PHANTOM®

2019
CASE STUDY

New Printing Process Leaves a Mark

Using a Phantom high-speed camera, MIT researchers observed what happens to the ink during a new printing process—opening up new doors for electronics.

How ink behaves when it's stamped onto a surface during flexographic printing might not seem like much of a concern. But as it turns out, understanding ink transfer dynamics is critical to a wide range of applications—particularly, electronics manufacturing.

A group of Massachusetts Institute of Technology (MIT) researchers developed a new printing process that improves on traditional flexography—a technique that applies ultra-thin layers of polymeric and colloidal inks to nonporous substrates. Flexography is important for many industries, including electronics manufacturing, and is often used to print on unconventional surfaces like paper and polymer films. Film transistors, RFID tags and transparent electrodes are just some of the mass-produced devices that benefit from this high-throughput process.

FLEXOGRAPHY AND INK TRANSFER DYNAMICS

During flexographic printing, an elastomer stamp makes contact with the substrate—causing the ink on the stamp's surface to form a liquid bridge between the two surfaces. Separating them ruptures the bridge, transferring tiny amounts of liquid to the substrate under each stamp feature. Despite being a highly scalable and fast process, flexographic printing has its limits. Due to the ink transfer dynamics, this process is limited to resolutions of tens of microns—in turn, limiting the resolution of printed display pixels and the performance of printed devices.

But with the help of a Phantom high-speed camera, the MIT research group has found that nanoporous stamps overcome these challenges, enabling ultra-thin film printing with micron-scale precision. "Specifically, nanoporous stamps don't experience the same squeeze-out and de-wetting instabilities as traditional polymer stamps—achieving significantly finer printed feature dimensions," explains researcher Dhanushkodi Mariappan.

THE PHANTOM v2511 CAMERA

The Vision Research Phantom v2511 high-speed camera is a helpful tool for any researcher looking to capture high-resolution images at ultra-high speeds. It can shoot up to 1,000,000 fps at lower resolutions and includes a global electronic shutter capable of sub 1-μs exposures. Due to these advanced features, the camera successfully freezes fast-moving phenomena while eliminating motion blur.

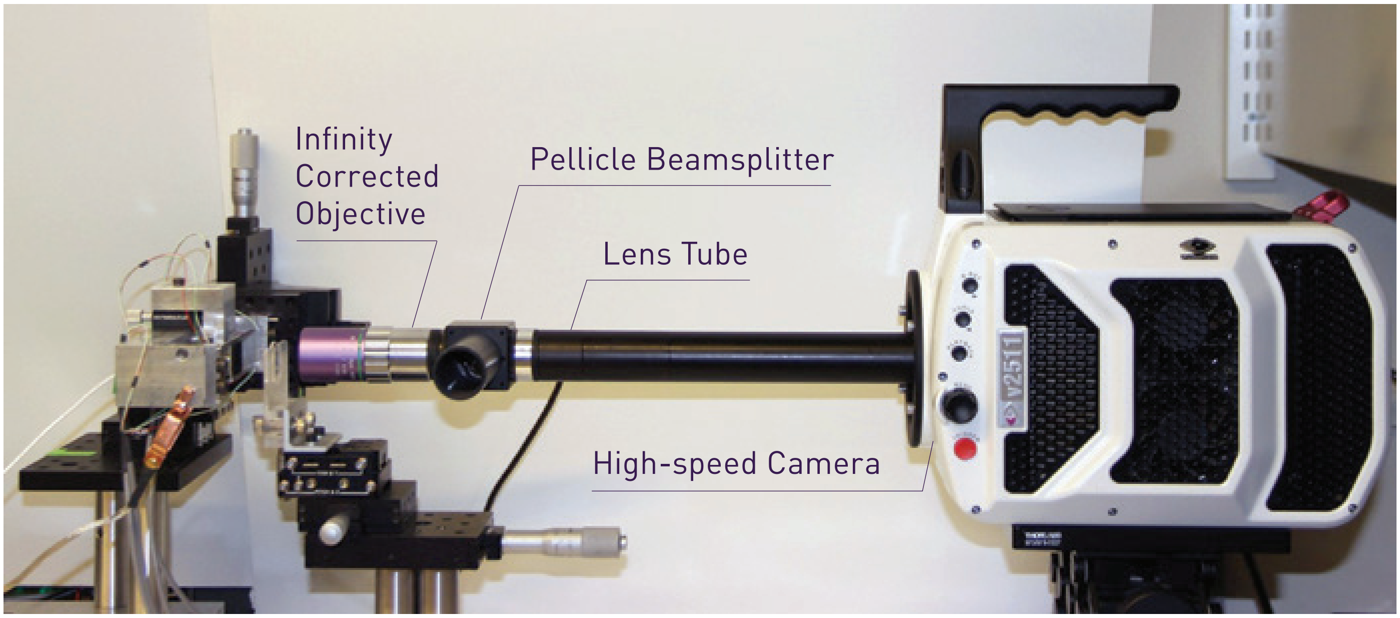
Thanks to its high light sensitivity, the Phantom v2511 enabled MIT researchers to capture the ink transfer dynamics during nanoporous stamp flexography.

SOME HIGH-SPEED HELP

To help them better understand how nanoporous stamps transfer ink, the researchers needed a way to capture the micron-scale stamp features during the fast flexographic printing process. "The high-speed camera was critical in this process," says Mariappan.

Using a Vision Research Phantom v2511 camera, Mariappan and his team investigated the liquid transfer dynamics between the substrate—in this case, a transparent, spherical lens—and a nanoporous stamp made of polymer-coated carbon nanotubes (CNT). Their experimental setup included a CNT stamp, which they affixed to a flexure stage, as well as a capacitance probe that measured the contact force between the stamp and substrate. The stamp pattern included an array of 100-μm circles with 30-μm spacing. The apparatus also incorporated a single-axis motion stage to align the two surfaces, as well as a custom microscope and Phantom v2511 camera positioned behind the transparent substrate.

After inking, the team placed the wet stamp on the flexure and brought it into contact with the lens. The Phantom v2511 recorded this critical step—including the stamp's approach and retraction at different speeds—at 25,000 frames per second (fps). "Essentially, we wanted to capture what's happening at the interface between the two surfaces," Mariappan explains. "To our knowledge, this kind of experiment has never been done before."



The apparatus that captured the contact between the CNT stamp and spherical lens. Images were taken through the back side of the lens using a Phantom v2511 camera.

SHEDDING LIGHT ON A HIGH-SPEED PROCESS

In general, lighting can be a challenge during high-speed photography. Due to the nature of the stamping experiments, having enough lighting became more important than ever. "Essentially, we're pressing two surfaces against each other," Mariappan explains. "Closing the gap restricts the light."

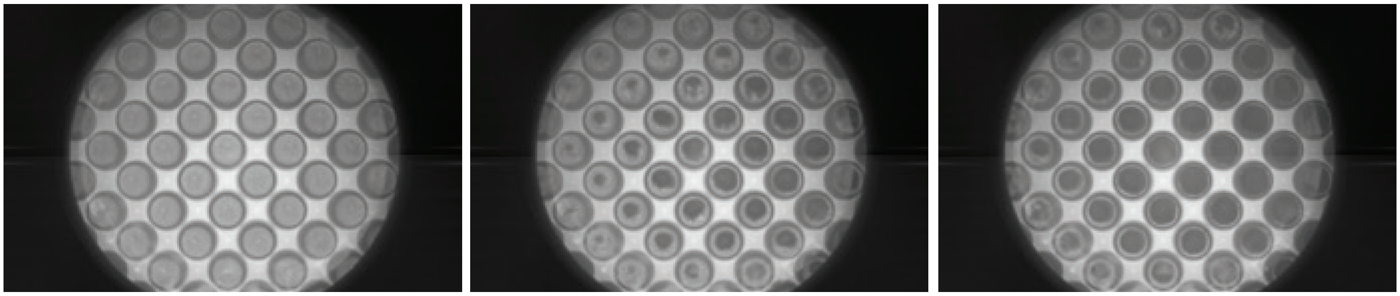
The highly sensitive Phantom v2511, as well as its successor, the Phantom 2512, are designed to maximize light response without sacrificing image quality or speed. The v2511 hits 25,000 fps at full 1-megapixel resolution and integrates a custom CMOS sensor with 28-micron pixel sizes for high light sensitivity. Each pixel has a depth of 12 bits, yielding 4,096 gray levels, for high-quality, detailed images. Together these features achieve a very high native ISO of 32000D mono and 6400D color—successfully overcoming typical high-speed lighting challenges.

STAMPING OUT THE RESULTS

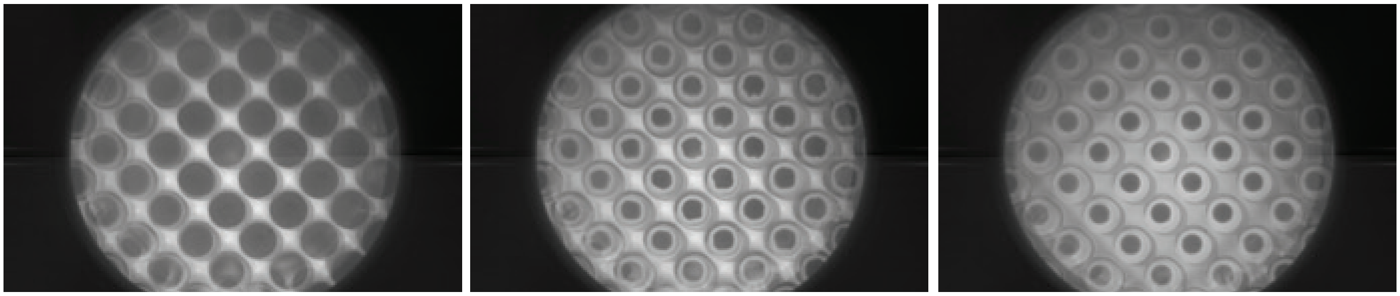
Using high-speed imaging and analytical modeling, the team successfully observed how the ink spread during stamping—shedding light on the transfer dynamics of nanoporous stamps at high and low approach speeds. Specifically, they demonstrate that the volume of printed ink and resulting thickness are both independent of contact pressure. They also show that thickness decreases with retraction speed.

"Nanoporous stamp flexography successfully prints nanoparticle films with thicknesses less than 100 nm at speeds commensurate with industrial equipment," Mariappan concludes. "Thanks to the camera, we've been able to show the potential of nanoporous stamps in industrial-scale electronics printing."

Mariappan and his colleagues published their findings in Langmuir in April, 2019.



The Phantom v2511 captures how the ink spreads when the stamp approaches the substrate at 10 mm/s.



The Phantom v2511 captures the evolution of the liquid bridge when the stamp retracts from the substrate at 10 mm/s.