Solutions for Nano and Micro-Structured Optical Films

Inorganic optical thin films and the means to deposit them (e.g. high-vacuum physical vapor deposition, PVD, and chemical vapor deposition, CVD) have supported a broad range of products and technologies for decades. However, many emerging thin-film optical technologies have fabrication requirements that fall outside the capabilities of conventional PVD and CVD tools and methods.

One such emerging technology is metasurface optics. Metasurface optics use nanometer scale structures to manipulate light in ways not previously achievable with traditional materials and designs. Of the many applications of metasurface optics, perhaps the most prevalent is diffractive waveguides used in augmented and virtual reality (AR/VR) headsets. These waveguides allow users to view virtual content and the real world simultaneously. They comprise multiple structures that serve to couple light from an optical projector into the waveguide, increase the viewable area of the virtual content (i.e. exit pupil expander), and then couple the virtual content light out of the waveguide and direct it towards the viewer's eye.

Metasurface optics can be fabricated using nanoimprint lithography (NIL) where the structures are physically imprinted into an organic film coated on a rigid substrate (e.g. a glass wafer) using a soft or rigid master tool (e.g. PDMS stamp or etched Si). Imprint materials are typically either UV cured polymers (coated onto the substrate as monomers) or thermoplastics heated above their glass transition temperature (T_g).

NIL can also be used to fabricate many different types of metasurfaces and is in no way limited to diffractive AR/VR waveguides. Metasurfaces can be designed to focus and steer light in much the same way as conventional refractive or diffractive optics can but with the added flexibility of being able to tune the effective material properties as well. Metasurfaces can also be fabricated for frequencies well outside the visible spectrum and can be designed to function in the RF/microwave, terahertz, IR, and UV bands. Further, 2D materials with special optical & electrical properties can be integrated to create electrically tunable metasurfaces.

Imprint lithography is also not limited to the nanometer realm. Surface relief optical structures with features that range in size from micrometers to millimeters can be fabricated, including but not limited to:

- Refractive optics (lenses, lens arrays, prisms, etc.)
- Dispersive gratings
- Diffractive optical elements (DOEs) & holographic optical elements (HOEs)
- Diffusers & beam shapers
- Pattern generators (lines, grids, crosshairs, etc.)

Regardless of the design, function, wavelength band or material system, imprinted metasurfaces require high quality films of the imprint material to produce high yield, high fidelity imprints.

A generalized workflow for fabricating imprinted surface-relief structures is shown below:

A successful imprint process begins with surface preparation. High adhesion between the substrate and the imprint material is critical such that the imprinted film does not delaminate from the substrate or stick to the master tool when the imprinted film and tool are separated. YES's inductively coupled plasma cleaning tools strip contaminants from the surface of the substrate prior to application of a vapor-deposited self-assembled monolayer (SAM) of a functionalized silane. Currently in widespread use in the semiconductor industry to promote adhesion of photoresists to Si wafers using hexamethyldisilazane (HMDS), all aspects of this process (including the silanes themselves) can be tailored to specific material systems.

For imprint materials processed from solution, complete removal of residual solvents is key to achieving repeatable and uniform results. With approximately 1% temperature uniformity over the volume of the process chamber and automated process controls, YES's vacuum cure ovens are effective at removing residual solvents such that imprint material properties are uniform wafer-to-wafer and lot-to-lot.

Lastly, particulates and other debris within the imprint film can cause localized imperfections of the imprinted structure, resulting in a degradation of optical performance. This is especially so with nanoscale structures. YES process tools are engineered for use in class 10 (ISO4) controlled environments with process chambers environments rated to class 1 (ISO3) to reduce physical contaminants.

YES Equipment Solutions for Imprint Lithography

YES provides equipment ranging from laboratory systems to high volume manufacturing solutions that leverage the demanding requirements of the semiconductor industry for accuracy and repeatability, to produce resist films that generate the highest fidelity imprints:

EcoClean System: Automated oxygen plasma surface cleaning solution.

- >95% uptime (only 3 moving parts), high throughput, and ~1/2 the footprint of comparable products.

EcoCoat System: Vapor phase deposition of functionalized silane self-assembled monolayers (SAMs) for adhesion promotion with excellent repeatability and precision.

- 3x better temperature uniformity across the substrate and up to 2x improvement in contact angle variability over comparable products.
- With >100 chemical precursors, can support a broad range of materials and technologies.

VertaCure System: Vacuum-based, low temperature curing.

- Highly uniform cure environment (~1% temperature variation over the internal volume of the chamber)
- ~50% improvement in cycle time and 2x improvement in temperature uniformity over comparable products

About YES

YES provides equipment ranging from laboratory systems to High Volume Manufacturing (HVM) solutions to serve customers at any scale. Our Clean, Coat, and Cure product lines provide unique capabilities to enhance materials, surfaces and interfaces at micro- and nano-scales.

YES customers include industry leaders in the optics sector, top-tier research institutions and the industry's most respected technology incubators. YES works closely with these customers to develop custom solutions for their unique requirements including process development, equipment selection and post-sales service support. These efforts and associated product development initiatives are supported by YES's state-of-the-art laboratory in the Silicon Valley.

How can YES assist you?

YES engineers are experts in controlled surface modification enabling several end markets: fabrication of silicon microprocessors, advanced packaging, (bio)MEMS, genomics, microfluidics, medical devices, and other advanced technologies.

For more information, please contact sales@yieldengineering.com or +1.925.373.8353.

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