NewsLetter
Spring 2018
SurFace
Surface imaging, analysis & metrology news from Digital Surf

In this issue

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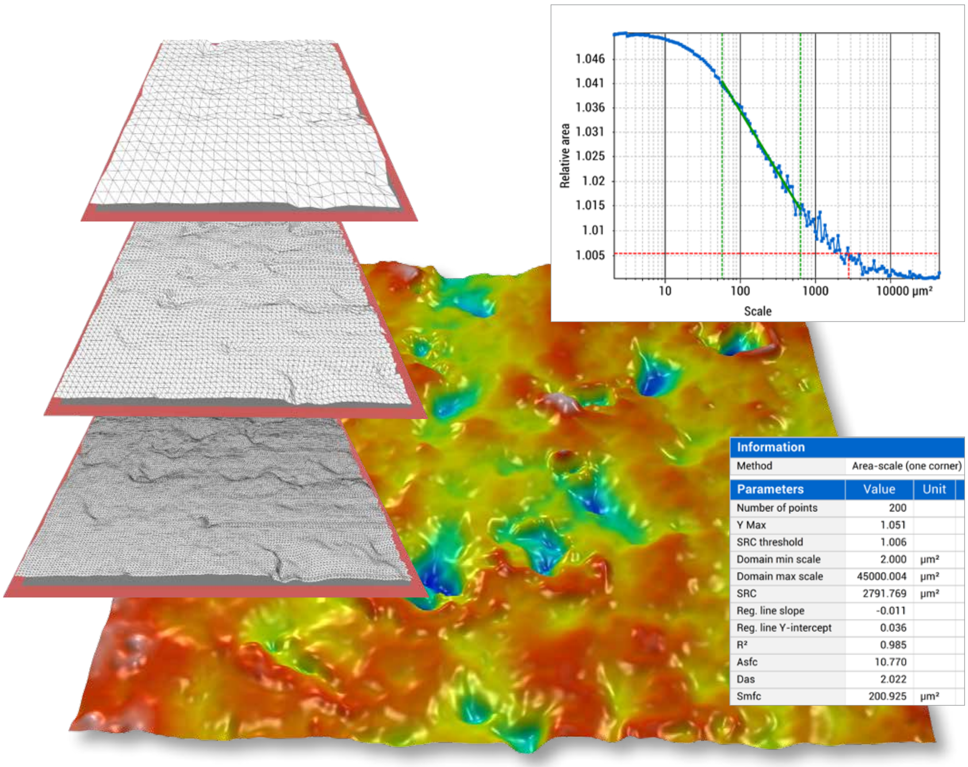
Scale-sensitive fractal analysis
What it is and how to use it



Scale-sensitive fractal analysis (SSFA) is already being used in many fields of research to study surface functionalities such as adhesion and wear.

Now tools for applying specialized SSFA to measured surfaces and profiles are coming to Mountains® software users.

Read our surface metrology expert's advice on using them and discover how they could be useful for your applications.

Turn to page 2

EVENT

We look forward to seeing you at:

Control

Stuttgart, Germany
April 24 - 28, 2018

Digital Surf stand #3412

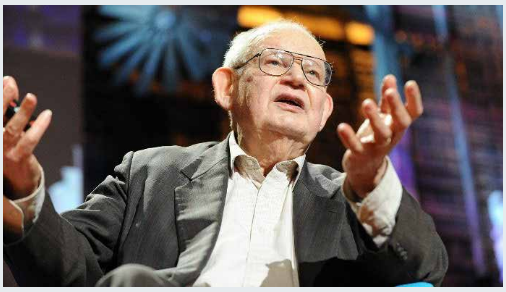
5 THINGS TO CONSIDER WHEN USING SCALE-SENSITIVE FRACTAL ANALYSIS

To mark the release of the new Scale-Sensitive Fractal Analysis optional module, now available to Mountains® software users, François Blateyron, Digital Surf's surface metrology expert, explains what SSFA is all about and how to use it.

1. WHAT IS FRACTAL ANALYSIS?

We all learned at school that geometrical objects are sorted by the number of coordinates required to describe them. A line segment is 1-dimensional, a plane is 2-dimensional and a cube is 3-dimensional. However, in the real world, lines may be more complicated than that.

Benoit Mandelbrot, the American-French-Polish mathematician, described the basis of a new branch of mathematics where geometrical dimensions could be **fractional** instead of integer. This theory had many interesting applications in physics, economy and even the arts. The fractal dimension was found to be an interesting parameter to describe physical surfaces, and especially engineering surfaces.



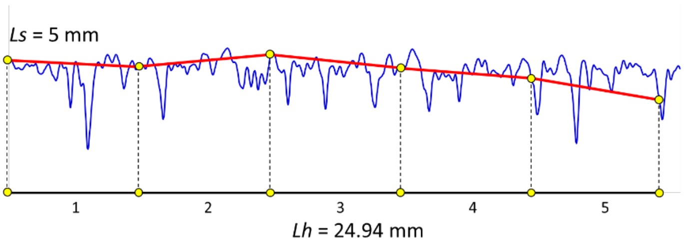
A rough surface is like a microscopic mountainous surface, and its fractal dimension can be seen as an attribute characterizing its complexity. A very smooth and planar surface will have a fractal dimension close to 2.0 but a ceramic surface, which features many pores and cavities, will have a higher value, maybe closer to 3.0 than 2.0.

The work of Mandelbrot applied to engineering surfaces was developed in particular by Professor Christopher Brown of Worcester Polytechnic Institute (WPI) who introduced length-scale and area-scale analyses, together with several other parameters and statistical methods to establish functional correlations and discriminations.

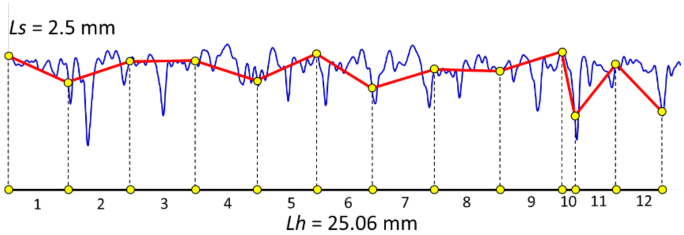
These techniques are designated by the acronym SSFA – scale-sensitive fractal analysis.

2. SCALE-SENSITIVE GRAPHS

When using length-scale analysis, a line-segment of fixed length (the reference scale) is used to measure the actual length of a profile (or a surface line). The cumulated length divided by the horizontal length is called relative length. This value is between 1.0 and 2.0

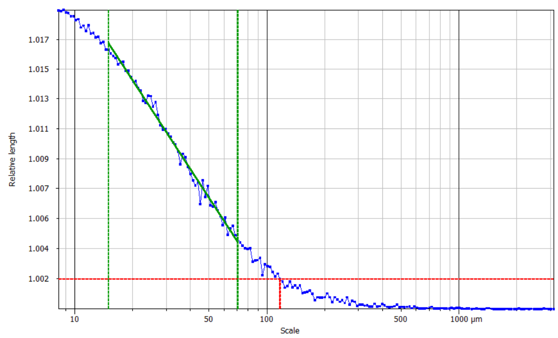


In the example above a segment of 5 mm length is used to measure a profile. We can fit 5 segments into a horizontal length of 24.94mm. The relative length is therefore 25.0/24.94 = 1.0024.



However, if we use a segment of 2.5 mm it is possible to fit 12 segments into a horizontal length of 25.06 mm, which gives a relative length of 1.197. In other words, the smaller the segment, the longer the measured length and the higher the relative length.

The measure is repeated with different segment lengths and a graph is drawn: log(relative length) in function of log(scale).

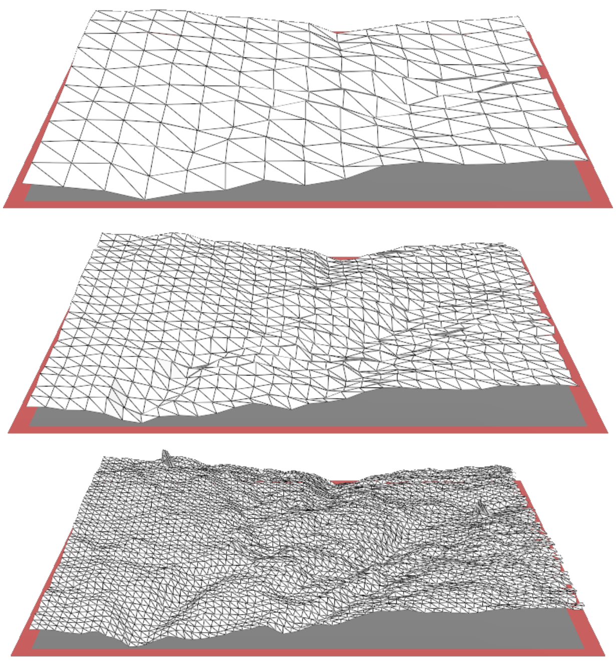


On this graph a threshold is set to find the smooth-rough crossover (SRC) which gives the scale of transition between large scales where the surface is analyzed from too far away (its fractal dimension is close to the Euclidian dimension 1.0) and scales where the fractal dimension really does describe the behavior of the surface. The central part, between the two green lines, is almost linear and its slope is used to calculate the fractal dimension.

3. CAN A SURFACE BE ANALYZED USING THE SAME METHOD?

The answer to this is yes, since relative length can be calculated on lines or on columns of the surface and the average value of relative length used to build the graph.

Alternatively, **area-scale method** can be used, where triangular tiles of a fixed area are used to calculate the actual area of the surface, and the relative area is obtained by division with the projected area. A similar graph is obtained and the same parameters can be calculated.



Above. Three tiling exercises with different tile sizes.

4. RELATED PARAMETERS

These parameters are used in various fields of metrology and research such as the study of adhesion strength, fracture analysis, thermal-spray coating, tool wear etc.

- **Smooth-rough crossover:** this parameter is very useful for applications related to friction and contact.
- **Maximum relative length/area:** the value at the finest scale. On a surface, this value converges towards the ISO parameter Sdr.
- **Fractal dimension:** calculated on the linear part of the graph.
- **Complexity:** characterizes how much the surface is more complex than a Euclidian plane (or a profile from a Euclidian line). This concept is somewhat similar to the ISO parameter Sdq.
- **Scale of maximum complexity:** scale at which the surface exhibits its higher complexity. This parameter can be used in correlation studies with functional attributes.
- **Regression coefficient R^2:** a high value confirms the accuracy of the complexity value.
- **Heterogeneity of complexity:** where the surface is analyzed by blocks (for example 5x5) and the dispersion of complexity is calculated.
- Some parameters initially developed for dental texture analysis by Rob Scott and Peter Ungar.

One advantage is that these parameters are calculated within a scale range where the function is found to be active. This scale-limited approach is more powerful than calculating a field parameter on a surface with a default filter.
> See our Surface Metrology Guide videos on scale sensitive approaches: goo.gl/WyE3G8

The parameters listed above are described in ISO 25178-2, clause 4.4.9 and are also part of ASME B46.1:2002.

5. WHERE CAN I FIND THE TOOLS?

Recent versions of MountainsMap® 7.4 offer a new optional module called **Scale-Sensitive Fractal Analysis** which implements most of the methods that were available in Sfrax software (developed by Prof. Brown). This module can be tested for free for 30 days and purchased as a separate module. Special prices are available until June 30, 2018.

References

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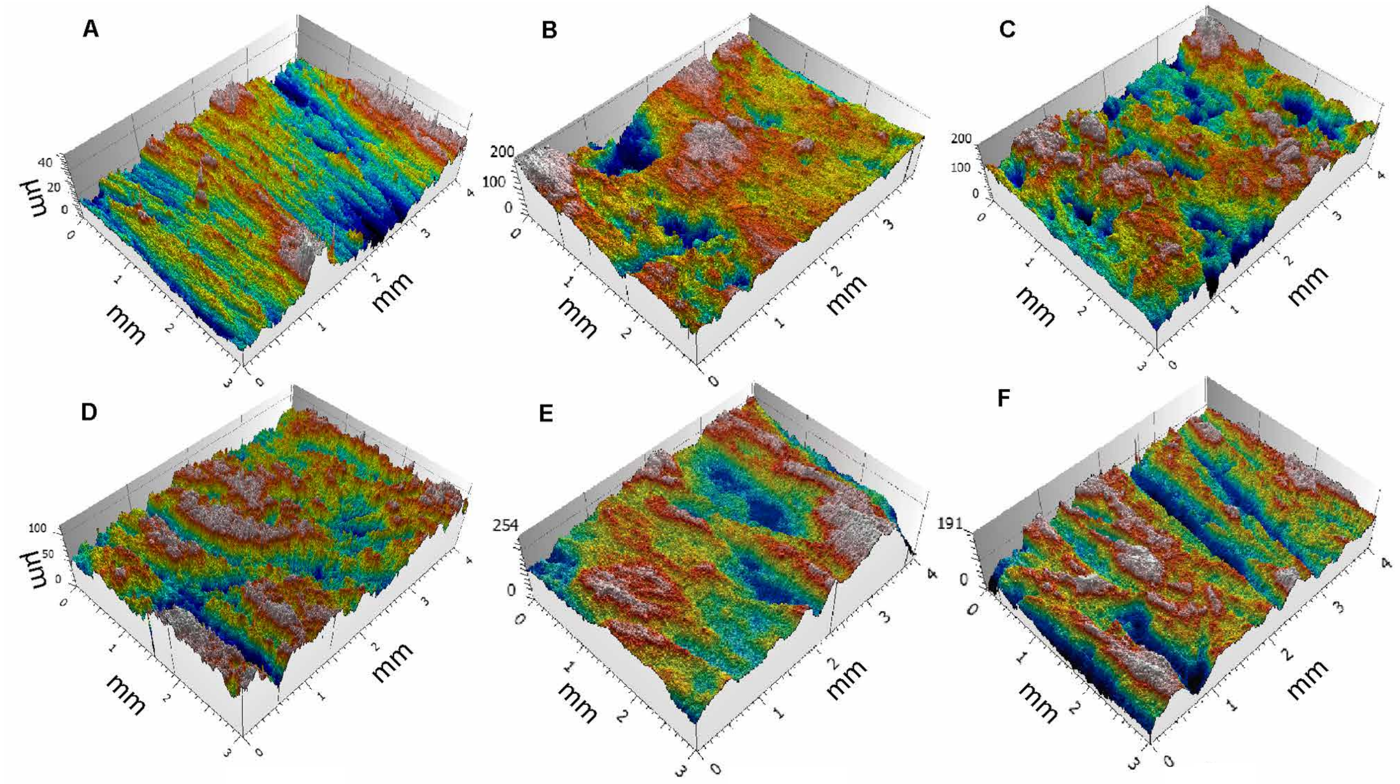
- Brown C.A. (2013) Areal fractal methods, in Leach: Characterization of areal surface texture, Springer.
- Scott R.S. et al. (2006) Dental microwear texture analysis: technical considerations, J Human Evol, 51(4):339-349.

SURFACE PARAMETERS GIVE CLUES TO LIFE IN THE MIDDLE STONE AGE



3D views of some of the experimental (A to C) and archaeological surfaces (D to F) used in the study, generated using SensoMap software based on Mountains® technology

Porc-Epic cave is located near Dire Dawa in eastern Ethiopia. It is home to the largest collection of ochre fragments ever discovered at a prehistoric site in East Africa, dating back to the Middle Stone Age (i.e. 35,000 to 40,000 years ago).

A team of archaeologists from the University of Bordeaux working at the site have recently been using conventional roughness parameters to analyze measurements taken on some of the ochre fragments. Alain Queffelec of the French National Centre for Scientific Research (CNRS/ PACEA) tells *Surface Newsletter* how, more widely speaking, this is contributing to a greater understanding of the behavioral system of stone-age man.

"The purpose of our study is to bring new light to the debate on the origin and development of cultural complexity and to improve our understanding of the symbolic behavior of hunter-gatherers during the Middle Stone Age in East Africa" says Alain Queffelec.

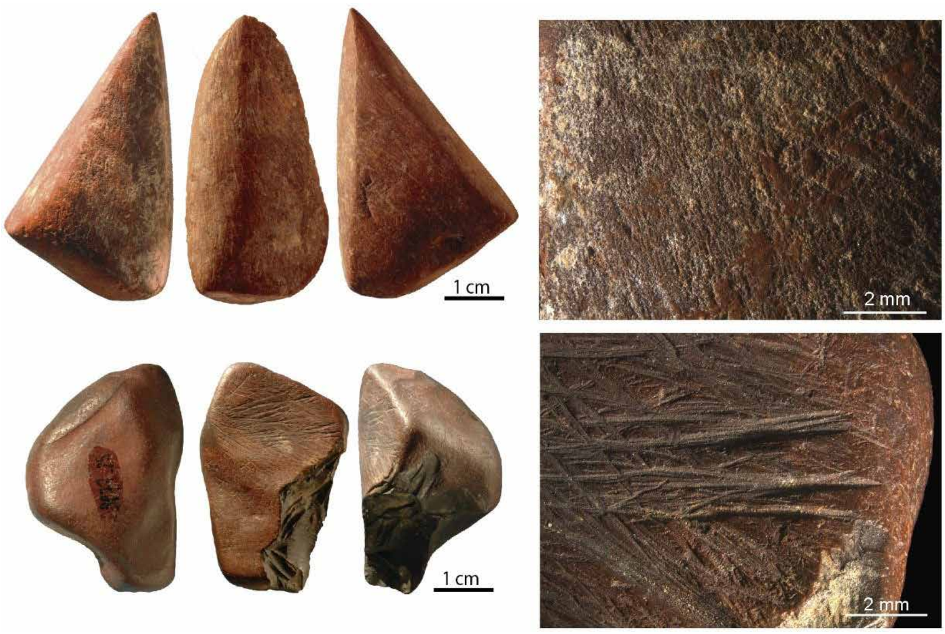
"In order to do this, we analyzed a collection of ochre pieces found at Porc-Epic cave. A large number of these show traces of use, in particular flaking scars and striations produced by grinding."

Analysis using surface parameters

"Non-invasive tribological analysis using a Sensofar S neox optical profilometer was conducted on 19 fine-grained archaeological ochre fragments with one or several abraded facets (see examples in figure page 5). The results of this analysis were compared to an experimental reference system established using pieces of ochre abraded on grindstones similar to those found at the site.

The resulting surfaces were processed using SensoMap software based on Mountains® technology in order to eliminate shape then remove outliers, fill in non-measured points and separate waviness from roughness by applying a Gaussian filter with a threshold of 0.25mm.

The term **"ochre"** refers to a variety of rocks characterized by a red or yellow color or streak, from soil lumps to ore minerals, containing a high proportion of iron oxides.



Left: Two examples of ochre fragments with facets and details of these facets showing striations.

The figure on page 4 shows some examples of these surfaces, including experimental surfaces. After testing multiple standard parameters (ISO 25178), Sq and Sdr were judged the most effective for differentiating experimental surfaces. As a result, these two parameters were used for the comparison of archaeological surfaces."

Confirming the symbolic use of ochre

"Our results indicate that some archaeological samples show similar wear on all facets whereas, in others, wear on different facets differs. This makes it possible, for the first time, to confirm that the ochre fragments were used on different grindstones and probably reused at different times to produce small quantities of ochre powders. These powders, of different colors and granulometry, may have been used for purposes of a symbolic nature (such as body painting, producing patterns on media or signaling)."

Conclusions and perspectives

"The results of this study greatly improve our understanding of the use of ochre by hunter-gatherers in the Middle Stone Age.

Measurement analysis using conventional roughness parameters allowed us to create, for the first time, a quantified referential model. Application of other analysis methods such as wavelets or fractal analysis could enable further research in this field in the future.

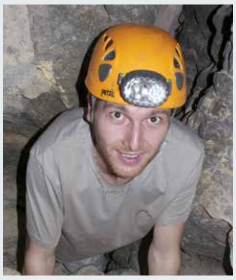
The study of ochre pieces from other sites analyzed using a similar methodology could help identify changes through time in the way ochre was modified and provide more information on its functions during the Middle Stone Age. Ultimately, this could help establish when early humans first used pigments symbolically."

About the authors

Alain Queffelec, Daniela Rosso and Francesco d'Errico belong to the PACEA laboratory, a research unit of the Centre National de la Recherche Scientifique (CNRS), the University of Bordeaux and the French Ministry of Culture.

PACEA research mostly focuses on Palaeolithic cultures in Europe and Africa and their environment, biological anthropology, funerary practices and rock art.

Learn more: www.pacea.u-bordeaux.fr



A.Queffelec

D. Rosso

F. d'Errico

Read more

Rosso, D.E., d'Errico, F., Queffelec, A., 2017. **Patterns of change and continuity in ochre use during the late Middle Stone Age of the Horn of Africa: the Porc-Epic Cave record.** PLOS ONE 12, e0177298. http://doi.org/10.1371/journal.pone.0177298

SEM IMAGE 3D RECONSTRUCTION: WHAT ACCURACY CAN I EXPECT?

Transforming a pair of standard two-dimensional scanning electron microscopy images into "topographic" images, in other words, those expressing x, y, and z (height) coordinates, can be very useful for quantifying surface features such as step height, volume, angles etc.

As a result of an ongoing research program spanning several years, Mountains® SEM software users have access to 3D reconstruction tools based on proprietary algorithms which benefit from constant improvements and updates.

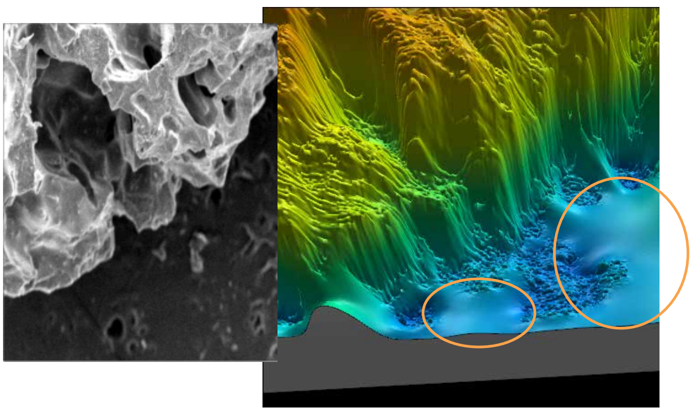
Using the principle of stereophotogrammetry, this technique requires acquiring two SEM images of the same object from different angles.

However, many different factors may influence the result of reconstruction achieved in this way.

Here, we discuss why it is important that users take time to set up appropriate experimental conditions before imaging their sample and what effect this will have on the accuracy of results.

1 Consider the nature of your sample surface

One of the major influences on good image generation is the nature of the sample surface. In particular, **sample images with large uniform zones** will make it difficult to correctly identify common points in each of the two images and thus perform reconstruction.



Above. *Detail of a SEM image (left) and the result of 3D reconstruction (right). The dark, uniform zones with no detail are not calculated and are "filled-in" by interpolation.*

2 Make sure you get sample tilt right

Creating a 3D height model of the sample requires two images that have been tilted relative to one another.

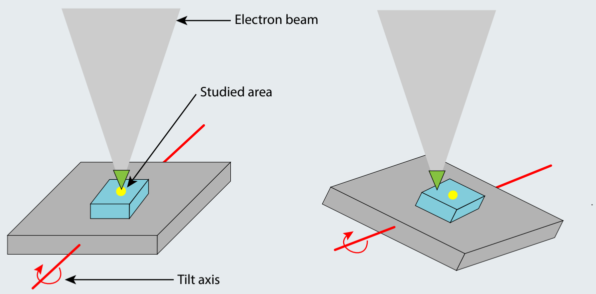
Most recent SEMs provide options for controlling sample tilt and rotation. For the most accurate results, it is preferable to use a SEM equipped with a eucentric table.

What is eucentricity?

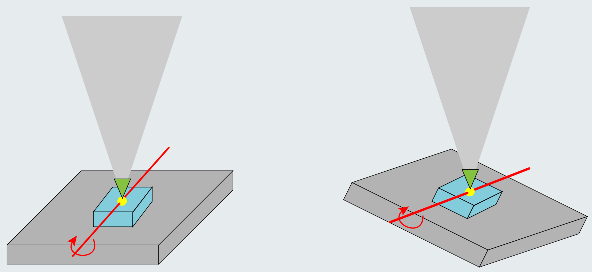
The "eucentric position" is the horizontal center of the objective lens. It is important that the sample be set to this height to avoid shift in position and focus when it is tilted. To do this, the tilt axis should:

- cross through the studied area of the sample (in order to avoid the sample "escaping" from the image field) AND
- be aligned or perpendicular to the scan direction.

Not eucentric:



Eucentric:



Respecting eucentricity when obtaining an image pair will significantly improve the accuracy of reconstruction.

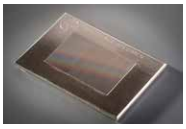
3 Use reconstruction software with a proven track record

Mountains® SEM software not only provides 3D surface visualization in color, it also makes it possible to carry out studies of surface metrology and in particular height measurement.

In the example below, a surface roughness reference specimen was imaged using a SEM following the guidelines in points 1 and 2.

> **Reference specimens** are used in quality control for checking and calibrating the metrological characteristics of surface measuring instruments.
>
> **Ra** is a roughness parameter calculated on a profile.

Example: 3D reconstruction using Mountains®



Surface roughness specimen
Ra = 3µm with cut-off 0.8 mm
Nominal lateral period: RSm = 100µm
Ref. 527 Rubert & Co

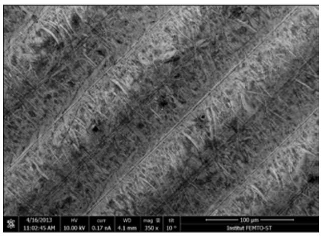


Image 1: 10° tilt

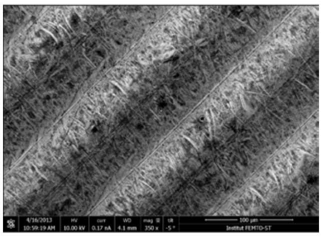
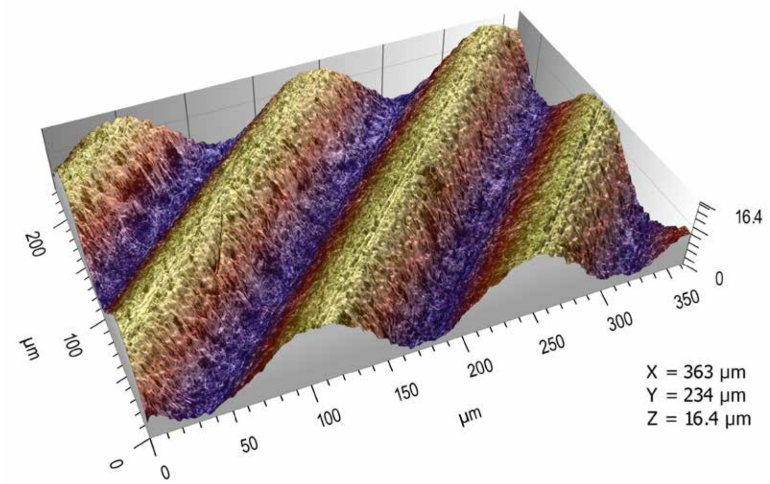


Image 2: -5° tilt

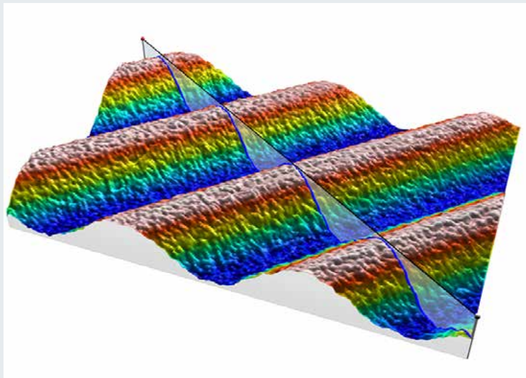


3D view of surface topography

How can I be sure of height accuracy?

Following calculation conditions defined in the ISO 4287 standard, Ra was calculated on the 3D reconstruction created using the SEM stereo pair.

A profile was extracted from the 3D model:



Ra was calculated on this profile:

ISO 4287			
Amplitude parameters - Roughness profile			
Ra	µm	*Gaussian filter, 0.8 mm*	3.00
Amplitude parameters - Primary profile			
Pa	µm		3.00

Result: the Ra of this reconstructed surface was found to correspond exactly to the Ra of the physical reference specimen.

Conclusion

Just as high quality ingredients will result in a premium food product, the quality of SEM images used for 3D reconstruction will strongly influence the end result.

Sample preparation may seem a tiresome process but, as the above example shows, output quality is dependent on getting this stage just right.

> See Mountains® SEM image 3D reconstruction in action
Watch this video (and many more) on our YouTube channel: youtu.be/V8yK65Jctyg

WHAT IS THE Sdr PARAMETER AND WHEN CAN IT BE USED?

With the wealth of parameters contained in ISO and other international standards and available to Mountains® software users, it can be easy to get a little lost.

Take one of the areal parameters, Sdr. What exactly is this parameter and what can it be used for?

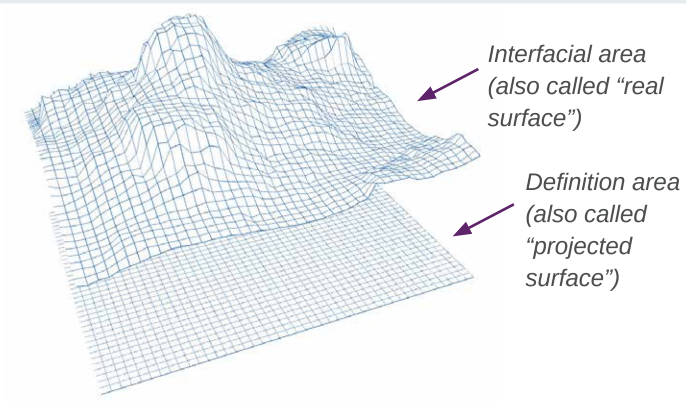
Isabelle Cauwet, Applications and Support Manager at Digital Surf, gives an expert answer to this frequently asked question.

Have you ever heard of the Sdr parameter? No? What if it turned out to be the ideal indicator for characterizing the functionality of your surface data?

In this issue, several Mountains® users share with us the benefits of studying the correlation between the developed surface area and surface functionalities including wettability, adhesion and conductivity.

So, to start with, what is Sdr?

To give a basic definition, the Sdr parameter can be considered as the ratio between the area of the "real" developed surface and the area of the "projected" surface. This ratio is sometimes called the "complexity" of the surface.



In the ISO 25178 standard, Sdr is defined by the following formula:

$$S_{dr} = \frac{1}{A}\left[\iint_A \left(\sqrt{\left[1+\left(\frac{\partial z(x,y)}{\partial x}\right)^2+\left(\frac{\partial z(x,y)}{\partial y}\right)^2\right]}-1\right)dxdy\right]$$

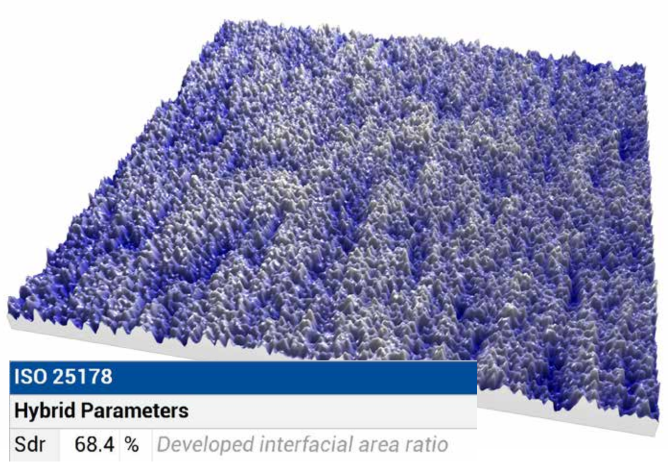
with A being the definition area

Case study: adhesion & conductivity in the electronics industry

The Sdr parameter has a important role to play in controlling surface properties of materials in electronics manufacturing.

Roy Li, application specialist at Carl Zeiss (Shanghai) told *Surface newsletter* "Customers in the printed circuit board (PCB) industry are using the developed interfacial area ratio as one of the key parameters for measuring the performance of brown oxide treatment."

"The purpose of brown oxide treatment on PCBs is to create a uniform layer of organic metal complex on copper surfaces to increase roughness and adhesion."



Sdr calculated on a surface treated with brown oxide

High frequency electrical conductivity is another functionality which must be evaluated within the electronics industry.

"We manufacture electro-deposited copper foil which has a wide range of applications in electronics" said Bodo Gemsleben of Circuit Foil Luxembourg.

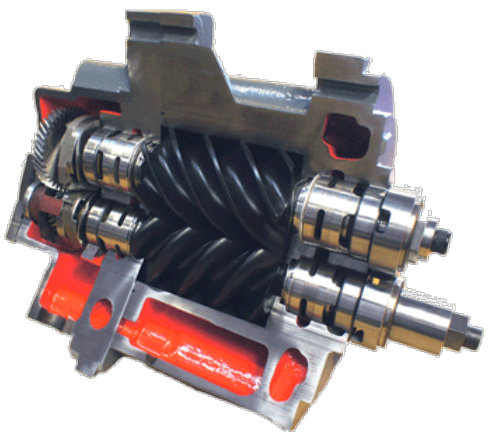
"At higher frequencies electrical signals are only conductive at the surface and no longer inside the copper tracks. For such applications, our customers often need to obtain lower surface roughness. However they also have to maintain high adhesion between the copper and the substrate materials (e.g. low-loss resins) in order to minimize the so-called conductor loss."

"The Sdr parameter, in combination with Sa and Sq, is especially useful for describing the surface in this case."

2 Case study: industrial coatings

Another example of use of the Sdr parameter is from the tool manufacturing industry. Daan Boden, PhD student in industrial engineering working at Atlas Copco (an air compressor manufacturing company) tells us more: "One of our specialties is oil-free compressors, the rotors and casing of which must be coated. To ensure coating adhesion, the surface must be made rougher (this is done with sand-blasting)."

"The forms of our workpieces are quite complex and the dimensions are rather big. We decided to use the Sdr parameter after performing optical measurement of these, as it is the areal variant of the Plo parameter (developed length)."



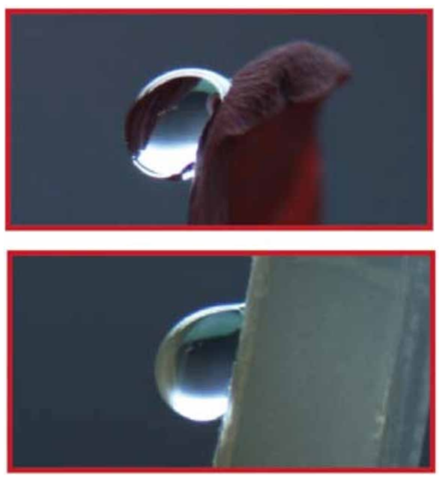
Coating adhesion on mechanical workpieces can be studied using the Sdr parameter.

3 Case study: biofilm wettability

Carolina Falcón García, Professor in Biomechanics at the Technical University of Munich (Institute of Medical Engineering), is using µsoft software from Nanofocus based on Mountains® technology to study the surface properties of biofilms. "The colonization of surfaces by bacterial biofilms constitutes a huge problem in healthcare and industry." explains Carolina. "When attempting biofilm inactivation or removal, it is crucial to sufficiently wet the biofilm surface with antibacterial agents. However, certain biofilms efficiently resist wetting and the origin of this behavior remains to date unclear."

"We discovered that the Sq value, which is generally accepted as a measure of the roughness of a surface, was not sufficient in describing the complexity of these biosurfaces. We found that Sdr was the actually the most accurate parameter for doing this. Using Sdr in combination with contact angle measurements, we were able to easily distinguish between a hydrophilic surface and two types of hydrophobic biofilm surfaces."

"In a recent study, we found that the Sdr values we obtained for the peripheral region of one biofilm were very close to the values we obtain for rose petals. This further underscored the analogy drawn between the wetting resistance of rose petals and that of one of the hydrophobic biofilms."



Top: rose petal. Bottom: hydrophobic biofilm. The Sdr values of the two surfaces are very close.

Read more : www.nature.com/articles/s41522-017-0018-1

How to get the most out of the Sdr parameter

According to the definition in the ISO 25178 standard, the Sdr value should be calculated on the scale-limited surface ie. the S-F or S-L surface. This means that the microroughness should be removed, as well as the nominal form.

The Sdr parameter is heavily influenced by the spatial resolution of the instrument, which depends on the x,y spacing between measured points and on the type and metrological characteristics of the sensor (numerical aperture, tip radius etc.)

The Sdr parameter (and the value of the developed area and projected area) is available in MountainsMap® Premium, as well as in the 3D Advanced Surface Texture and the new Scale-sensitive analysis modules (see pages 2-3).

Read more on surface parameters in the Surface Metrology Guide: www.digitalsurf.com/guide

EVENTS & PRODUCT HIGHLIGHTS

Looking back at a busy winter show season

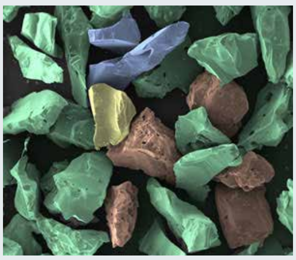
With over 6,500 attendees representing 54 countries, the **Materials Research Society Fall Exhibit** in Boston, USA is an important event and an excellent opportunity to meet customers working in the vast field of materials science. Nicolas, Arnaud, Anne and François represented Digital Surf on booth #702 where visitors viewed the latest Mountains® capabilities as well as 3D printed models of our competition winner's data!

The Digital Surf team was also very excited to participate at the world's biggest event in nanotechnology, **Nanotech**, in Tokyo, Japan mid-February. Arnaud and Damien presented Mountains® software features on the EU-Japan Centre for Industrial Cooperation booth.

Finally, it was in Digital Surf's native France that the **Forum des Microscopies à Sondes Locales** took place mid-March. Nicolas and Arnaud were on hand to meet with the French-speaking scanning probe microscopy community and demonstrate Mountains® and SPIP tools for image analysis.

Product news

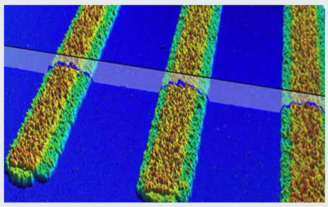
▶ TopoMAPS software



Researchers and engineers using **Thermo Fisher Scientific**'s revolutionary scanning electron microscopy (SEM) systems (including FEI Company) now have access to all the power of Mountains® technology. New TopoMAPS software opens up exciting possibilities for SEM colorization and reconstruction in a wide variety of application areas.

Read more: goo.gl/ZUkZgJ

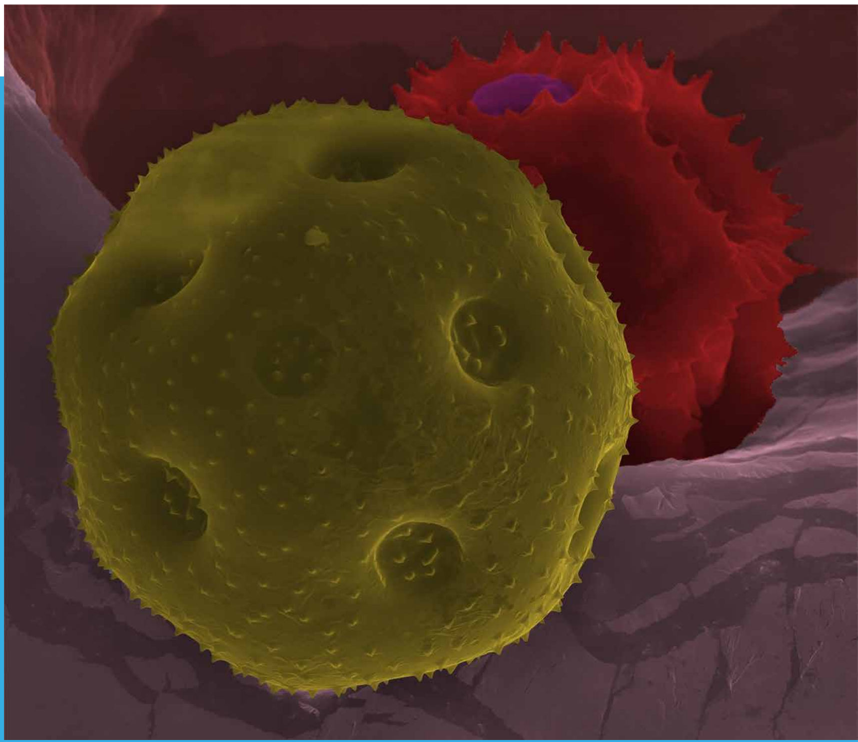
▶ FocalSpec Map



Finnish high-tech company **FocalSpec**, specializing in devices for fast surface measurement and on-line testing of challenging materials and shapes, and Digital Surf announced they have teamed up to release FocalSpec Map, a cutting-edge software package bringing a whole new set of tools to users of the company's innovative Line Confocal Imaging (LCI) technology.

Read more: goo.gl/s9bWab

WHAT'S HOT ON-LINE



Seen on Twitter @YorkUMicroscopy

3/12/18: A striking scanning electron microscope image of pollen colorized using MountainsMap®. Nice work Magdalena Jaklewicz at York University Imaging Facility in Toronto, Canada. Spring has definitely sprung!

Have you visited our YouTube channel recently?

Discover tips for getting started in Mountains®, tutorials for SEM image reconstruction & colorization and much more!

www.youtube.com/channel/UC5cyEQHs-9IWZdn0p-cJcJA

Popular on Facebook

3/8/18: Celebrating International Womens Day with some of the amazing women in the Digital Surf team.

Surface Newsletter

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16 rue Lavoisier
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www.digitalsurf.com

Tel: +33 38150 4800
contact@digitalsurf.com

Surface Newsletter
Editor: Christophe Mignot
Content editor: Clare Jamet - Contributors:
Anne Berger, François Blateyron, Isabelle Cauwet, Cyrille Charles, Alain Queffelec, Daniela Rosso, Arnaud Viot
Contact: marketing@digitalsurf.com
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