

**Paper Surface Roughness
With 3D Metrology**



Prepared by
Craig Leising

INTRO:

Paper is still a primary source for communication around the world and is now more portable, from size reductions and has triggered new research developments with cleaning products, printing, foods and many others. An important key to growth in the paper and pulp industry is sustainable use which will require continued research to improve renewable product quality.

IMPORTANCE OF SURFACE METROLOGY INSPECTION FOR R&D AND QUALITY CONTROL

Paper surface topography is vital to the intended use and quality of the product. To control paper product quality it will heavily rely upon quantifiable, reproducible and reliable surface measurement. Precise surface measurement and evaluation of a paper product can lead to the best selection of processing and control measures. The Nanovea 3D Non-Contact Profilometers utilize chromatic confocal technology with unmatched capability to measure paper surfaces. Where other techniques fail to provide reliable data, due to probe contact, surface variation, angle and reflectivity, Nanovea Profilometers succeed.

MEASUREMENT OBJECTIVE

In this application, the Nanovea ST400 is used to measure the surface of three paper samples for comparative review. The samples range from very rough to premium surface. Additionally, each sample has received a printed letter from a laser printer to study the effect surface roughness on ink settling. Several surface parameters can automatically be calculated including the most common, Sa (average surface roughness), step height, area and many others.

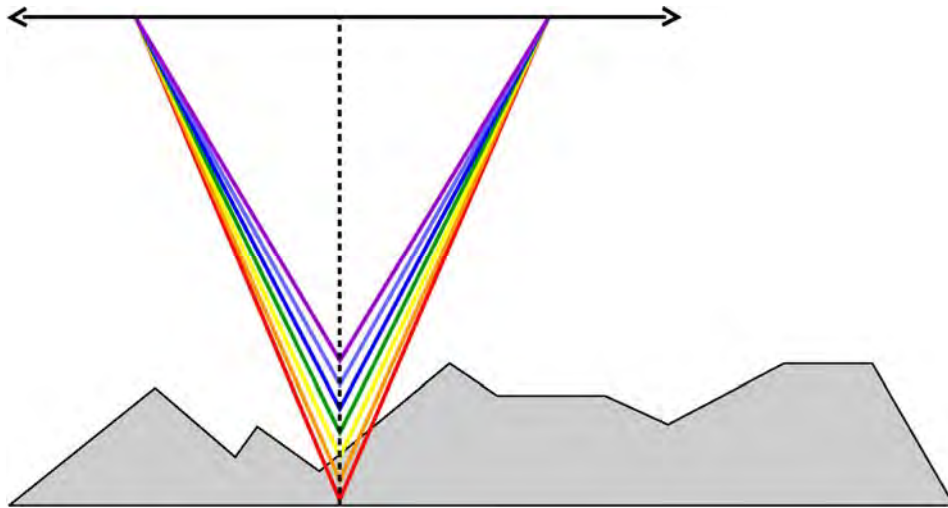


MEASUREMENT SET-UP & TIPS:

All samples were subject to the same process and measurement. The optical pen used provides 12 nanometers of Z resolution.

MEASUREMENT PRINCIPLE:

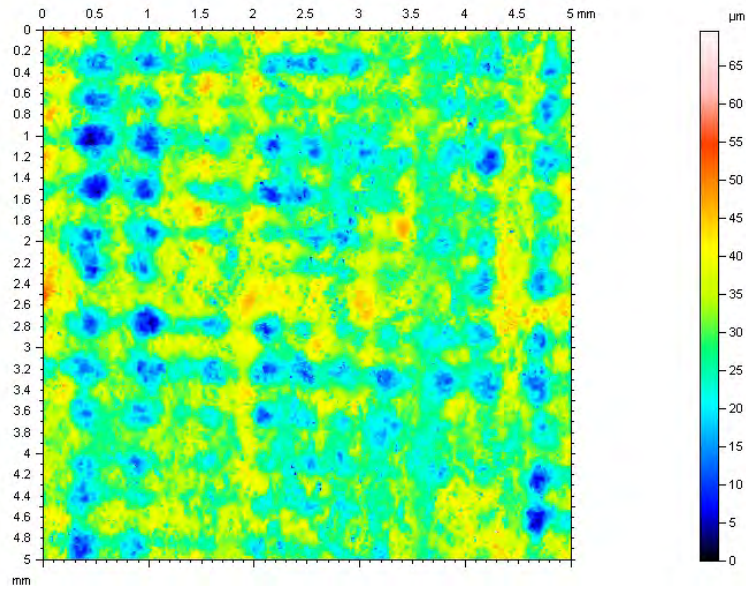
The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



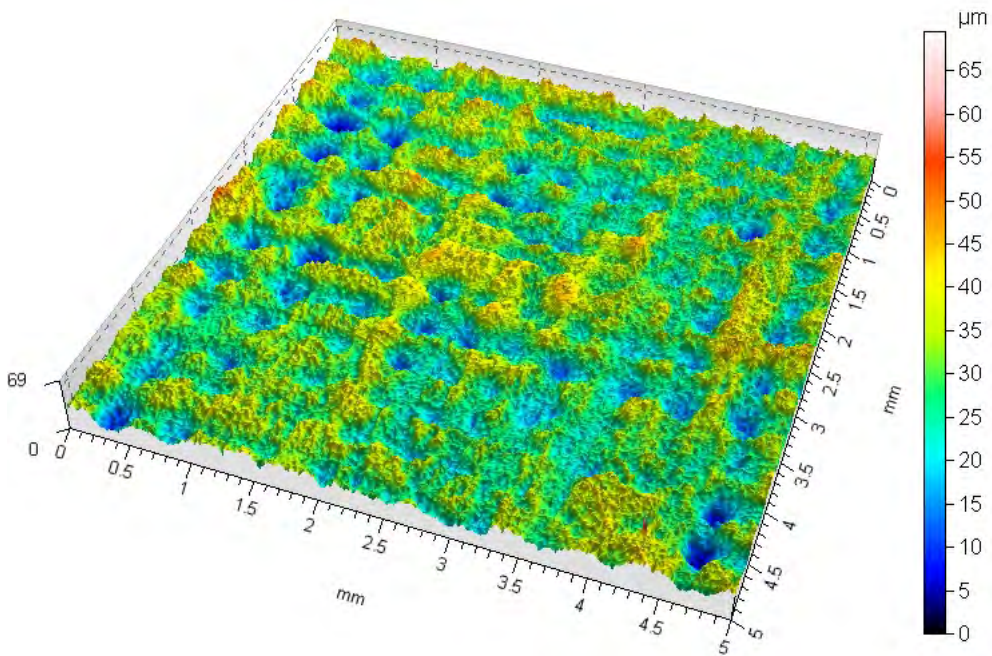
Nanovea optical pens have zero influence from sample reflectivity. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent/opaque, specular/diffusive, polished/rough.

RESULTS:

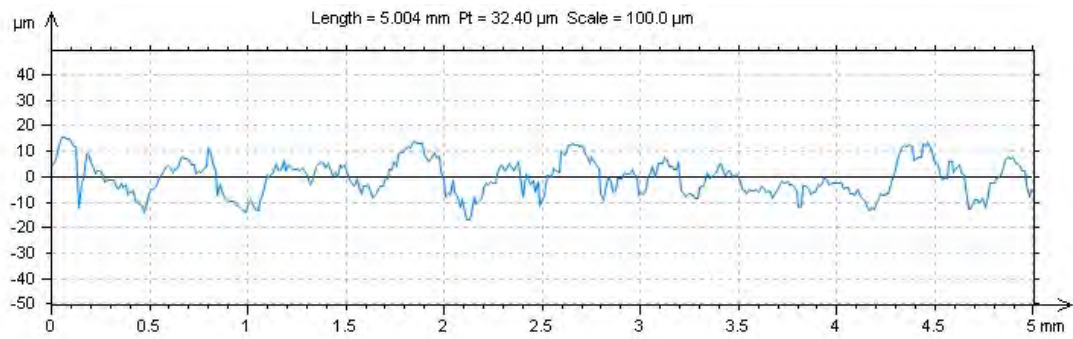
Linen Paper



2D Top Surface of Linen Paper

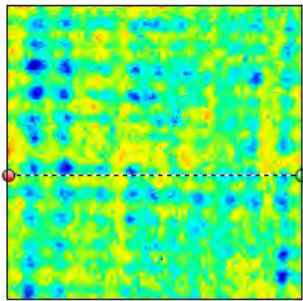


3D Image of Linen Paper Surface



Profile Extracted From Linen Paper

Profile Extracted



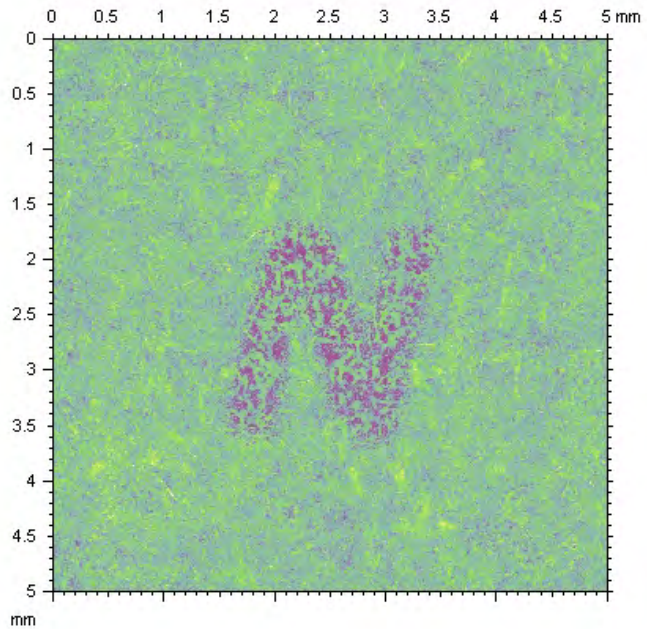
**ISO 25178
Height Parameters**

Roughness values calculated outside of ink area:

Sq	6.806	μm
Ssk	-0.2662	
Sku	3.056	
Sp	40.64	μm
Sv	28.85	μm
Sz	69.49	μm
Sa	5.435	μm

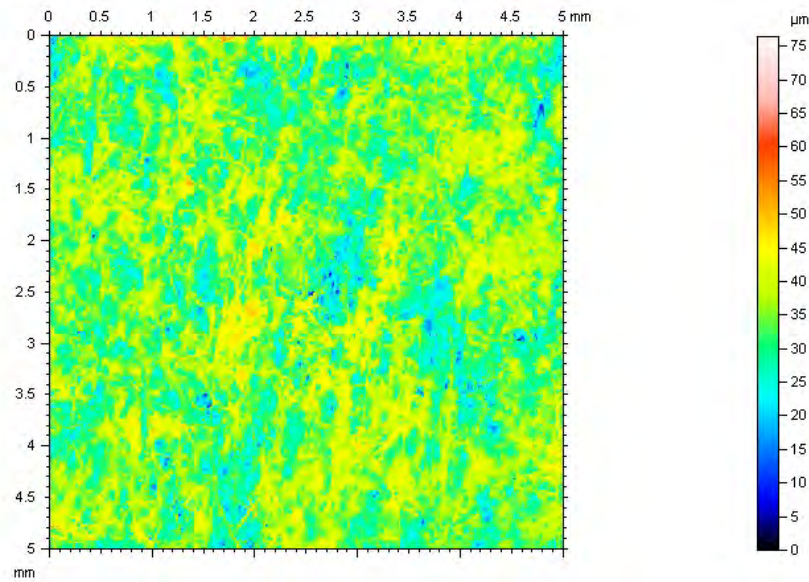
2D Surface Contrast Image

Here we had to use a contrast image of the surface in order to see the absorbed ink.

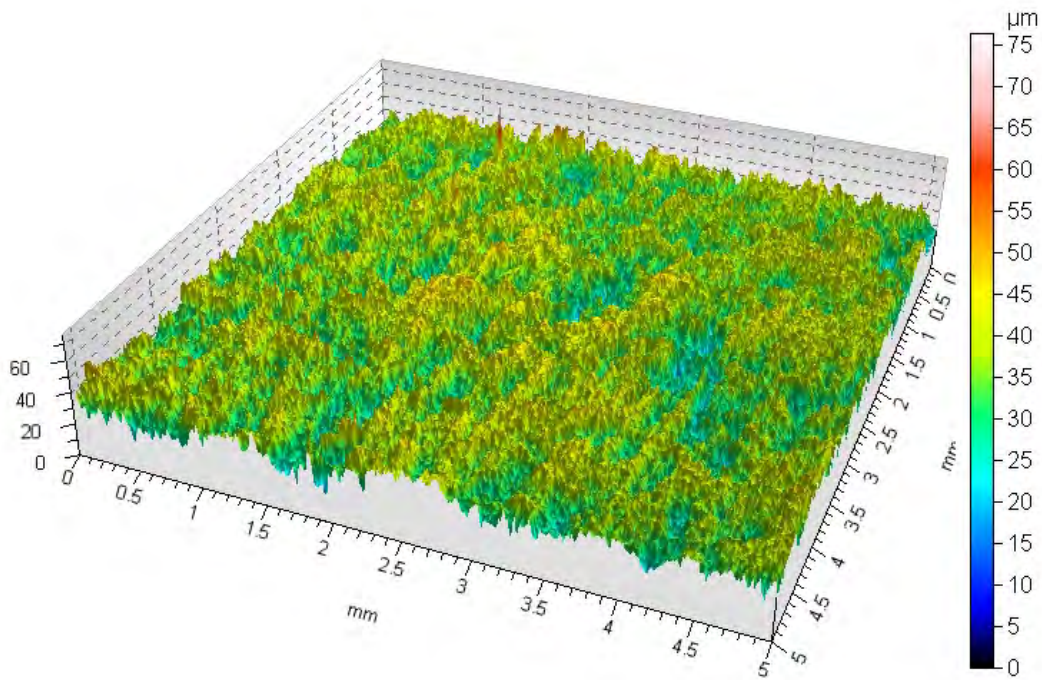


RESULTS:

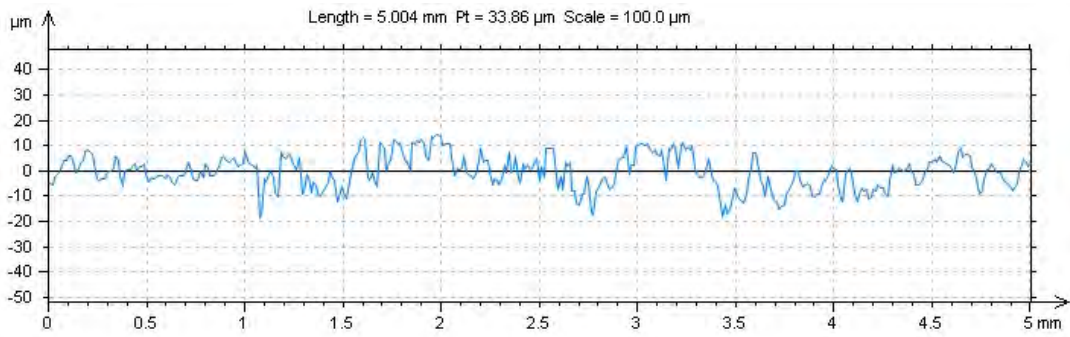
Standard Paper



2D Top Surface of Standard Paper

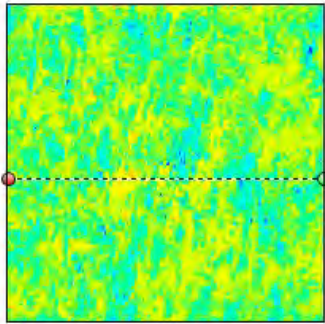


3D Image of Standard Paper Surface



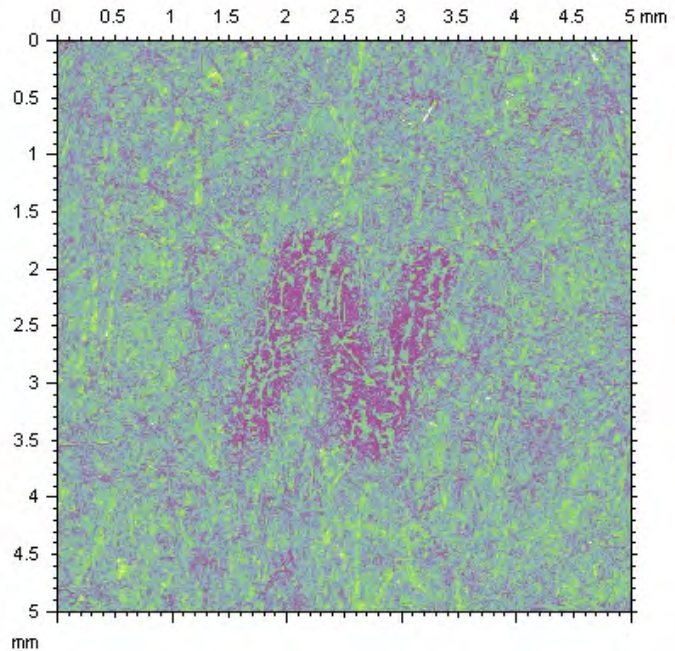
Profile Extracted From Standard Paper

Profile Extracted



2D Surface Contrast Image

Here we had to use a contrast image of the surface in order to see the absorbed ink.



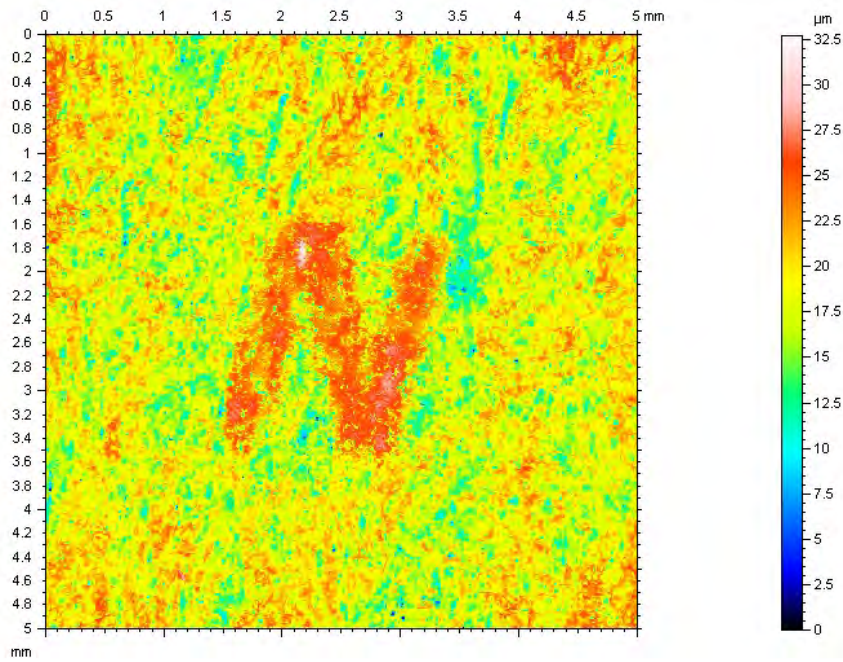
ISO 25178 Height Parameters

Roughness values calculated
outside of ink area:

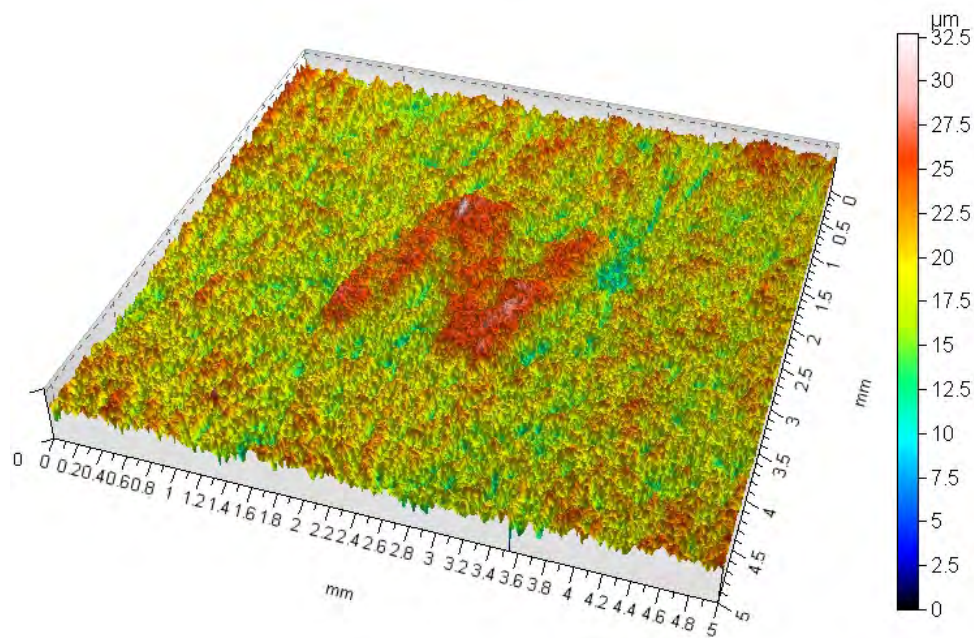
Sq	5.722 μm
Ssk	-0.3142
Sku	3.080
Sp	42.26 μm
Sv	34.19 μm
Sz	76.45 μm
Sa	4.586 μm

RESULTS:

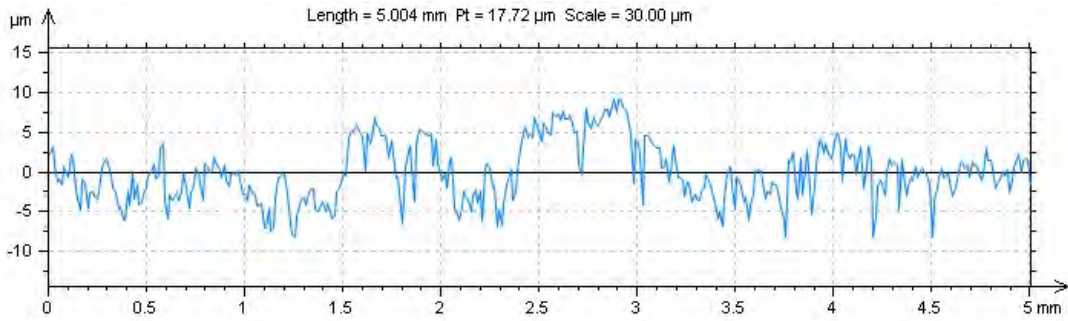
Premium Paper



2D Top Surface of Premium Paper

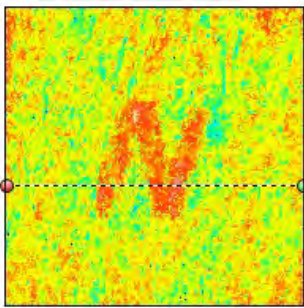


3D Image of Premium Paper Surface



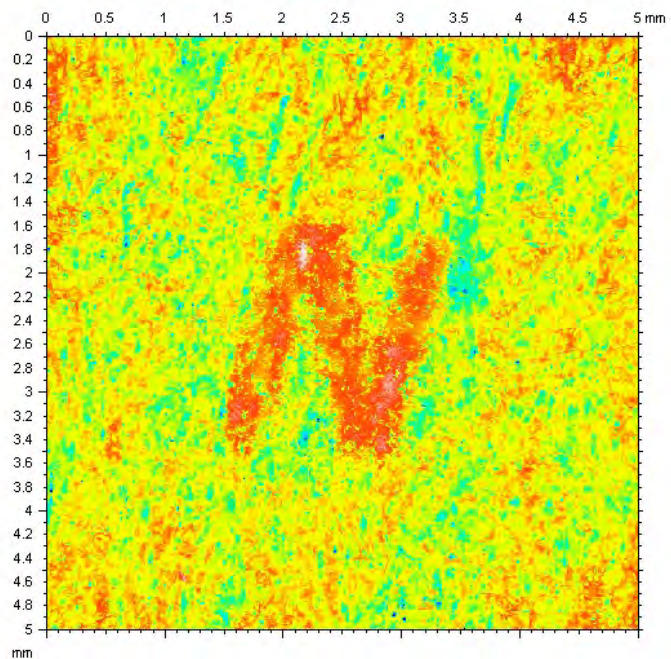
Profile Extracted From Premium Paper

Profile Extracted



2D Surface Measurement

Here we did not have to use a contrast image because the ink was still measurable resting on the surface.



ISO 25178 Height Parameters

Roughness values calculated outside of ink area:

Sq	3.176	μm
Ssk	-0.08975	
Sku	3.302	
Sp	14.07	μm
Sv	18.62	μm
Sz	32.69	μm
Sa	2.498	μm

Height Parameter		Definition
Sa	Arithmetical Mean Height	<p>Mean surface roughness.</p> $S_a = \frac{1}{A} \int_A z(x,y) dx dy$
Sq	Root Mean Square Height	<p>Standard deviation of the height distribution, or RMS surface roughness.</p> $S_q = \sqrt{\frac{1}{A} \iint_A z^2(x,y) dx dy}$ <p>Computes the standard deviation for the amplitudes of the surface (RMS).</p>
Sp	Maximum Peak Height	Height between the highest peak and the mean plane.
Sv	Maximum Pit Height	Depth between the mean plane and the deepest valley.
Sz	Maximum Height	Height between the highest peak and the deepest valley.
Ssk	Skewness	<p>Skewness of the height distribution.</p> $S_{sk} = \frac{1}{S_q^3} \left[\frac{1}{A} \iint_A z^3(x,y) dx dy \right]$ <p>Skewness qualifies the symmetry of the height distribution. A negative Ssk indicates that the surface is composed of mainly one plateau and deep and fine valleys. In this case, the distribution is sloping to the top. A positive Ssk indicates a surface with a lot of peaks on a plane. Therefore, the distribution is sloping to the bottom.</p> <p>Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.</p>
Sku	Kurtosis	<p>Kurtosis of the height distribution.</p> $S_{ku} = \frac{1}{S_q^4} \left[\frac{1}{A} \iint_A z^4(x,y) dx dy \right]$ <p>Kurtosis qualifies the flatness of the height distribution.</p> <p>Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.</p>

CONCLUSION:

In this application, we have shown how the Nanovea ST400 3D Profilometer can precisely characterize both the topography and the nanometer details of paper surface. From our results we can see how the difference in surface roughness clearly changed the settling and possibly the absorption of ink from the laser printer. With this information the surface topography of paper can be investigated and to what effect it has on the settling and distribution of ink on the surface; a crucial understanding for paper product use. To further view in detail a 2D cross section can quickly be chosen to analyze, at nanometer range, step height and planarity among others. Special areas of interest could have been further analyzed with integrated AFM module. Nanovea 3D Profilometers speeds range from 20mm/s to 1m/s for laboratory or research to the needs of hi-speed inspection; can be built with custom size, speeds, scanning capabilities, Class 1 Clean Room compliance, with Indexing Conveyor and for Inline or online Integration.