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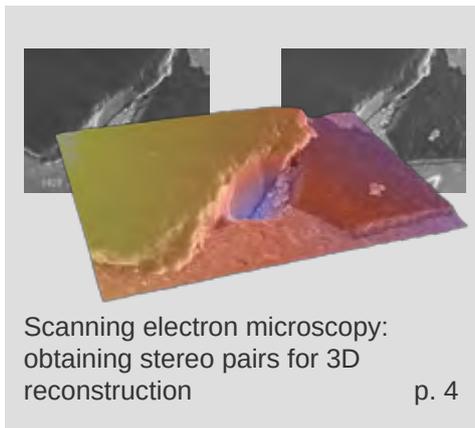
Dealing with surface defects

A new standard for calibration specimens



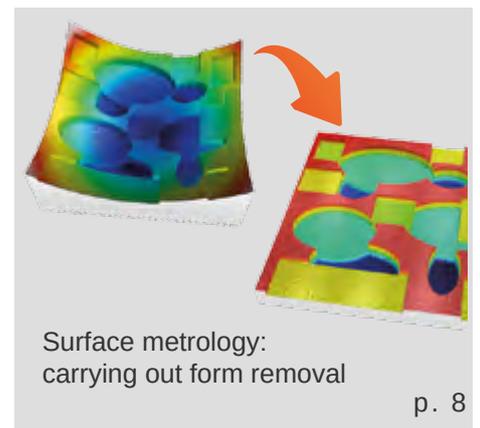
Paul Rubert, reference standards expert, explains how a new international standard, currently in preparation, will help metrologists deal with the problem of surface defects

[Read article overleaf](#)



Scanning electron microscopy: obtaining stereo pairs for 3D reconstruction

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Surface metrology: carrying out form removal

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PLUS

We look forward to seeing you at



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STAND #3412

Met&Props

16th Conference on
Metrology & Properties of
Engineering Surfaces

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IDENTIFYING AND RESOLVING THE PROBLEM OF SURFACE DEFECTS



The appearance of defects on the surface of a part or workpiece presents difficulties for surface metrology at many different levels. Paul Rubert, reference standards expert, outlines the problem for Surface Newsletter.

When dealing with surface defects, the following questions must be answered:

1. Is this defect serious, and will it prevent the part from working properly?
2. How should we check the part for defects, and how should we measure them or describe them?
3. How can we be sure that this feature, which we can see with our naked eye or under a microscope, really is a defect? In other words: how should a defect be defined?

Over the last few decades, the national standards bodies, together with ISO, have published hundreds of standards to enable manufacturers (suppliers) and customers (users) to agree on features which a product should have. But when it comes to specifying undesired features, the situation is very different. Very little guidance is available, and in many cases the guidance that exists is confusing and even contradictory.

Industry-wide standards which describe defects on a manufactured product exist in only a few highly specialized areas. For example, ISO 10110-7 deals with defects on optical components. In most cases, however, defects are defined and described only in the internal documents of individual companies.

Can international standards deal with this issue?

Because of this, there is a demand for international standards to deal with defect-definition for engineered surfaces that have to perform a certain function or job. As a result, metrologists are often under pressure to provide these standards.

Nevertheless, in the case of such functional surfaces it is best to leave the work of defining defects to experts in each field of application. Clearly it has to be a marine engineer who defines what is and what is not a defect on a submarine propeller blade, and it has to be medical specialists who decide what is a defect on the surface of a hip implant.

Why is the situation different for reference standards?

In the special case of calibration standards for surface metrology, the situation is different, because calibration standards are not functional surfaces that are designed to perform a physical job. Instead, they exist only to be measured here and there. This makes it easier to define both the defects themselves and also the various ways of dealing with those defects.

A Geometrical Product Specifications (GPS) standard for surface defects on calibration specimens is currently being prepared by ISO TC213 / WG16 and will appear as part 73 of the ISO 25178 family of standards.



In science and industry, surfaces are inspected for simple defects such as pits, bumps, scratches and holes or more complex ones like laminations and oxidation (see ISO 8785).

What the new standard will do

1 The new standard currently in preparation defines a few simple terms for classifying defects according to :

- whether they are visible to the naked eye or not
- whether they are topographically upward (outward) from the surface or downward (inward)
- and whether they are large enough (effective) or too small (ineffective) to influence a measurement.

This group of terms will help educate users of calibration specimens about the relative significance of different types of defect on calibration specimens. It often happens that a feature which is clearly visible and may "look bad" has a negligible effect on measurements, whereas on the other hand, a defect which will seriously affect a measured value may be invisible to a naked eye.

A few examples

One common type of defect which in most cases is completely without influence on measured values is the case of **discolorations or stains**.



Stain on a sinusoidal profile with $R_a = 3 \text{ }\mu\text{m}$



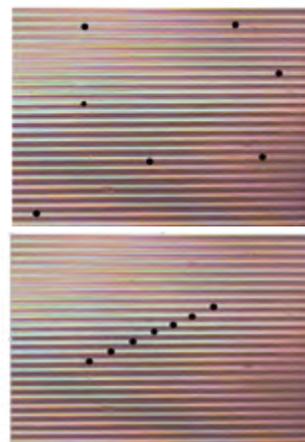
Edge of the stain, shown at higher magnification

2 The standard also defines all the possible ways of responding to a defect on a calibration standard, for example:

- to avoid that defect and measure somewhere else
- to measure the defect and use the data
- to pay no attention to whether there are defects and measure according to some other rule
- or to repair the defective data by altering the data at the software stage.

This group of terms is needed whenever it is necessary to state what procedure has been followed when calibrating a reference specimen. In the case of a calibration certificate, for example, it is important that the customer knows exactly how the calibrating laboratory responded to the occurrence of surface defects on his specimen.

Another type of cosmetic defect which has no influence on measured values but is visible by naked eye are the so-called **Gestalt defects**. These consist of small distortions of the surface, individually completely invisible and ineffective but which are arranged in a pattern that is then noticeable but still ineffective. Many scratches which appear on surfaces are found to consist of such patterns.



Several small defects are invisible when randomly arranged

The same defects arranged in a straight line become noticeable

About the author



Paul Rubert is director of **Rubert & Co. Ltd.**, a specialist manufacturer of reference standards and comparison specimens for use in surface metrology. Founded in 1941, the company began manufacturing electrical tools and equipment, branching out into mechanical engineering during the 1950s. Since then it has concentrated exclusively on surface measurement.

In 2015 **Rubert & Co.** achieved UKAS accreditation to ISO 17025 for its Calibration Laboratory, making it only the second calibration service in the UK to offer roughness measurements with 2% uncertainty.

The company has participated in several EU-funded research projects and is active in standards-writing work both at national level and on ISO committee TC213 Working Group 16 which publishes surface metrology standards.

Learn more: www.rubert.co.uk

7 TIPS FOR PRODUCING SEM STEREO PAIRS

For accurate 3D reconstruction with Mountains®



“ The Stereoscopic Reconstruction operator available in Mountains® enables users to obtain a precise 3D model from a stereoscopic pair of SEM images in just a few seconds. However, before running this operator, there are a few things you need to know.

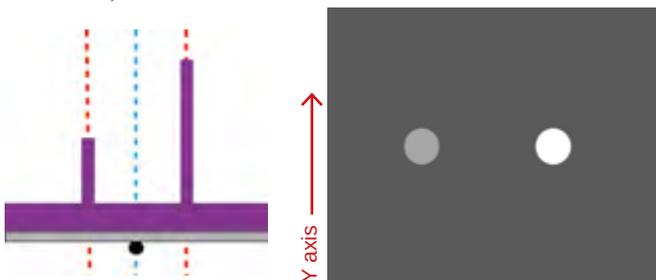
Isabelle Cauwet, applications engineer, takes us through her recommendations for producing good quality stereo pairs.

1 Capture two images of your sample

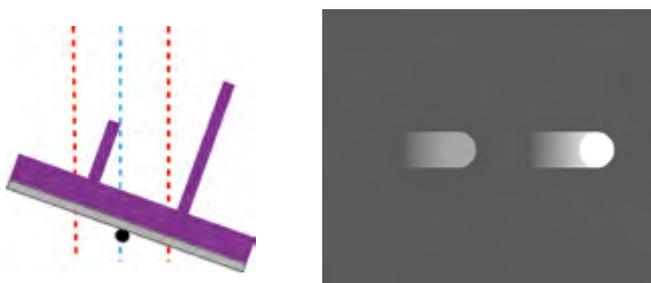
For stereoscopic 3D reconstruction to work correctly and accurately, the two SEM images used must be taken from two different angles of view.

A stereo pair is typically obtained by tilting or rotating the sample by a few degrees along the X or Y axis.

The diagram below represents the SEM tilt stage (left) and a sample to be studied (right). Topography has been simplified to two "pillars", one low and one high (the sample is pictured from above):

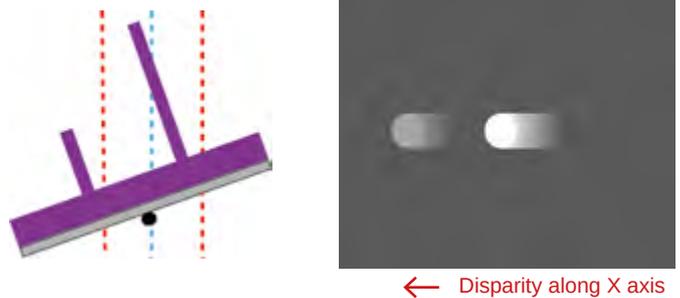


When the sample is rotated around the Y axis, we can see that the top of the pillars have moved right along the X axis:



Disparity along X axis →

Now if we reverse rotation, the pillars move left along the X axis:



← Disparity along X axis

In the two resulting images, the difference between the positions of the pillars is called **disparity**. Note that the higher the pillar, the greater the disparity.

And if disparity and angle of rotation are known values, it is possible to determine the height of the pillars.

A few other things to bear in mind...

Remember that image disparity is increased by:

- increasing magnification
- increasing tilt difference between two images
- increasing image resolution

If you already have a rough idea of the height value of your sample, you should choose a magnification value which will result in an image 20 times as wide as the expected height value and use a tilt value of 5 to 10°.

Example for an expected height value of 1µm:

- rotate the sample 10° around the Y axis and set image width at 20µm along the X axis
- or rotate the sample 10° around the X axis and set image width at 20µm along the Y axis

After a bit of practice, you will be able to reconstruct samples featuring smaller height values.

2 Ensure disparity is along one axis only

To achieve accurate reconstruction it is important to make sure that the sample table is rotated **around one axis only** between image takes.

If the table is rotated around the X axis only, disparity will be along the Y axis. Similarly if the table is rotated around the Y axis only disparity will be along the X axis.

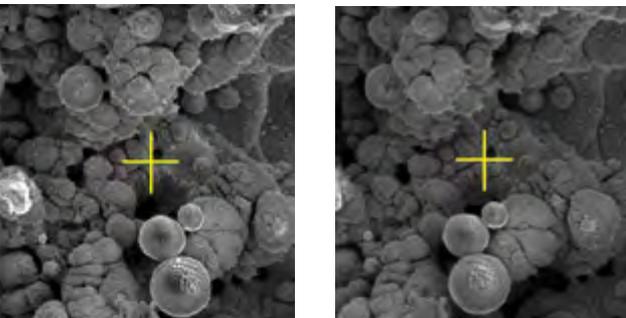
NB. Reconstruction is still possible with a disparity of just a few pixels along two axes (X and Y), but calculation time will be significantly longer and the result will be less accurate.

3 Eliminate shift

In order to avoid image shift, if you have a eucentric table, the center of the rotation axis should coincide with the center of gravity of the sample.

In all other cases, when rotating the table between two image takes, you should ensure that a significant feature of your sample is positioned at the same point on each.

Once again, Mountains® can deal with image shift of a few pixels, but this significantly increases calculation time.

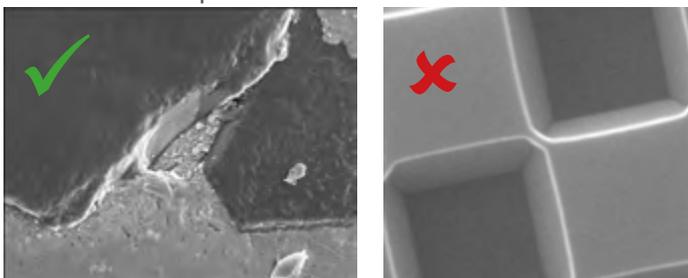


4 Use the same magnification and working distance

As a general rule, magnification and working distance (distance from the sample to the projected image) should be the same for both images.

5 Work with textured images

Only sufficiently textured areas in images may be successfully matched. It is important to avoid uniform zones.



Similarly overexposed zones do not contain enough texture and cannot be matched correctly.

6 Only use clear and focused images

Make sure that the images are clear and properly focused. If the images are blurry then the quality of the reconstructed image will be reduced.

7 Use images with the same contrast and brightness

Make sure that both images have the same contrast and intensity. This will make point matching a lot easier.

The Enhance Image Operator in Mountains® can be used to correct image contrast and brightness before reconstruction.



Check your images: Once you have your stereo pair, you can do a quick visual check by opening the images in your File Explorer and switching quickly from one to the other.

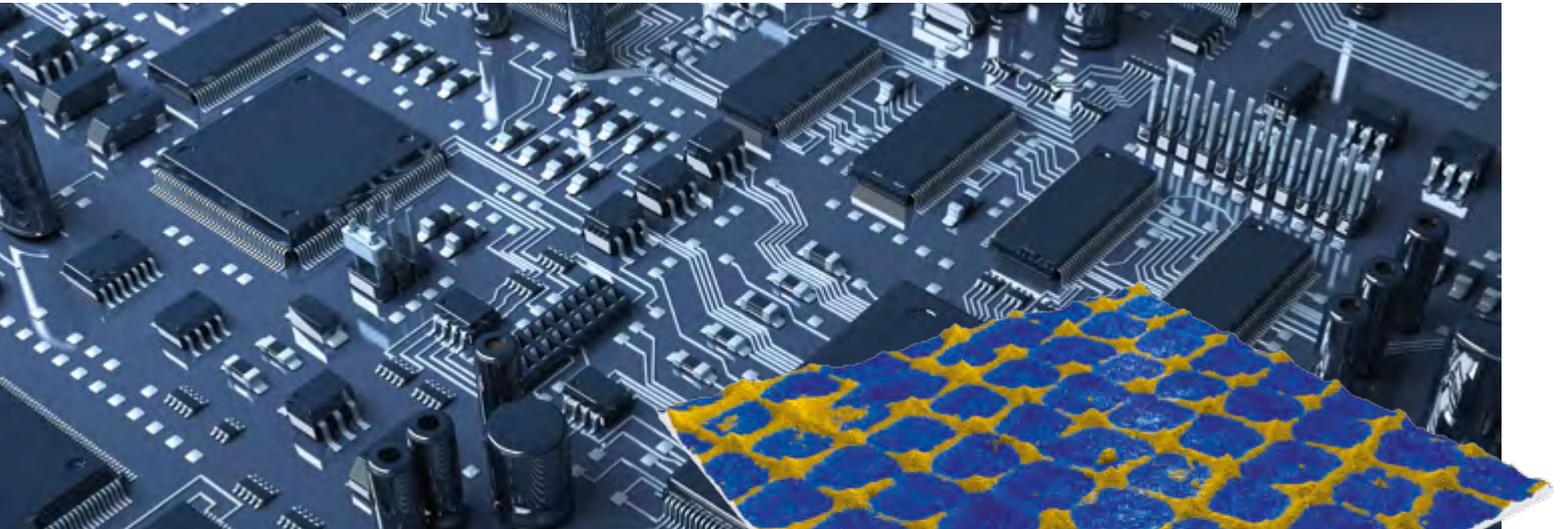
> Find out more about stereoscopic reconstruction

Watch our video on YouTube:
youtu.be/V8yK65Jctyg



MY FIRST PROJECT WITH MOUNTAINSMAP®

ONE USER'S EXPERIENCE



When using new software, getting started can be tricky. But did you know that MountainsMap® product users benefit from personalized assistance right from the word go? As well as access to a whole host of online resources, this includes technical support supplied by an in-house team who will guide you while you get accustomed to the software and answer any questions you may have on specific applications. Let's have a look at one customer's first steps using the software and see what he was able to achieve within the first few weeks of use.

Peter Van Rompuy is Primary Lab Technician with Agfa-Gevaert, provider of imaging systems and IT solutions for the printing and healthcare industries (HQ located in Mortsel, Belgium). He recently acquired MountainMap® software to analyze the broad range of samples and analysis requests from internal research departments and the company's open innovation platform AgfaLabs (see www.agfa.com/sp/global/en/internet/agfa-labs/).

What instruments do you work with?

In 2002 we bought a stylus profiler, quickly followed by an interferometer and later on a confocal microscope. Now, 15 years later, we have 6 other interferometers worldwide for quality control purposes! A growing business...

What are the main challenges of your work?

At the central research department of Agfa-Gevaert we are challenged by a lot of issues. We characterize new materials but we also support our different business group's research and application departments. Furthermore, our open innovation platform AgfaLabs is growing consistently

and demands high-tech equipment, software and knowledge.

Up until now we were using our interferometer application software for all topographical analyses. A user-friendly software with lot of capabilities but also with some restrictions with respect to more complex analysis requests.

How did you hear about MountainsMap®?

At the end of last year a colleague told me about MountainsMap®. I was interested and had a look on the Digital Surf website. I decided to download the trial version and soon realized the software would have an added value for our research department!

What were your first impressions?

Installation and initialization were trouble free. The screen layout was innovative and functional but to be honest, it was not easy to begin with. I was not used to working with a ribbon toolbar which changes depending on which operator or study is selected. I was not familiar with the nomenclature used by the software (studiables, operators, studies and Minidocs). But I soon discovered some nice tutorials and examples together with a splendid on-line manual. Once you know how to open a dataset, perform some processing actions and analyze the processed data, I was surprised how easy and smooth the whole analysis worked out, resulting in a nice report!

What are the features you find most useful?

A very fine feature is the fact you can swap the loaded dataset with a new one and processing is done automatically, generating a new report! You can also save a report as a template for further use (called "minidocs"). At the right of the screen you will find an analysis workflow containing all the processing steps. At first it didn't know the added value of this list but soon you realize this is the place to alter settings in order to fine-tune your analysis. Once again, the software carries out the new processing immediately.

A very nice feature of MountainsMap® is the fact you can load almost any commercially used topographic file. Also, MountainsMap® processed files can be converted to instrument-type files for further use in the instrument-related software or to be further analyzed by our customer's applications.

What additional modules do you use?

We decided to buy the MountainsMap® Universal package with some extra optional modules: Grains & Particles, 3D Fourier & Wavelets and Advanced 3D surface texture. These modules are of great importance with respect to topographical analysis of spatial features. It is worth mentioning that this software package is extremely useful for dedicated wavelength or wavelet filtering of the measured surface texture. The Fourier analysis gives us the possibility to evaluate spatial features while the Grains & Particles module is useful for segmenting and characterizing local features.

What helped you most in your first few weeks using the software?

Aside from the software capabilities, I was very impressed by the comprehensive online reference guide (or the printed version like we have!) This guide is not just a manual but also a tutorial providing very useful information regarding all existing filter techniques and analysis algorithms. Furthermore textural parameters in MountainsMap® are categorized into their ISO standard group. This is very useful when you have to work according to a certain ISO standard.

To finalize this review it is worth mentioning Digital Surf's user-friendly customer support. It was not easy to start using the software (I didn't expect it would be!). Sometimes you wonder if a certain feature is available or not or you don't immediately find a solution in the help manual. At these times, you really need good and quick responding customer support. I must say, thumbs up for Digital Surf's support. They assist you by generating an analysis report with the necessary comments. Even when I was using the trial version I was able to benefit from email support many times.

In conclusion, superb software and great support! In my opinion, MountainsMap® is the way to go if you want to raise the bar and get the most out of your topographic datasets.

Tell us about your applications

"One of the things we have been using MountainsMap® for in particular is **studying substrates printed with conductive inks** in the aim of improving the performance of our printed electronics products.

Measuring the exact height of these inks is very important to us as their conductivity depends on this factor (see figure 1). We also need to quantify volume (figure 2) and area.

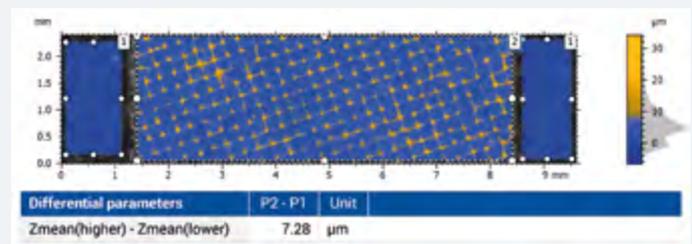


Figure 1. Height measurement of conductive ink

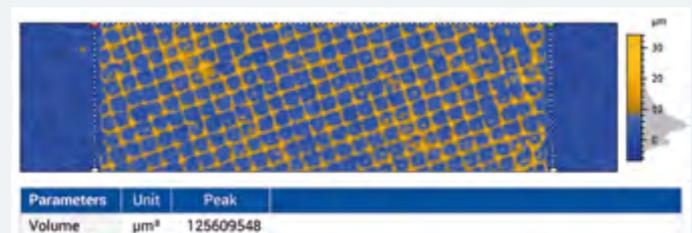


Figure 2. Volume measurement of the sample

We also use MountainsMap® to analyze the **hardness of our synthetic paper**. After performing an indentation test, we measure the "damaged" surface with our interferometer. However, this type of surface is difficult to measure due to the diffuse light scattering. Measurement of the center of the indentation is of good quality but the steep edges of the indentation pit result in a lot of non-measured points.

By means of MountainsMap®, it is easy to process these images (using the Filter and Remove outlier operators). We then are able to extract a representative 2D profile which runs through the center of the indentation."

New to Mountains® software? Have any questions?

Isabelle, Damien and Catharine from the MountainsMap® support team would be happy to help.

- **Contact them by phone +33 38150 4800 (9:00am - 6:00pm CET) or from Asia +81 368 21 1009 (9:00am - 6:00pm JST) or by e-mail support@digitalsurf.com**

Free support is included in all MountainsMap® products. If you are working with an OEM version of the software, you may contact your instrument manufacturer directly.

WHAT IS FORM REMOVAL AND WHY IS IT IMPORTANT?



Form is a component of surface finish which corresponds to the general shape of the surface. When analyzing surface texture (i.e. waviness and roughness), form should be removed.

François Blateyron, Digital Surf's ISO surface metrology expert, explains why and how this operation should be carried out.

The ISO 3274 standard specifies that the primary profile should not contain the nominal form of the workpiece. The form component must therefore be removed prior to any other metrological operation.

When the form is just a line segment or a plane, this action is called **leveling**. When the form is non-planar, it is called **form removal**.

So how do I go about leveling or removing form from my measured surface ?

What is nominal form?

Nominal form is the geometric form intended by the designer of a mechanical workpiece. Usually it is a planar form or a rotary form (cylinder, cone, sphere).

Surface texture specifications are made in reference to a flat surface, regardless of geometrical form, so the metrologist must apply an operation to flatten the profile or the surface before carrying out metrological analysis. This operation consists in modeling a shape and associating it with the cloud of measured points in order to subtract form.

In the case of a non-manufactured object, there is no nominal form, but it can still be useful to remove natural form.

Internal reference of instruments

On a 2D contact profilometer, the scanning axis along X gives the reference and defines the origin of heights. This reference is usually provided by a high precision steel rod on which pads slide to move the sensor and the stylus during scanning. Any straightness deviation from this reference is injected into the measured profile as a height bias.

Some profilometers can calibrate this straightness

deviation by measuring a reference glass flat and saving a straightness profile that is then subtracted from any subsequent measurement.

With a 3D optical profiler, the reference depends on the optical technology. In the case of a vertical scanning device, the alignment and linearity of the device influence the reference. The reference mirror of an interferometer also influences the height reference. In general, any disturbance is mapped during a calibration routine done in the factory or sometimes by users. See also ISO 25178-700.

Manual leveling and alignment

The metrologist should align the workpiece with measurement axes as closely as possible. For example, on a contact profilometer, the sample is positioned as horizontally as possible and aligned along the X axis, which is itself aligned on the internal reference of the instrument. This guarantees that heights are correctly recorded along the Z axis of the instrument which is very close to the Z axis of the workpiece. The leveling operation then subtracts the remaining fractions of degrees of the residual slope.

When measuring a surface, for example with a confocal microscope, the sample will be placed horizontally to ensure that the vertical scanning axis is as perpendicular as possible to the sample plane.

Reference line and reference plane

On a profile, the reference line is defined by leveling or form removal, and therefore depends on the association method. By default, the least squares line is associated with the profile. It becomes the horizontal reference of the primary profile, and defines the origin of heights. Similarly on a surface, the mean plane is calculated by the F Operator.

The default association method for surface texture metrology is the least squares association

Local structures and geometrical features may affect this reference by deviating from the associated plane.

Association methods

Association is an operation that configures a mathematical model in order to best fit a real workpiece, usually represented by a cloud of points. Models are geometrical forms (line, plane, portion of a sphere, of a cylinder, of a cone, polynomial, etc.)

Association methods used in surface texture metrology are:

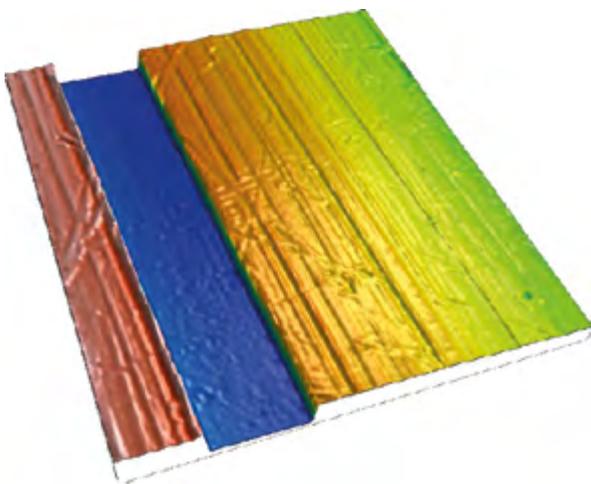
- least squares, simple or total, constrained or not;
- minimum zone.

The default association method for surface texture metrology is the least squares association. This is the best method if surface texture is globally random (stochastic), without any particular structure or geometrical shapes.

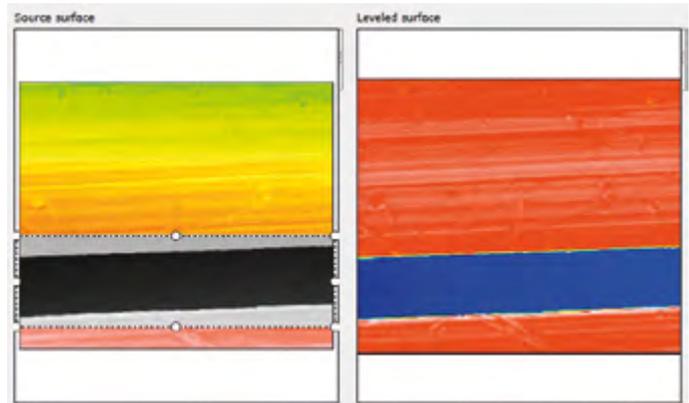
Exclusion of structures

When using Mountains® software, exclusion of structures can be manual or automatic, and allow the calculation to take into account only a subset of points of the profile or the surface when estimating the nominal form.

In the case of the surface below, the groove is not centered, which alters the calculation of the least squares plane, leading to incorrect leveling.



The solution consists in excluding the groove from the calculation by selecting it in the **Leveling** or **Form removal** operator dialog and to exclude this area from the calculation. The excluded area is marked in gray below.

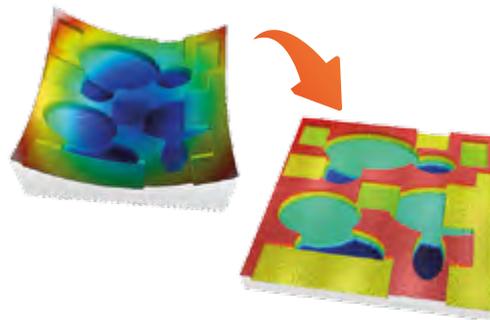


In other cases, structures can be automatically excluded (least-squares plane is calculated correctly only from points on the flat plane).

Multi-plane leveling

A surface with several planes at different heights may be leveled using the **Partition and level operator** that segments the surface using watersheds and pruning algorithms.

In more complex cases, when the different planes are affected by a general curvature that needs to be removed, it is necessary to use the multi-plane leveling function. This will assess curvature but ignore edges and heights.



Above. Multi-plane leveling is particularly useful in applications such as inspection of micro-systems having undergone thermal drift, sheet-metal embossing or height measurement of ink on a non-rigid material (bank notes etc.)

Resources

- This article is based on extracts from the new page on **Leveling and form removal**, in the Digital Surf Surface Metrology Guide: www.digitalsurf.com/en/guide-leveling-form-removal.html
- **ISO 1101:** GPS - Geometrical tolerancing - Tolerances of form, orientation, location and run-out
- **ISO 17450-1:** GPS - General concepts - Part 1: Model for geometrical specification and verification
- **ISO 17450-2:** GPS - General concepts - Part 2: Basic tenets, specifications, operators, uncertainties and ambiguities
- **ISO 22432:** GPS - Features utilized in specification and verification

EVENTS & PRODUCT HIGHLIGHTS

Mountains® ♥ Materials Research

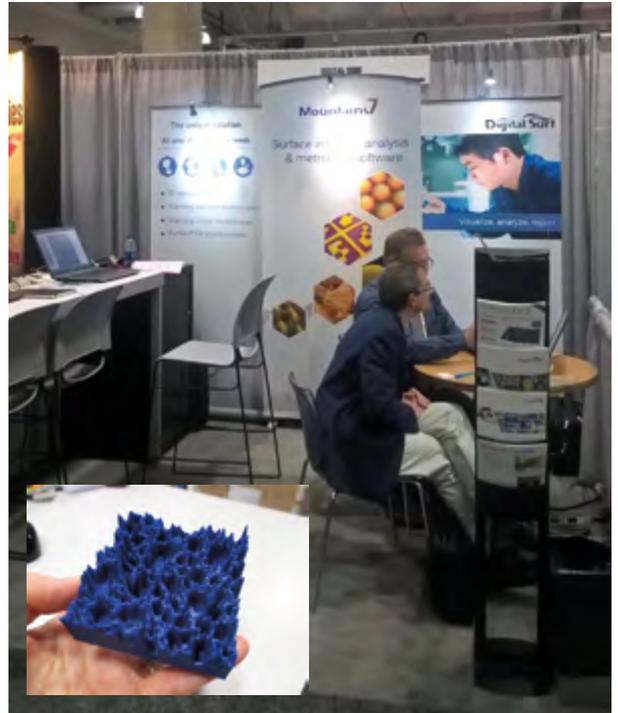
Even if Digital Surf is a regular participant at the Materials Research Society (MRS) Fall Exhibit, it is always a pleasure to make the annual trip to Boston.

Last fall, Anne, Arnaud and Nicolas welcomed visitors to Digital Surf's booth to discuss how Mountains® software can help scientists and engineers working in many different fields of application: glass and coatings, nanomaterials, ceramics, thin films etc.

For the first time, several 3D printed models were presented on the booth (see inset), illustrating an exciting new feature allowing users to create and export 3D printed models of their data directly within the Mountains® software interface.

Thanks to one and all for a great few days and we look forward to seeing you next year!

More info: www.mrs.org/fall2017



Surface metrology seminar in Paris

A new edition of Digital Surf's Surface Metrology Seminar took place in Paris on March 28th.

François and Anne were on hand to welcome an audience of 20 surface metrology professionals for a presentation of all the latest analysis methods including areal surface texture and filtration techniques. A MountainsMap® workshop provided participants with hands-on experience of the software.

A big thank you to our guest speaker Dr Chris Brown from WPI for his expert insight on multiscale analysis.

Presentations and videos available here: goo.gl/NwE9VW



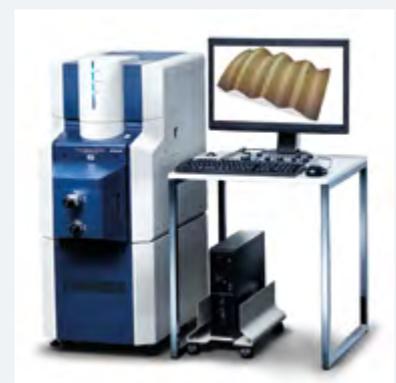
Product news

► Hitachi map 3D

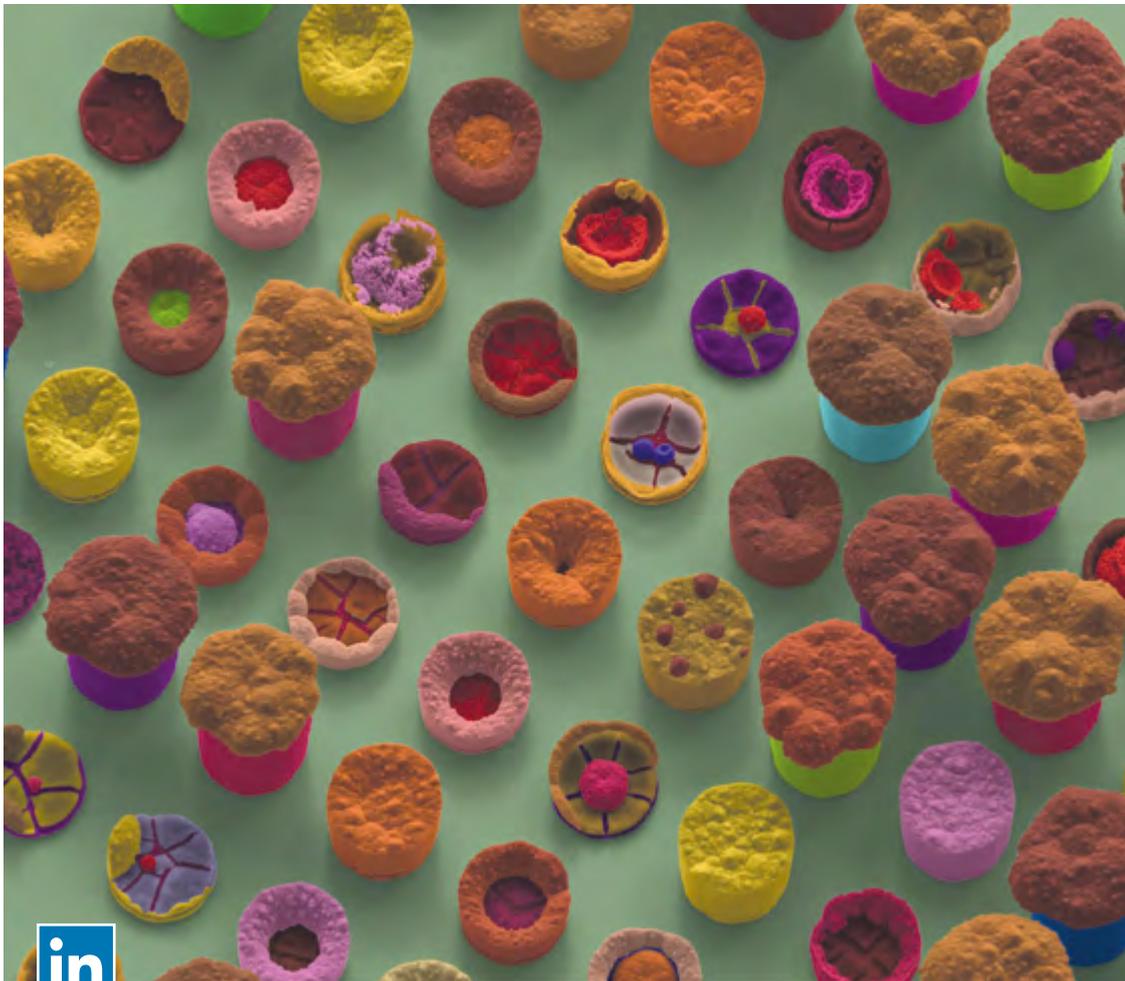
Together with Hitachi High-Technologies, one of the biggest names in electron microscopy, Digital Surf is thrilled to announce the launch of Hitachi map 3D, a new software package exclusively designed for scanning electron microscope (SEM) users.

The release of new Hitachi map 3D software based on Mountains® Technology opens up a new world of opportunities for researchers and industrial engineers using Hitachi High-Technologies' cutting-edge scanning electron microscopy (SEM) systems.

See the full press release: goo.gl/CKJcsw



WHAT'S HOT ONLINE



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



These cute “nano-cupcakes” are in fact a serious application. This is an SEM image of nickel cylinders grown by electroforming, after a failed attempt to lift off the corresponding resist mask.

Colors were added using Mountains® click-and color tool for SEM data.

Courtesy of Marina Raschetti, FEMTO-ST Laboratory, Université de Franche-Comté, Besançon, France.



Surface newsletter

Know a friend or colleague who would be interested in receiving the *Surface Newsletter*? Let us know: contact@digitalsurf.com

The newsletter is available for download on our website www.digitalsurf.com



Popular on Facebook

In February, the 29th meeting of ISO TC213 WG16 took place at St Pete Beach, Florida. 15 years ago the work on areal surface texture standards that led to the publication of ISO 25178 was initiated exactly at the same place! This new meeting was dedicated to the new profile standard, ISO 21920, which will replace ISO 4287, 4288, 12085 and 13565. This new standard will be implemented in the upcoming version 8 of MountainsMap®.



USEFUL LINKS



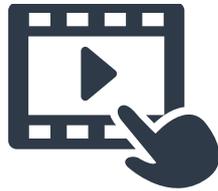
TRY MOUNTAINS MAP®

MountainsMap® Premium Software with all the options, free for 30 days!



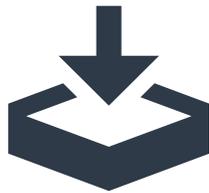
CONTACT US FOR AN UPDATE

Contact us for information about updating MountainsMap® 6 or earlier software to the latest version of MountainsMap® 7



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Get the most out of Mountains® software by watching one of our tutorial videos



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Learn more about Mountains® software by downloading a brochure in English, French, German or Japanese



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Control trade fair
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Landesmesse Stuttgart
Germany
May 9-12, 2017
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16th Conference on Metrology & Properties of Engineering Surfaces
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