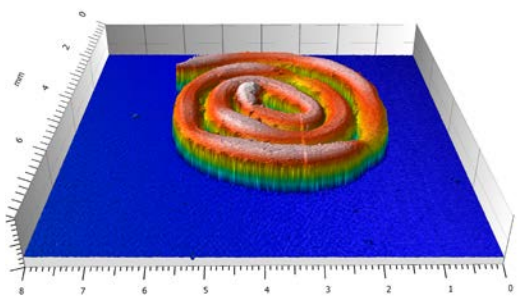
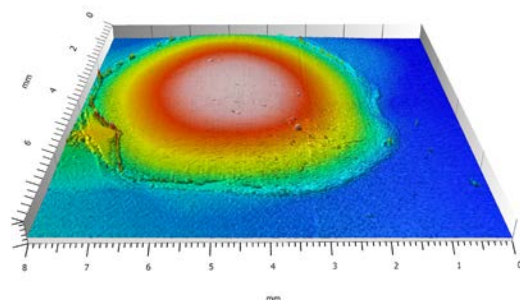
IN SITU HIGH TEMPERATURE SURFACE MORPHOLOGY USING 3D PROFILOMETRY

23 °C:



180 °C:



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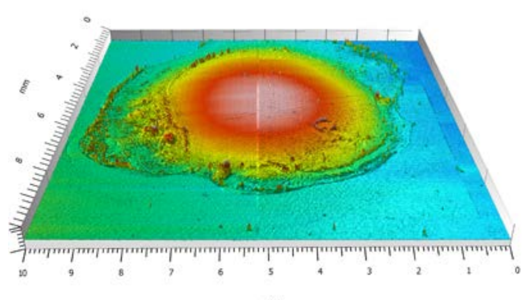
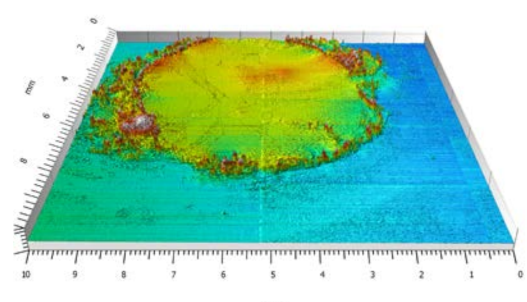


400 °C:



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INTRO

The 3D dimensional shape of a material or device is vital to its service quality and functionality. Surface roughness and texture can change at elevated temperatures. For example, shape-memory alloys (also called smart metals, etc.) remember their original shape and return to the pre-deformed shape when heated. Most polymeric materials melt and degrade rapidly at high temperatures, leading to change of shape and structure. Therefore, it is crucial to investigate the mechanism of shape deformation and the limit of the materials exposed to high temperature environment so as to select the proper material for the target applications.

IMPORTANCE OF 3D NON-CONTACT PROFILOMETER FOR SURFACE MORPHOLOGY MEASUREMENT AT HIGH TEMPERATURES

High temperature environment can change the surface texture, roughness and shapes of materials, resulting in device malfunction and mechanical failures. To ensure the quality of materials or devices used at elevated temperatures, accurate and reliable *in situ* monitoring of the shape evolution at high temperatures is in need to provide insight into the mechanism of material deformation. Moreover, real-time monitoring of surface morphologies at high temperatures is very useful in materials processing, such as laser machining. The Nanovea 3D Non-Contact Profilometers measure the surface morphology of materials without touching the sample, avoiding introducing additional scratches or shape alteration which may be caused by contact technologies such as sliding stylus. Its capacity of non-contact measurement also makes it possible to measure the shape of melted samples.

MEASUREMENT OBJECTIVE

In this application, the Nanovea ST400 non-contact profilometer equipped with a line optical sensor is used to monitor the surface evolution of a Sn60Pb40 solder sample heated from the room temperature up to 400 ºC. We showcases the capacity of Nanovea non-contact profilometer in providing fast and precise 3D profile measurement at elevated temperatures.

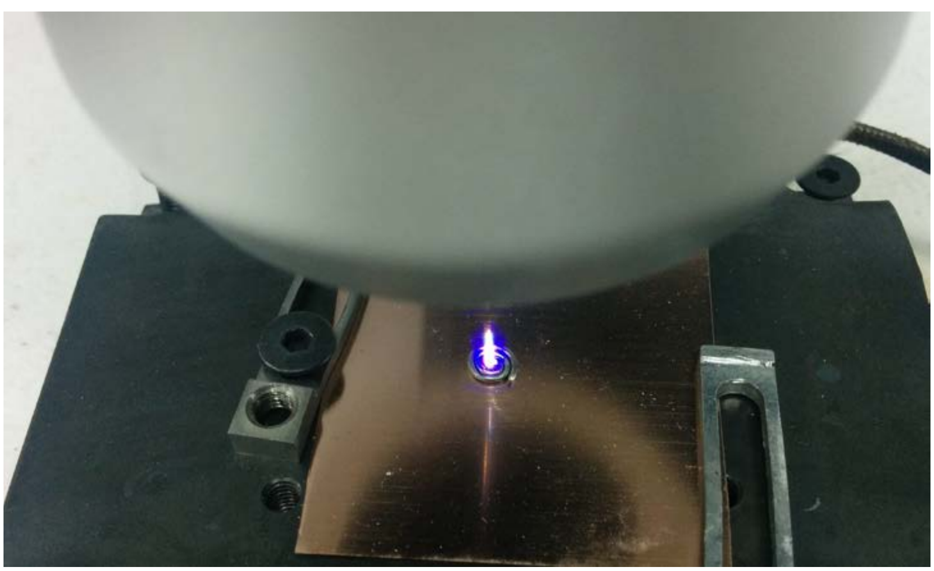


Fig. 1: Optical line sensor scanning on the surface of the solder sample.

RESULTS AND DISCUSSION

A Sn60Pb40 solder sample was heated up from the room temperature to 400 °C. The evolution of its 3D topography was monitored *in situ* using Nanovea ST400 non-contact profilometer equipped with a line sensor. The optical line sensor generates a bright line of 192 points, as shown in Fig. 1. These 192 points scan the sample surface at the same time, leading to significantly increased scan speed. An 8×8 mm^2 area scan at each temperature in this study can be finished in 5 s.

The 3D view of the solder surface topography at representative temperatures is shown in Fig. 2, providing an ideal tool for users to observe the solder sample from different angles. The 2D cross section profiles are compared in Fig. 3. The solder maintains its shape as heated up from room temperature until ~180 °C, where its melting point is reached. The solder rapidly changes its shape and adheres to the copper substrate underneath it, forming a smooth spherical cap. As the temperature continues to raise to ~300 °C, rosin flux starts to burn at the edge of the solder, leading to roughening of the surface. When a temperature of ~400 °C is reached, the solder spreads to the surrounding area and lowers its height. Meanwhile, the rosin flux on and around the solder continues to burn, leaving behind trace of formed graphite. The evidence of such observations is displayed in Fig. 4.

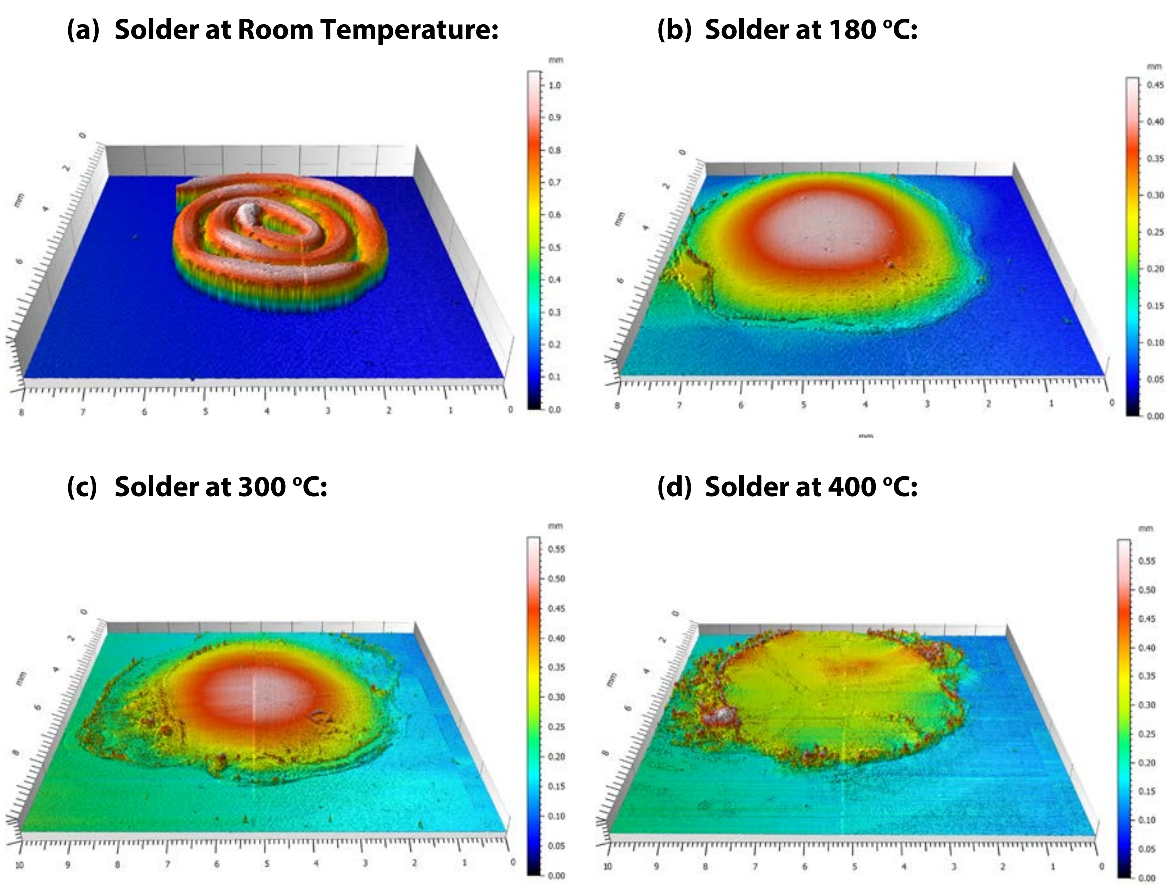
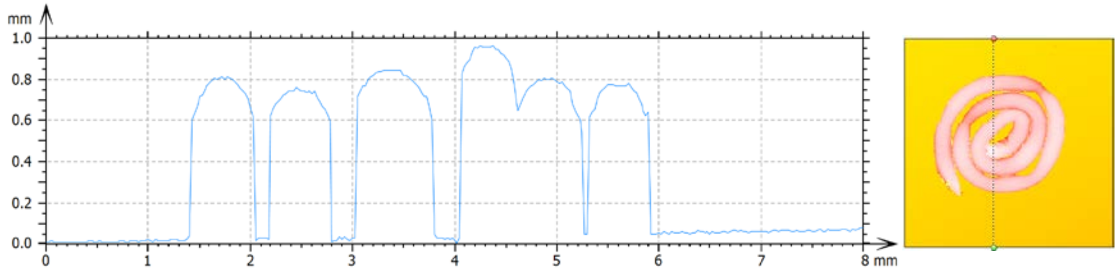
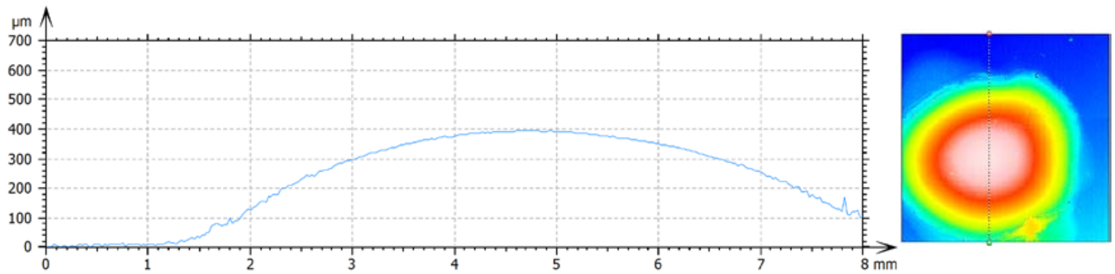


Fig. 2: Evolution of the solder sample at different temperatures.

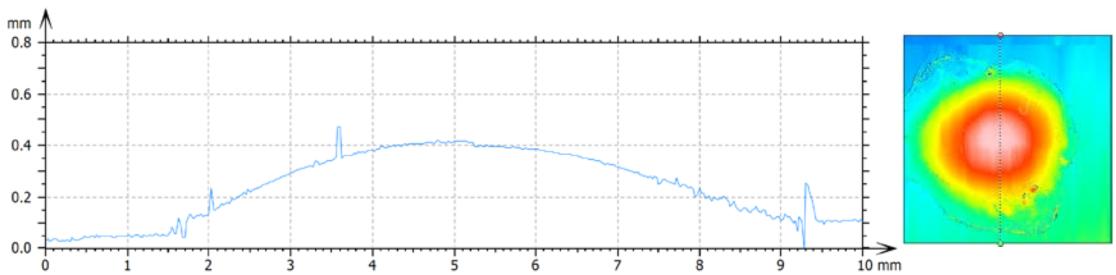
(a) **Solder at Room Temperature:**



(b) **Solder at 180 °C:**



(c) **Solder at 300 °C:**



(d) **Solder at 400 °C:**

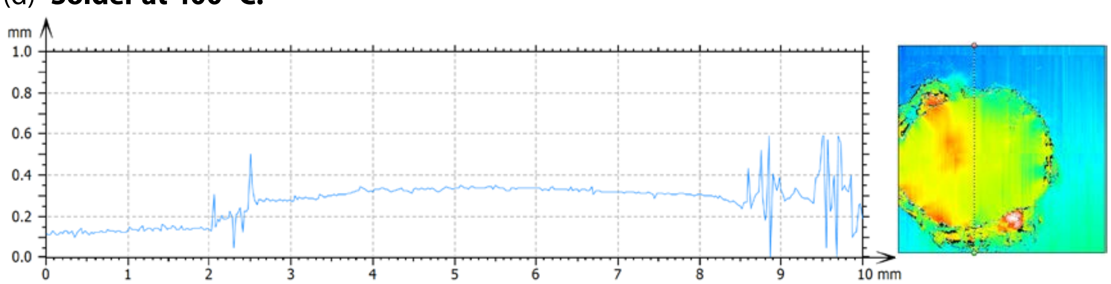


Fig. 3: 2D profile of the solder sample at different temperatures.

(a) Solder at 300 °C: **(b) Solder at 400 °C:**

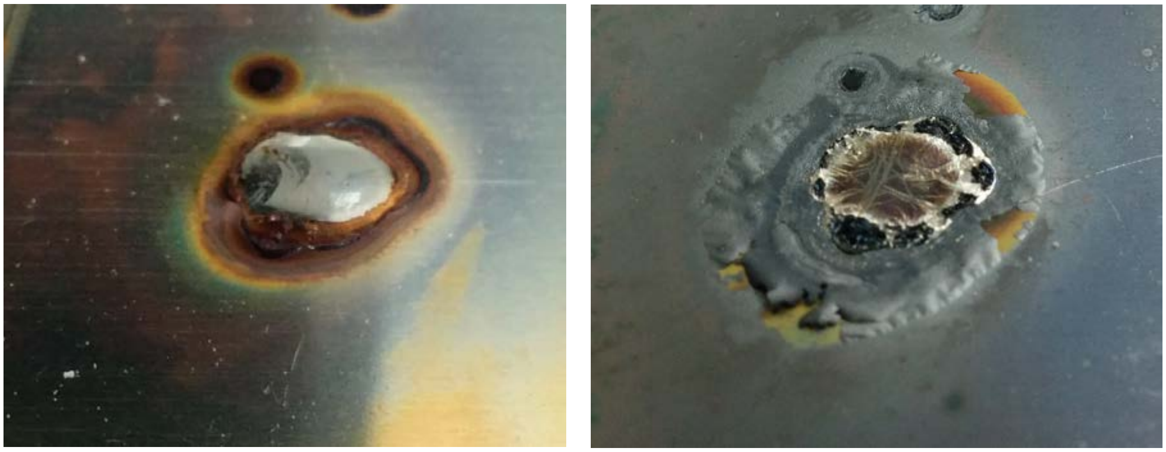


Fig. 4: The solder sample at 300 and 400 °C.

CONCLUSION

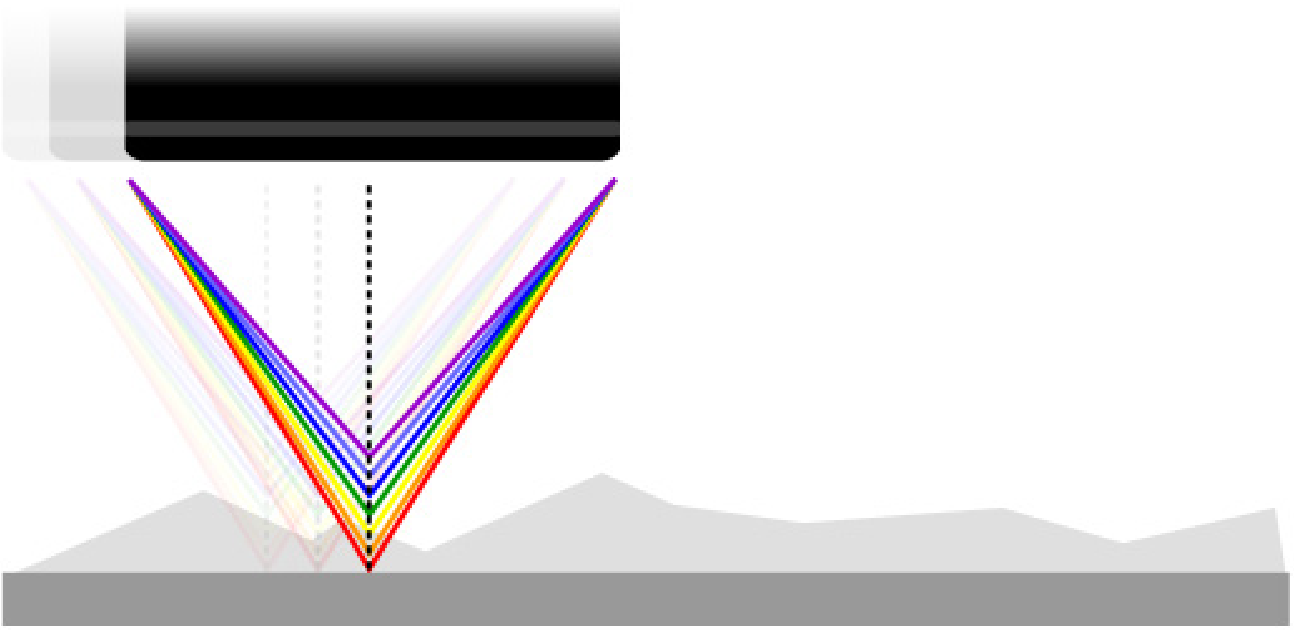
In this application, we have showcase that the Nanovea ST400 3D Non-Contact Profilometer monitors the evolution of the surface morphology on a solder sample heated from the room temperature to 400 °C. The optical line sensor generates a line consisting of 192 light spots that scan the sample surface at the same time. It significantly increases the scan speed, enabling monitoring the 3D shape evolution of the solder *in situ*. It is observed that the solder melts at ~180 °C. Its shape continues to change as the temperature progressively increases to 300 °C and 400 °C.

The data shown here represents only a portion of the calculations available in the analysis software. Nanovea Profilometers measure virtually any surface in fields including Semiconductor, Microelectronics, Solar, Fiber Optics, Automotive, Aerospace, Metallurgy, Machining, Coatings, Pharmaceutical, Biomedical, Environmental and many others.

Learn more about the Nanovea Profilometer or Lab Services

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.