The microscopic topography of ink on paper

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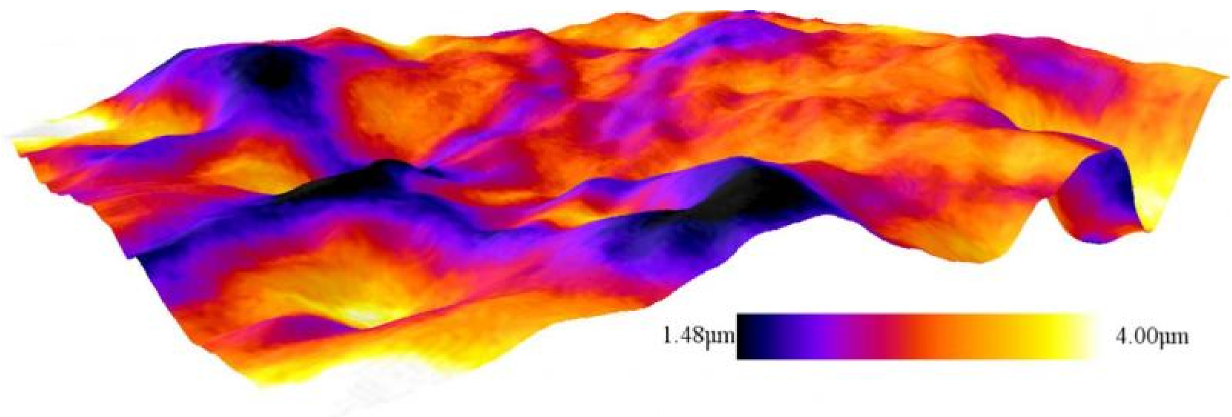


3-D visualization of the toner layer on top of coated paper. The dark blue areas show thin layers of toner, whereas the yellow shows thicker layers. Credit: Markko Myllys/University of Jyvaskyla

A team of Finnish scientists has found a new way to examine the ancient art of putting ink to paper in unprecedented 3-D detail. The technique could improve scientists' understanding of how ink sticks to paper and ultimately lead to higher quality, less expensive and more environmentally-friendly printed products.

Using modern X-ray and laser-based technologies, the researchers created a nano-scale map of the varying thickness of toner ink on paper. They discovered that wood fibers protruding from the paper received relatively thin coatings of ink. In general, they also found the toner thickness was dictated mainly by the local changes in roughness, rather than the chemical variations caused by the paper's uneven glossy finish.

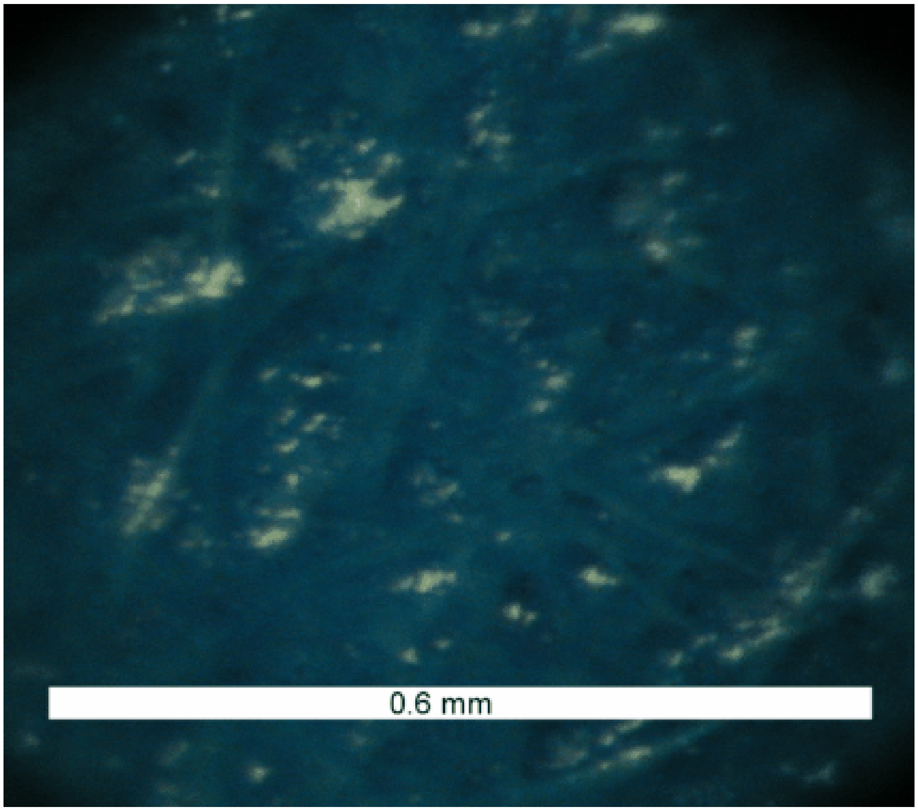
The team describes their results in a paper published in the *Journal of Applied Physics*.

"We believe that this gives new insight, especially on how the topography of paper impacts the ink setting or consolidation," said Markko Myllys, an applied physicist at the University of Jyvaskyla in Finland. "This in turn helps us understand how glossy and non-glossy printed surfaces should be made."

Intricate Ink and Paper Microstructures

To achieve their detailed picture of ink thickness, the researchers first examined the underlying paper with X-ray microtomography, a smaller cousin of the CT scanning technology used in hospitals to produce images of the inside of the body.

To analyze the cyan ink layers, the researchers used two additional technologies: optical profilometry, which bounced a light beam off the surface of the ink to obtain a surface profile, and laser ablation, which zapped away controlled amounts of ink with a laser to determine the ink depth.



This animated series of images shows a printed sheet of paper as a laser progressively removes layers of black ink. Variations in paper roughness lead to some areas becoming brighter much earlier than others. Credit: Markko Myllys/University of Jyvaskyla

Although none of the imaging techniques are themselves new, the researchers were the first to combine all three to achieve a complete, high-resolution 3-D image of the intricate ink and paper microstructures.

The final images resemble a rugged mountain landscape, with the higher peaks generally showing thinner coatings of ink, and the valleys showing thicker pools.

The researchers found the typical ink layer was approximately 2.5 micrometers deep, about 1/40 the thickness of an average sheet of paper, but with relatively large spatial variations between the thickest and thinnest areas.

Knowing how topographical variations affect ink thickness will help the printing industry create more environmentally-friendly and less energy-demanding ink and optimize the size distribution of ink particles, Myllys said. It could also help the papermaking industry design more sustainable paper and packaging, for example from recycled components, while still maintaining the quality needed to make ink stick well. Additionally, the papermaking industry could use the findings to help decide how best to incorporate smart and novel features into paper, Myllys said.

The team believes the imaging methods they used can also be adapted to effectively analyze the thickness variations in other types of thin films, including those found in microelectronics, wear-resistant coatings and solar panels.

"This result can certainly be generalized, and that makes it actually quite interesting," Myllys said. "Thickness variations of thin films are crucial in many applications, but the 3-D analysis has been very difficult or impossible until now."

More information: "X-ray microtomography and laser ablation in the analysis of ink distribution in coated paper," by M. Myllys, H. Hakkanen, J. Korppi-Tommola, K. Backfolk, P. Sirvio and J. Timonen, *Journal of Applied Physics* , April 14, 2015. DOI: 10.1063/1.4916588

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