch nanotechnology company, develops and sells Roll-to-Plate (R2P) imprint technology & equipment. Our market-proven R2P imprint technology enables the mass-manufacturing of such nano/micron-size surface structures over extremely large areas. This leads to unprecedented cost advantages and radically improved products for our customers in the display, sensing, solar, and other deep technology sectors, where such manufacturing precision with cost-competitiveness is the prerequisite for mass-market entry.

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Morphotonics' R2P imprint equipment can imprint on substrates with a width of up to 1100 mm (GEN5-size, 1100 x 1300mm^2, as shown with Portis 1100 in Figure 1). The process of this R2P imprinting technique is schematically represented in Figure 2. The large area imprint capability enables the manufacturing of a larger number of smaller products in a single imprint step ('product tiling'). The R2P process can imprint 5 to 20 times more products in comparison to the traditional wafer-scale Nanoimprint Lithography (NIL) systems. Consequently, the cost per product will be significantly lower when using R2P imprinting.

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Figure 1. Portis 1100 Gen-5 (1100 x 1300mm^2) Imprinting Equipment

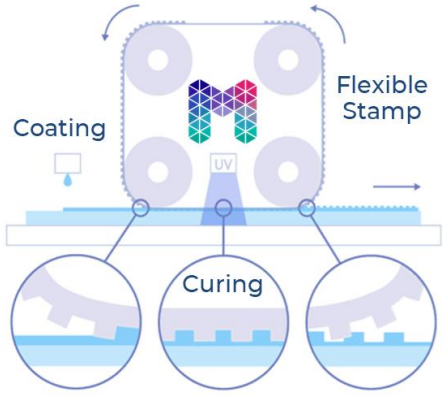


Figure 2. Roll-to-Plate Imprinting Principle of Operation

Since the origination of textures is usually limited to wafer scale, upscaling is needed to fabricate the large-area stamps. Morphotonics has developed a proprietary master-upscaling method that enables the upscaling of textures from wafer-scale to beyond 1m^2 (an example is shown in Figure 3 related to an SPIE paper published with partners). Next to the master-upscaling method, Morphotonics has also developed large-area flexible working stamps that can last well over 500 imprint cycles, proven in production of commercially available products. This flexible stamp enables a reproducible nanoimprint process.

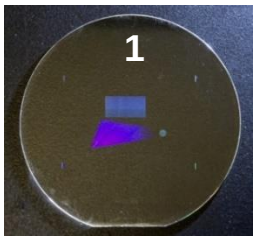
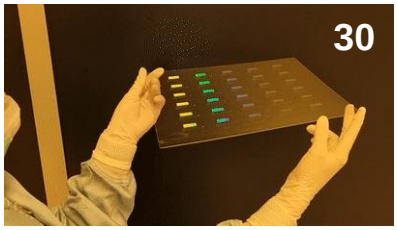
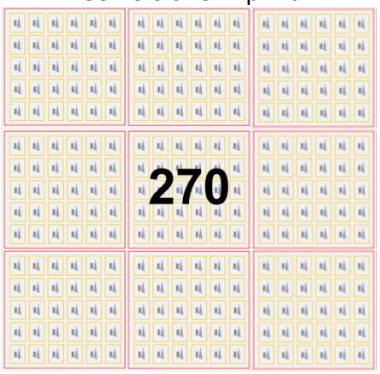
Single AR Waveguide Master (1 waveguide/per)	Upscaled Submaster (30 waveguides/per)	Large-area Imprint Production (120-270 waveguide/per)
 4” glass master supplied by NIL Technologies	 Using 300 x 290mm^2 Schott Realview 1.9 RI glass wafer	 Gen-3.5 size Imprint  Gen-5 size Imprint

Figure 3. Master-upscaling method example for Augmented Reality (AR) Waveguides

Besides offering an unprecedented manufacturing scalability advantage through large-area imprinting, our R2P imprint technology is also quite precise and versatile. Some of the disruptive highlights of the R2P imprint technology are as follows:

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- **Accurate:** Precise structures with feature sizes from 500 µm to 50 nm, with typical aspect ratios of 1:2-1:3 in micron-scale and up to 1:5 in nano-scale
- **Fast:** Imprint cycle times of below 2 minutes in mass production
- **Cost effective:** Working stamp 'Flexible Stamp' can be reused over 500x, as publicly disclosed by our customers. Minimal resin waste (no spin coating) due to unique resin dispensing method.
- **Versatile:**
    - Rigid & flexible substrate (glass, foil, metal) with thickness range of 0.5 – 10 mm
    - Many resin choices - in-house developed, solvent-free resins from 1.4-1.62 refractive index (see Table 1) and co-developed higher refractive index resins from 1.65-1.89
    - Durable & cost-effective Flexible Stamp choices to match the dimensional stability demands of different product imprints
    - Any nanostructures shape, (see Figure 4) from period gratings of different kinds (blazed, binary, slanted), to microlens arrays, fresnel lenses to nanopillars, and more…
    -

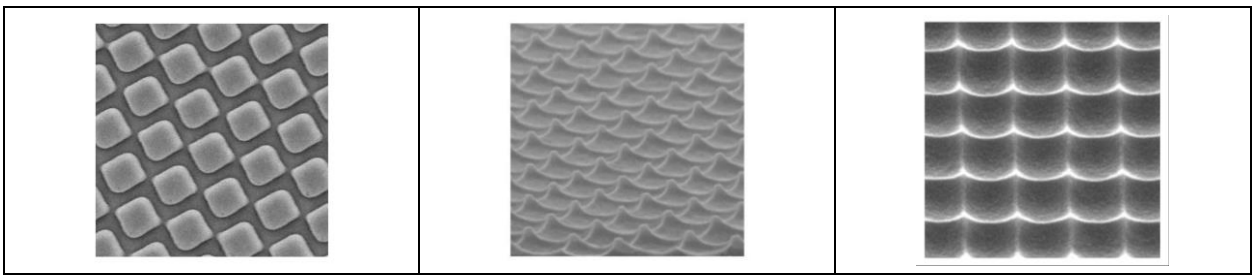
Physical properties measured at ambient conditions, *i.e.* 25 °C unless otherwise specified.

Resin		Refractive index (uncured @ 589nm)	Refractive index (cured, approx.*)	Viscosity (mPa·s)	Shrinkage	Flexibility	Yellowing resistance	Hardness
MM1078	Low refractive index	1.380	1.41	150	●	●●●	●	
MM1092B	High Tg, high toughness	1.503	1.53	130	●●		●	●●
MM2394G	Dry etch resist (pattern transfer)	1.490	1.51	25	●●	●●		●
MM1165	High refractive index, good adhesion	1.565	1.62	160	●●	●●		
MM2017A	Extra low viscosity	1.457	1.51	6	●●●		●●	●●
MM1043C	Low yellowing	1.472	1.51	88	●●●	●	●●●	●
MM2138B2	Low viscosity, good toughness	1.469	1.51	35	●●●	●	●●	●
MM2075B	Excellent pattern transfer	1.514	1.54	1750	●	●●●		
MM2083A2	High clarity	1.495	1.52	375	●●	●	●●●	●●
MM1130B2	High hardness, abrasion resistant	1.468	1.50	95	●●●		●●	●●●
MM2480A	Very high hardness	1.460	1.49	66	●●●		●●	●●●

*Values are indicative. Batches are released based on uncured refractive index and viscosity.

Low → high = ● → ●●●

Table 1: Morphotonics in-house developed solvent-free UV curable resin choices



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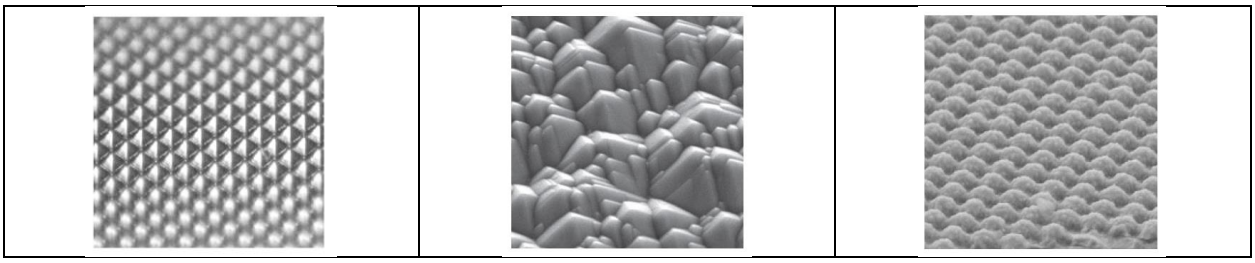

Figure 4. Several examples of structures that were imprinted using R2P

Given many advantages in terms of scaling, replication quality, and versatility that R2P imprint technology can offer, many applications and products can greatly benefit from and become commercially viable using R2P imprint technology. At Morphotonics, we focus on some segments of our addressable market such as displays with high potential that we consider to be our 'focus' markets (as shown in Figure 5), while other markets like the high-end lighting could be addressed using R2P imprint technology yet are niche opportunities.

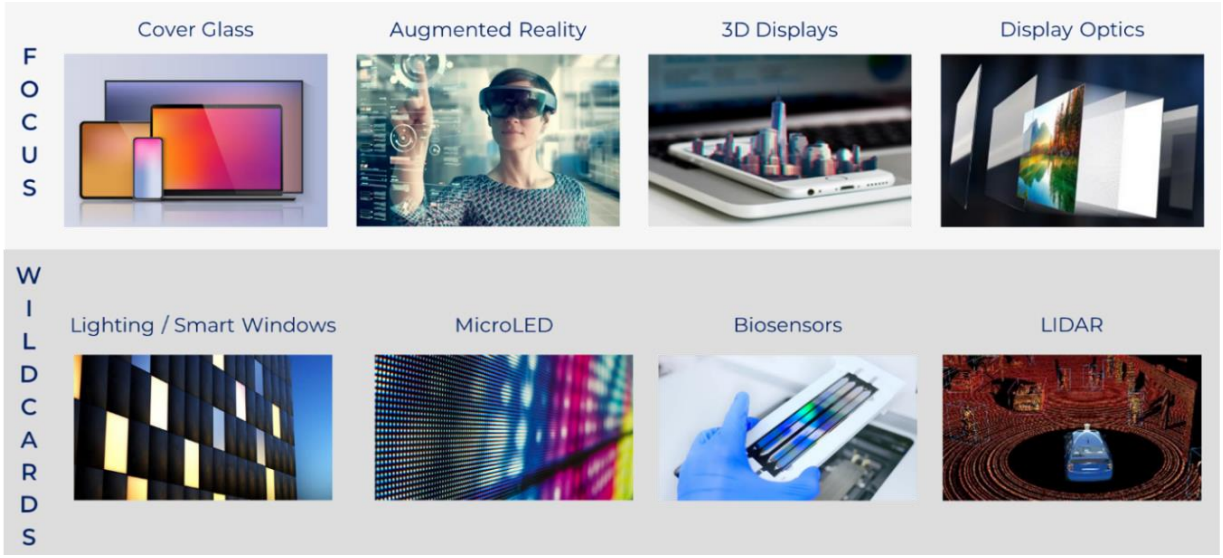

Figure 5. Products and applications that can benefit from R2P technology

Products such as AR glasses could only become feasible as a consumer product if their relatively large optical eye pieces are manufactured at scale and reasonable costs. Many similar products with the necessary built-in nano/micron textures are beyond the capability of incumbent manufacturing methods, in terms of scale or precision, or both. As such, Morphotonics' R2P imprint offers an unprecedented alternative to take such products from lab to fab and make them viable consumer grade products that can improve our daily lives.

Learn more about us: www.morphotonics.com

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