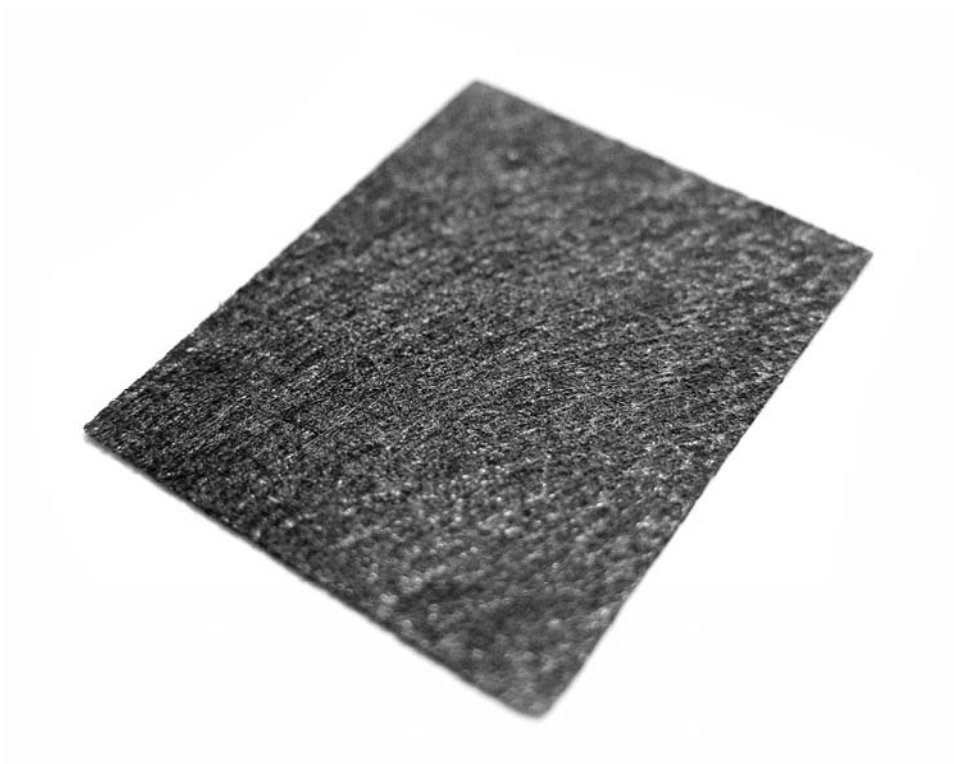
FUEL CELL GAS DIFFUSION LAYER INSPECTION WITH 3D PROFILOMETRY



Prepared by
Craig Leising

6 Morgan, Ste156, Irvine CA 92618 · P: 949.461.9292 · F: 949.461.9232 ·nanovea.com
Today's standard for tomorrow's materials. © 2010 NANOVEA

INTRO:

The search to perfect green energies is constantly evolving. Fuel cell research has exponentially grown over the past several years, driving the need to improve efficiencies and reduce costs.

A fuel cell is based on an electrochemical cell that generates electricity through an electrochemical reaction by using the stored chemical energy from Hydrogen. One of the major components of the fuel cell is the gas diffusion layer (GDL), which in this case is a carbon paper. The diffusion media are often composed of either a single gas diffusion layer or a composite structure of a gas diffusion layer and a microporous layer. These material types promote effective diffusion of the reactant gases to the membrane/electrode assembly. The structure allows the gas to spread out as it diffuses to maximize the contact surface area of the catalyst layer membrane.

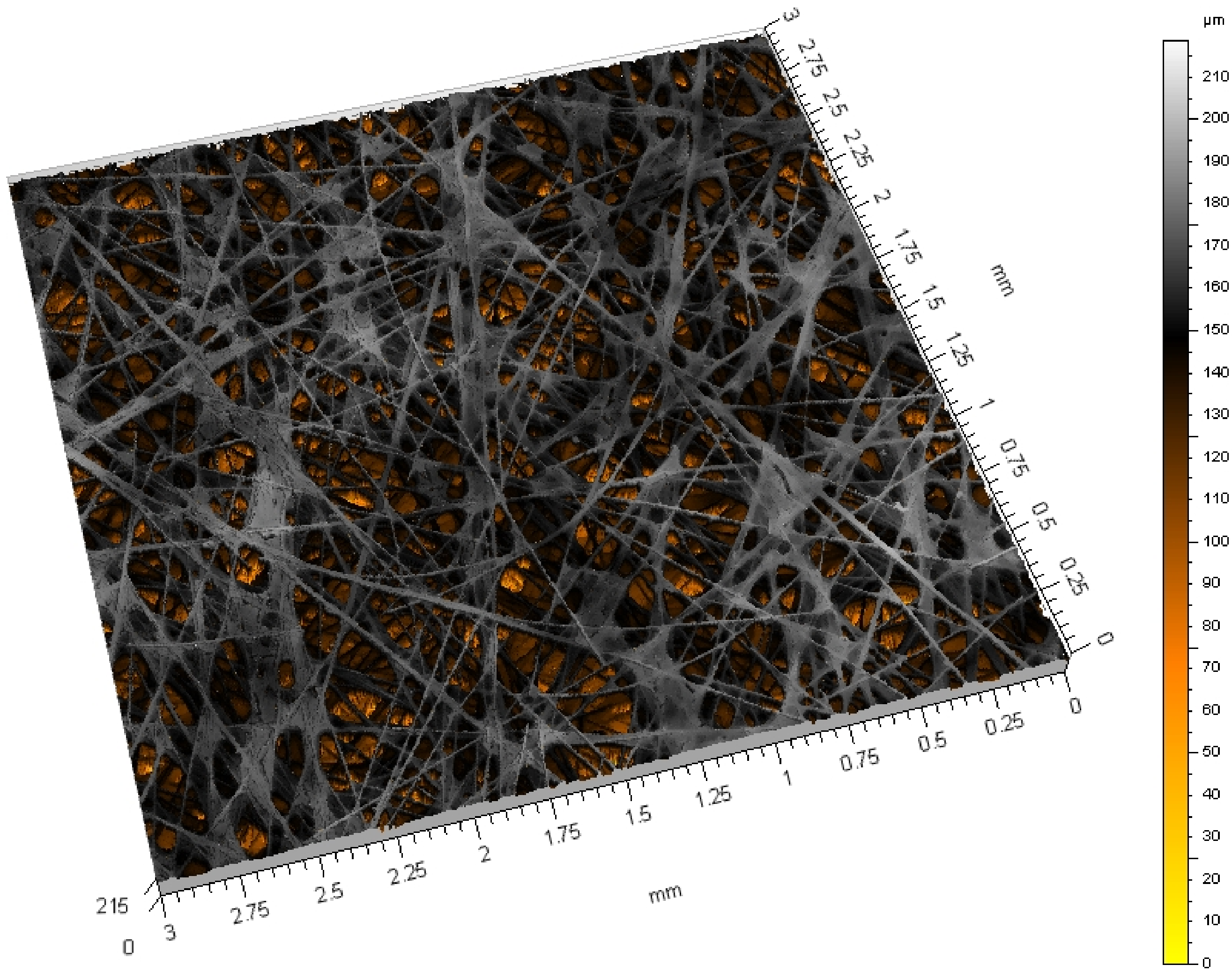
IMPORTANCE OF SURFACE METROLOGY INSPECTION FOR QUALITY CONTROL

From the description above, it can safely be said that the surface quality of the diffusive layer is highly important to the overall performance of the cell. It has been shown that the surface roughness, surface area and the fractal dimension have all been used to describe the quality of these diffusive materials.

MEASUREMENT OBJECTIVE

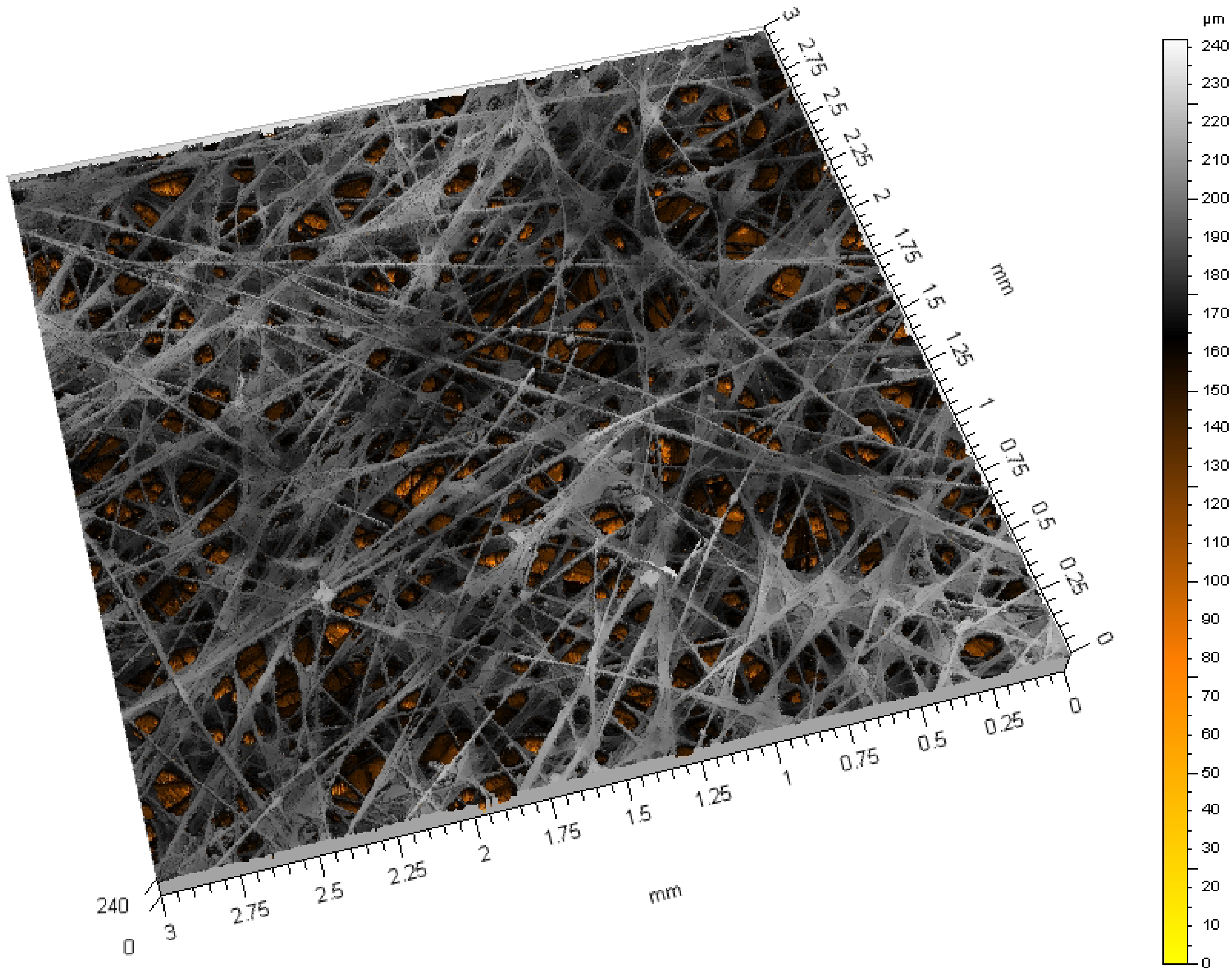
In this application, the Nanovea ST400 is used to measure three different GDL's that were exposed to different treatments. The surface roughness, surface area and the fractal dimension will be looked at to show a difference in the surface structure. *Samples courtesy of Laboratory for Fuel Cells and Green Energy, University of Waterloo.*

Sample 1:



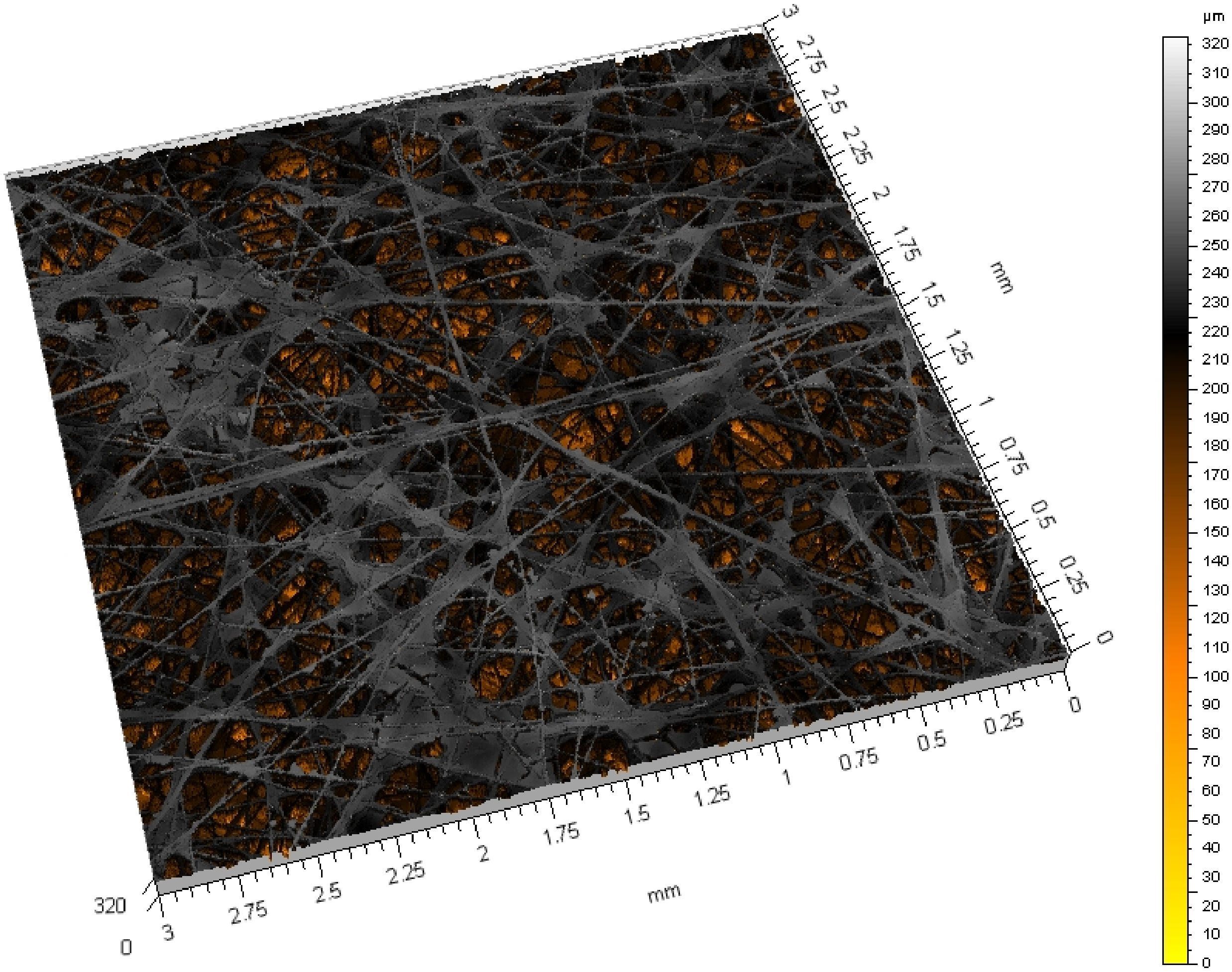
False color representation of surface

Sample 2:



False color representation of surface

Sample 3:



False color representation of surface

SURFACE ROUGHNESS PARAMETERS:

SURFACE ROUGHNESS VALUES

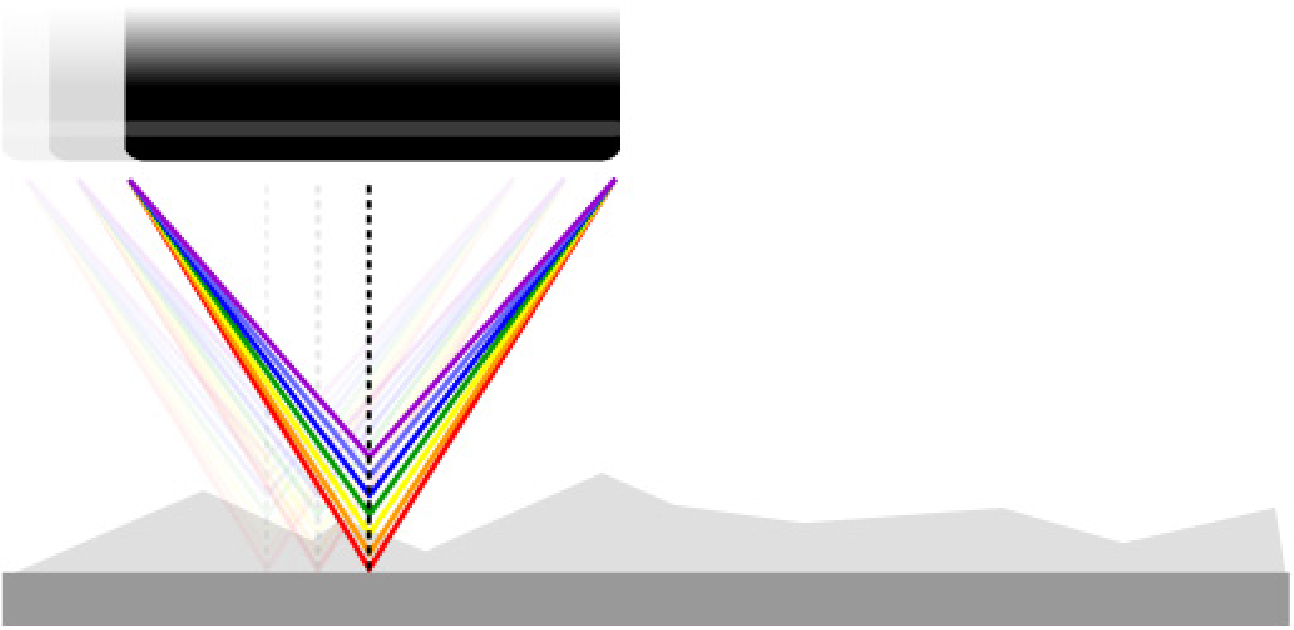
	Sample 1	Sample 2	Sample 3	
Sa	15.781 µm	16.683 µm	22.206 µm	*Arithmetical Mean Height*
Sq	21.560 µm	22.692 µm	28.879 µm	*Root Mean Square Height*
Sp	63.537 µm	60.529 µm	98.571 µm	*Maximum Peak Height*
Sv	155.12 µm	181.28 µm	224.23 µm	*Maximum Pit Height*
Sz	218.660 µm	241.81 µm	322.80 µm	*Maximum Height*
Ssk	-1.7041	-1.5271	-1.4199	*Skewness*
Sku	7.546	6.746	5.634	*Kurtosis*
Surface Area	21.846 mm^2	25.085 mm^2	37.941 mm^2	
Fractal Dimension	2.4112	2.4286	2.7412	

CONCLUSION:

After reviewing the 3D images you can see differences between the three samples measured. These differences are verified when analyzing the surface roughness parameters, surface area and the fractal dimension data. These tests can be performed to easily test different manufacturing processes, and directly compare their effect on the surface quality of the gas diffusion layer. Likewise, the Nanovea ST400 could also be used as an inline quality control method to insure sample consistency.

MEASUREMENT PRINCIPLE:

The Chromatic Confocal 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.



Unlike the errors caused by probe contact or the manipulative Interferometry technique, Chromatic Confocal technology measures height directly from the detection of the wavelength that hits the surface of the sample in focus. It is a direct measurement with no mathematical software manipulation. This provides unmatched accuracy on the surface measured because a data point is either measured accurately without software interpretation or not at all. The software completes the unmeasured point but the user is fully aware of it and can have confidence that there are no hidden artifacts created by software guessing.

Nanovea optical pens have zero influence from sample reflectivity or absorption. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent or opaque, specular or diffusive, polished or rough. Measurement includes: Profile Dimension, Roughness Finish Texture, Shape Form Topography, Flatness Warpage Planarity, Volume Area, Step-Height Depth Thickness and many others.

DEFINITION OF HEIGHT PARAMETERS

Height Parameter		Definition
Sa	Arithmetical Mean Height	Mean surface roughness. $$Sa = \frac{1}{A}\iint_A \lvert z(x,y)\rvert dxdy$$
Sq	Root Mean Square Height	Standard deviation of the height distribution, or RMS surface roughness. $$Sq = \sqrt{\frac{1}{A}\iint_A z^2(x,y)dxdy}$$ Computes the standard deviation for the amplitudes of the surface (RMS).
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	Skewness of the height distribution. $$Ssk = \frac{1}{Sq^3}\left[\frac{1}{A}\iint_A z^3(x,y)dxdy\right]$$ 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. Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.
Sku	Kurtosis	Kurtosis of the height distribution. $$Sku = \frac{1}{Sq^4}\left[\frac{1}{A}\iint_A z^4(x,y)dxdy\right]$$ Kurtosis qualifies the flatness of the height distribution. Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.
Spar	Projected Area	Projected surface area.
Sdar	Developed Area	Developed surface area.