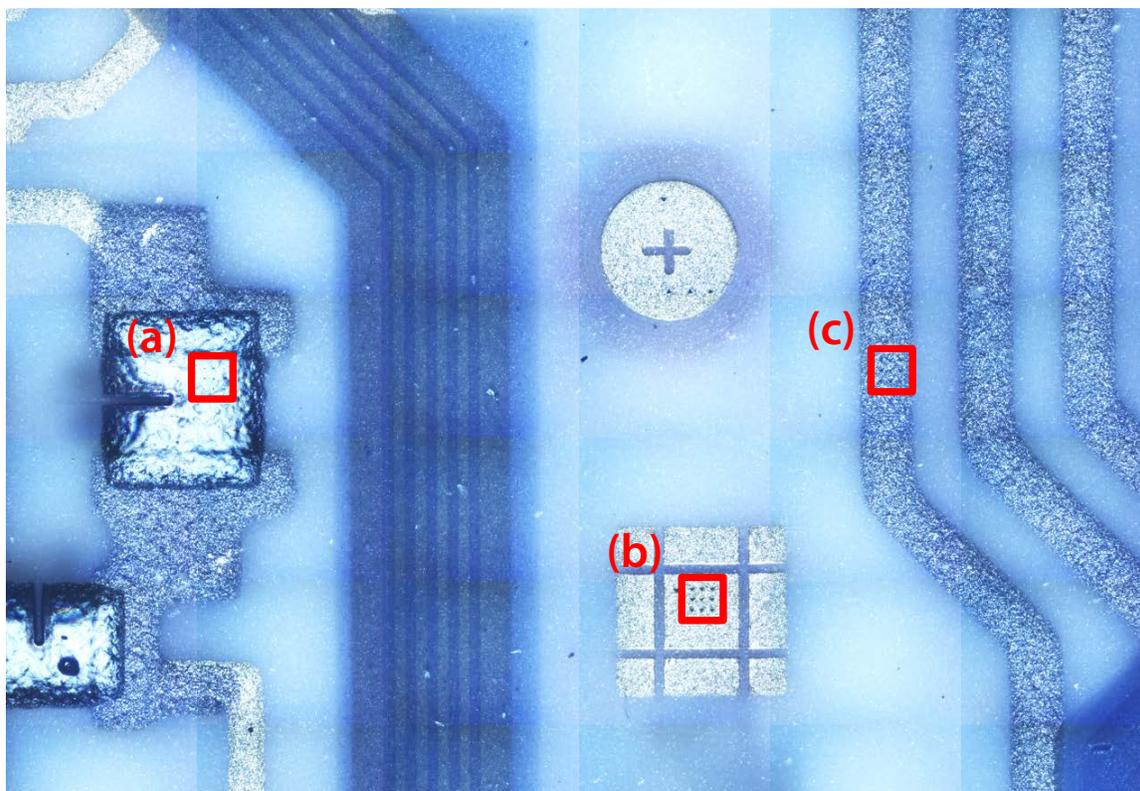


**MECHANICAL MAPPING OF PCB USING
BROADVIEW MAP SELECTION TOOL**



Prepared by
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INTRODUCTION

Printed circuit boards (PCB) are widely used on a variety of electronic devices, including phones, radios, radar and computer systems. Mechanical integrity of the PCB is a key factor in manufacturing failure free product. The scale-down of the PCB production technology into the micron/nanometer level not only enables increased number of electronic components on a single board, but also brings challenges to defect inspection and quality control of the PCB.

IMPORTANCE OF NANOINDENTATION FOR MECHANICAL INSPECTION OF PCB

The thinner wires and more complex structure of the electronic circuit on the advanced PCB demands high-precision mechanical integrity inspection. Nanoindentation is widely applied to measure the mechanical behaviors of materials at small scales^{i ii}. In order to accurately evaluate the mechanical properties of different wires and electronic components on the PCB, high precision position control of the nanoindentation location is critical. A reliable and user-friendly procedure of nanoindentation testing can significantly facilitate the quality control and R&D of advanced PCB. In addition, the small indentation force applied using the nanoindentation technique provides an ideal non-destructive mechanical testing solution to prevent damages to PCB under the test.

MEASUREMENT OBJECTIVE

In this application, the Nanovea Mechanical Tester, in Nanoindentation mode is used to measure the mechanical properties of different locations of a PCB. We would like to showcase the capacity of Nanovea Mechanical Tester in performing nanoindentation measurement on a PCB with high precision and user friendliness using *Broadview Map Selection Tool* (Patent Pending).

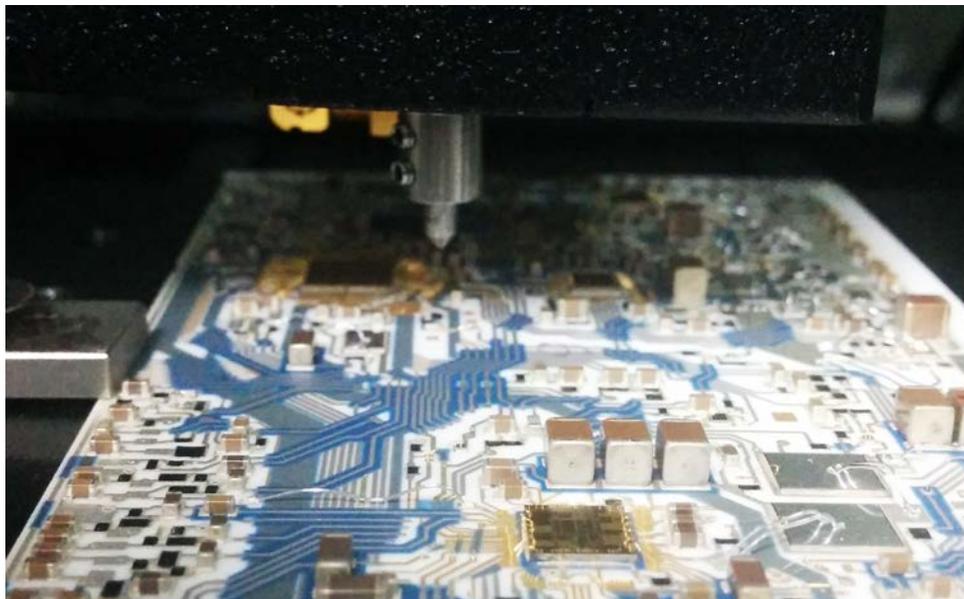


Fig. 1: Nanoindentation tip on the PCB.

TEST CONDITIONS

Broadview Map Selection Tool provide a user-friendly tool to observe and precisely select the intended area for mechanical testing. In this particular study, a map of 10×10 images were taken by the optical microscope integrated in the Nanovea Mechanical Tester as shown in Fig. 2, in order to obtain a better observation of the overall area of interest on the PCB. Three representative areas on the PCB were directly selected on the image for nanoindentation mapping as numbered on Fig. 2. The nanoindentation mapping (3×3, spaced 50 μm apart, 9 indents in total) was performed under the test conditions summarized in Table 1.

The procedure set up by *Broadview Map Selection Tool* can be saved and reapplied on other samples of the same geometry, so that the indentations at the same load and location will be automatically performed. This function substantially facilitates quality control of large batches of samples of the same geometry. Moreover, the Fastmap function of Nanovea Mechanical Tester further accelerates the indentation tests.

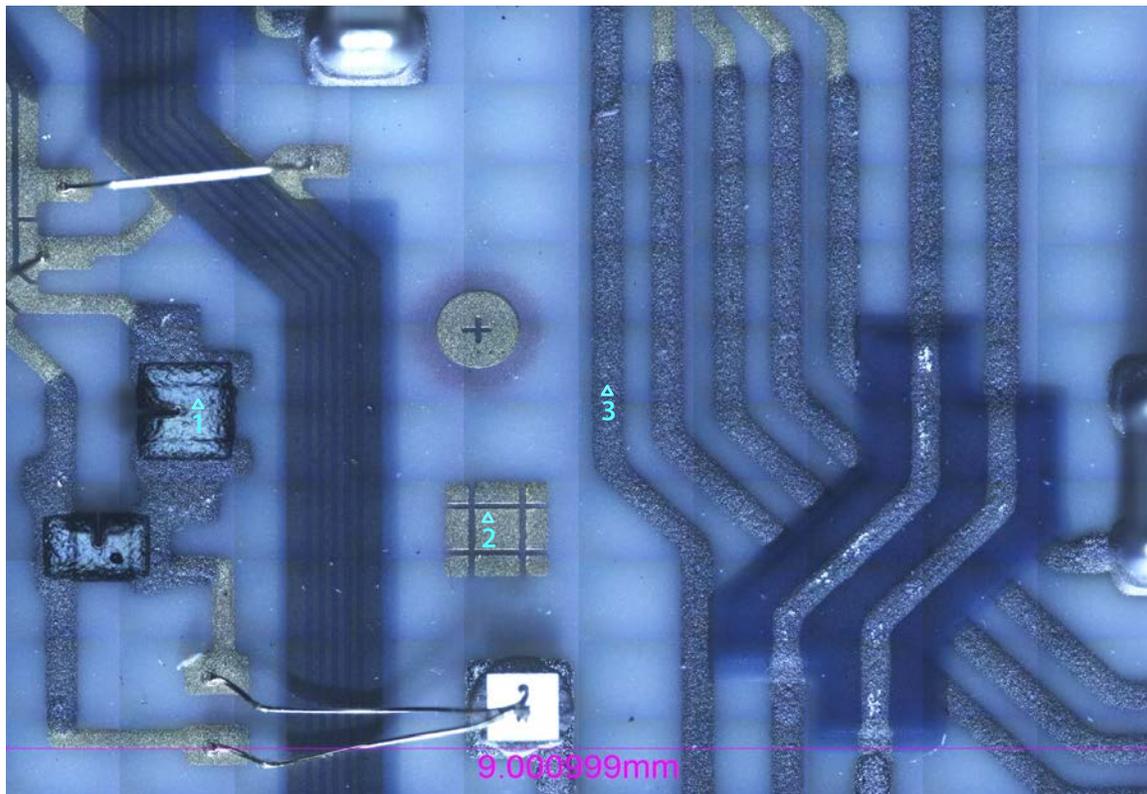


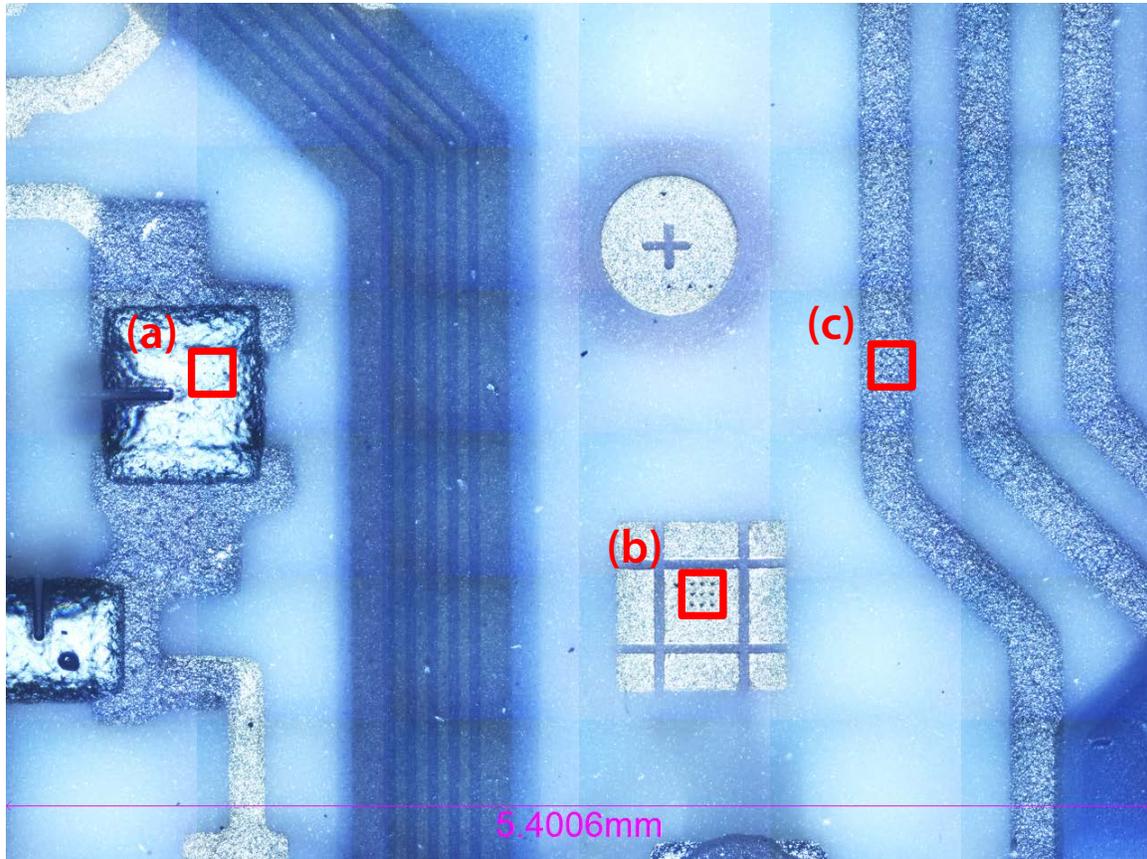
Fig. 2: Broadview Map Selection of nano indentations on the PCB.

Maximum force (mN)	200
Loading rate (mN /min)	400
Unloading rate (mN /min)	400
Indenter type	Berkovich

Table 1: Test conditions of the nanoindentation.

RESULTS AND DISCUSSION

The images of the 3×3 indentation matrix at the three selected areas are displayed in Fig. 3. We demonstrate that the excellent position control of the sample stage in Nanovea Mechanical Tester allows users to precisely pinpoint the target area on this image map for mechanical properties testing, i.e. 3×3 nanoindentation mapping. This makes measurement of the local mechanical properties at small scales substantially less time-consuming and more user friendly.



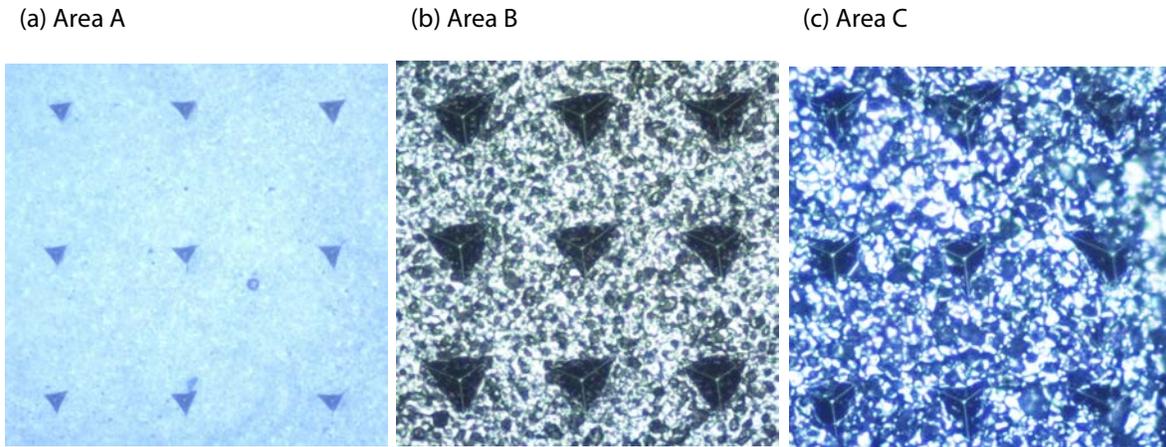


Fig. 3: Nano indentations on the PCB.

The representative load-displacement curves of the indentations are shown in Fig. 4, and the corresponding hardness and Young's Modulus calculated using Oliver and Pharr Method ⁱⁱⁱ are summarized and compared in Fig.5. Area A possesses an average hardness of ~5.2 GPa, compared to ~0.91 GPa and ~0.59 GPa, respectively, for Areas B and C. It also has a higher Young's modulus of 22.9 GPa.

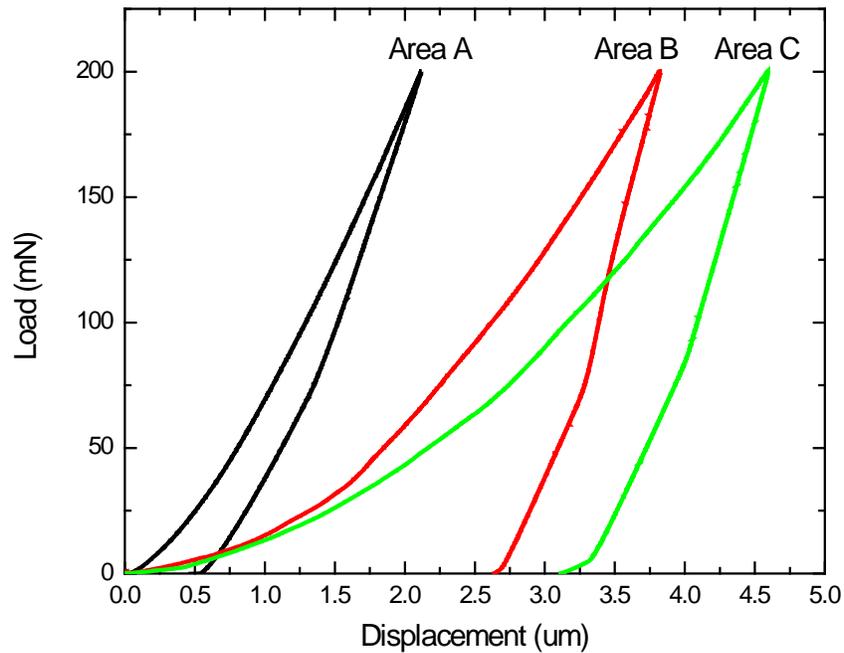


Fig. 4: Load-displacement curves of the indentations.

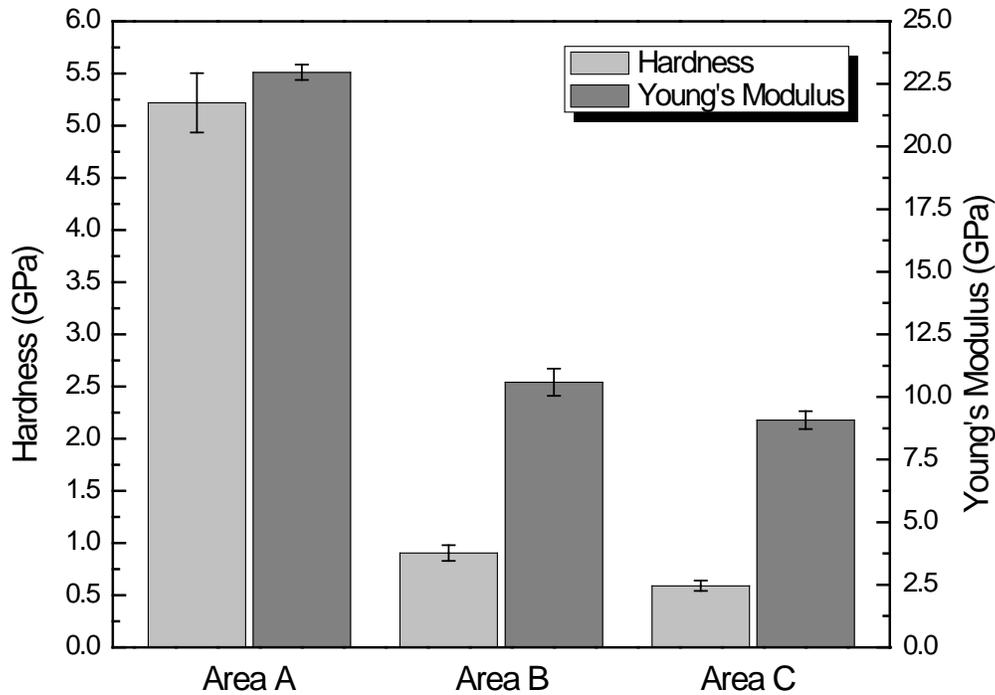


Fig. 5: Hardness and Young's Modulus at different locations of the PCB.

CONCLUSION

In this study, we showcased the capacity of Nanovea Mechanical Tester in performing nanoindentation mapping on target areas of a PCB using patent pending *Broadview Map Selection Tool*. The precise position control allows users to directly select the areas of interest for nanoindentation on a large optical image array and perform accurate mechanical property measurements. The superior precision and repeatability of the nanoindentation tests is attributed to the piezo load control and direct load/displacement measurement of the Nanovea Mechanical Tester.

The Nano, Micro or Macro modules of the Nanovea Mechanical Tester all include ISO and ASTM compliant indentation, scratch and wear tester modes, providing the widest and most user friendly range of testing available in a single system. Nanovea's unmatched range is an ideal solution for determining the full range of mechanical properties of thin or thick, soft or hard coatings, films and substrates, including hardness, Young's modulus, fracture toughness, adhesion, wear resistance and many others.

In addition, optional 3D non-contact profiler and AFM Module are available for high resolution 3D imaging of indentation, scratch and wear track in addition to other surface measurements such as roughness.

To learn more about [Nanovea Mechanical Tester](#) or [Lab Services](#).

APPENDIX: MEASUREMENT PRINCIPLE

Nanoindentation is based on the standards for instrumented indentation, ASTM E2546 and ISO 14577. It uses an established method where an indenter tip with a known geometry is driven into a specific site of the material to be tested, by applying an increasing normal load. When reaching a pre-set maximum value, the normal load is reduced until complete relaxation occurs. The load is applied by a piezo actuator and the load is measured in a controlled loop with a high sensitivity load cell. During the experiment the position of the indenter relative to the sample surface is precisely monitored with high precision capacitive sensor.

The resulting load/displacement curves provide data specific to the mechanical nature of the material under examination. Established models are used to calculate quantitative hardness and modulus values for such data. Nanoindentation is especially suited to load and penetration depth measurements at nanometer scales and has the following specifications:

Maximum displacement (Dual Range)	: 50 μm or 250 μm
Depth Resolution (Theoretical)	: 0.003 nm
Depth Resolution (Noise Level)	: 0.15 nm
Maximum force	: 400 mN
Load Resolution (Theoretical)	: 0.03 μN
Load Resolution (Noise Floor)	: 0.3 μN

Analysis of Indentation Curve

Following the ASTM E2546 (ISO 14577), hardness and elastic modulus are determined through load/displacement curve as for the example below.

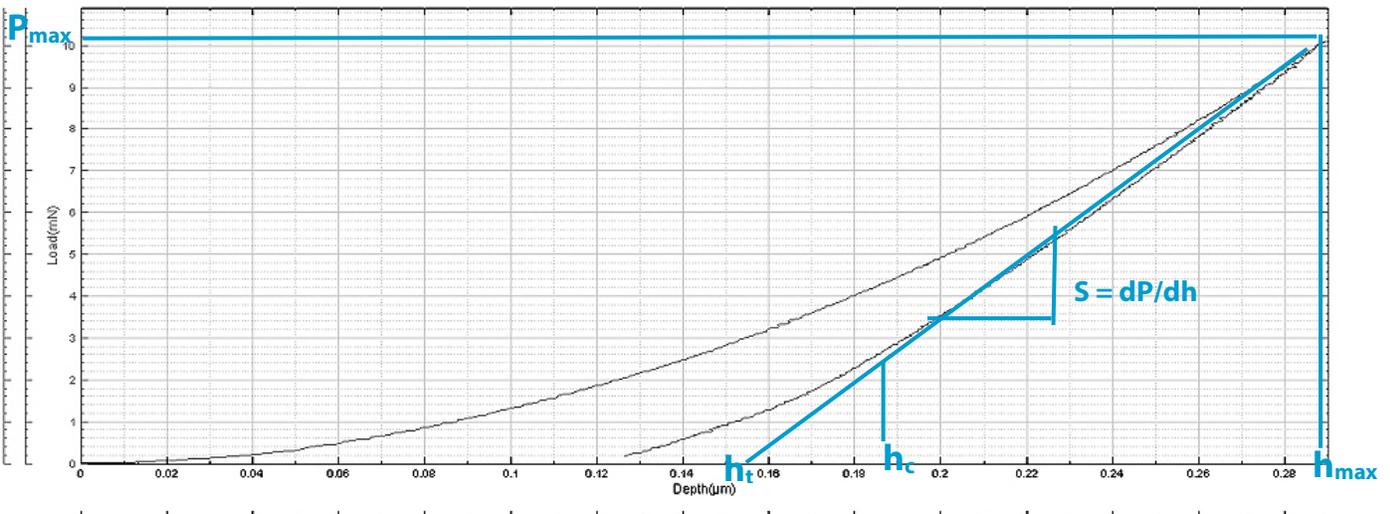


Fig. 6: Load-displacement curve of nanoindentation.

Hardness

The hardness is determined from the maximum load, P_{\max} , divided by the projected contact area, A_c :

$$H = \frac{P_{\max}}{A_c}$$

Young's Modulus

The reduced modulus, E_r , is given by:

$$E_r = \frac{\sqrt{\pi}}{2} \frac{S}{\sqrt{A_c}}$$

Which can be calculated having derived S and A_c from the indentation curve using the area function, A_c being the projected contact area. The Young's modulus, E , can then be obtained from:

$$\frac{1}{E_r} = \frac{1-\nu^2}{E} + \frac{1-\nu_i^2}{E_i}$$

Where E_i and ν_i are the Young's modulus and Poisson's ratio of the indenter and ν the Poisson's ratio of the tested sample.

How are these calculated?

A power-law fit through the upper 1/3 to 1/2 of the unloading data intersects the depth axis at h_t . The stiffness, S , is given by the slope of this line. The contact depth, h_c , is then calculated as:

$$h_c = h_{\max} - \frac{3P_{\max}}{4S}$$

The contact Area A_c is calculated by evaluating the indenter area function. This function will depend on the diamond geometry and at low loads by an area correction.

For a perfect Berkovich and Vickers indenters, the area function is $A_c=24.5h_c^2$. For Cube Corner indenter, the area function is $A_c=2.60h_c^2$. For Spherical indenter, the area function is $A_c=2\pi R h_c$, where R is the radius of the indenter. The elastic components, as previously mentioned, can be modeled as springs of elastic constant E , given the formula: $\sigma = E\varepsilon$ where σ is the stress, E is the elastic modulus of the material, and ε is the strain that occurs under the given stress, similar to Hooke's Law. The viscous components can be modeled as dashpots such that the

stress-strain rate relationship can be given as $\sigma = \eta \frac{d\varepsilon}{dt}$, where σ is the stress, η is the viscosity of the material, and $d\varepsilon/dt$ is the time derivative of strain.

Since the analysis is very dependent on the model that is chosen, Nanovea provides the tool to gather the data of displacement versus depth during the creep time. The maximum creep

displacement versus the maximum depth of indent and the average speed of creep in nm/s is given by the software. Creep may be best studied when loading is quicker. Spherical tip is a better choice.

Other possible measurements by Nanovea Mechanical Tester:

Stress-Strain & Yield Stress, Fracture Toughness, Compression strength, Fatigue testing and many others.

ⁱ Oliver, W. C.; Pharr, G. M., *Journal of Materials Research.*, Volume 19, Issue 1, Jan 2004, pp.3-20

ⁱⁱ Schuh, C.A., *Materials Today*, Volume 9, Issue 5, May 2006, pp. 32–40

ⁱⁱⁱ Oliver, W. C.; Pharr, G. M., *Journal of Materials Research*, Volume 7, Issue 6, June 1992, pp.1564-1583