The "Oliver and Pharr method" for coated materials

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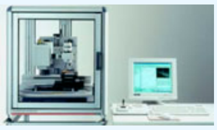
Introduction

For the correct determination of Young's modulus and yield strength of a coating an extension of the classical Oliver and Pharr method [1] is necessary. This extension is based upon a completely analytical mathematical approach [2]. The principle scheme of this new method is presented at **www.siomec.de/O&PfC-demo**.

Here it is shown on the example of some Fischerscope® measurements from Helmut Fischer GmbH & Co. KG, that even in those cases, where the so called Bückle rule can't be fulfilled at all and the experimentalist also faces bad foundation conditions, meaningful coating parameters can be extracted by the means of the "Oliver&Pharr method for coated materials" (O&PfC). The corresponding software used for the evaluation is called Oliver&Pharr for Coatings (OPfC).

The software of Fischer® equipment is able to export all data as an OPfC project file (except material information), hence the complete evaluation (except input of material information) is processed automatically.



Step 1: Obtain classic measurement results

In order to get more information from your performed measurements, firstly, you can start where your measurement and classic evaluation ended: With the load-displacement curve and the results of the classic Oliver&Pharr method [1]. If your measurement equipment is able to export load-depth curves as ASCII files, you can directly import them to OPfC. In this case, the only things missing yet in this step are the results of the Oliver&Pharr method and the contact radius respectively contact area, both of which you can type in manually. In our example the sample was loaded with up to 20mN using a diamond indenter.

Now, the effective indenter is automatically fitted to the unloading part of your load-displacement curve by OPfC. Concerning calculation time ask here or see animation on booth #32.

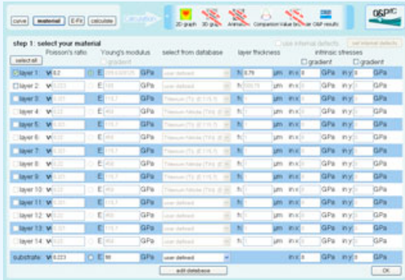
Step 2: Material definition

Secondly, the geometrical and mechanical material parameters of the sample are required. Easy if your measurement equipment allows direct export of OPfC project files, like the **Fischerscope®**. Otherwise, the material structures can also be typed in by hand. Here, we investigated a 500µm thick Si substrate covered with a sub-micron hard layer of 790nm thickness.

Caution: Measurements can be flawed!

(e.g.: unclear foundation conditions, unknown residual stresses, inclusions, defects, unsuitable sample holder etc.)

This can be taken into account by our model!



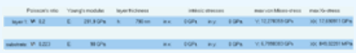
Step 3: Fit of the yet unknown coating Young's modulus

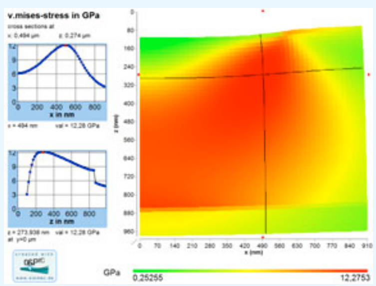
Then the Young's modulus of the layer in question is fitted to the indentation unloading curve, taking into account the effective indenter and the complete solution of the contact problem for layered materials (geometry of the system, parameters of additional layers etc.). As known from the classical O&P method the Poisson's ratio has to be estimated unless it is known.

The result of 289GPa for the coating Young's modulus is in very good agreement with previous measurements performed on an UMIS 2000 system [3].

Step 4: Evaluation results

Finally, this Oliver&Pharr for Coatings method (O&PfC) determines the yield strength for nearly any practical relevant material configuration. In dependence on the experimental setup also other critical parameters (like critical tensile stress) can be obtained from the effective elastic field at the initiation of unloading.





Conclusion

Your affordable Fischerscope® together with our software OPfC enables you to determine mechincal parameters of nano-thin film coatings and evaluate realistic contact situations.

Benefits:

- ✔ Gain more physical information out of your measurements
- ✔ Avoid buying expensive measurement equipment
- ✔ Avoid expensive and time consuming trial-and-error tests
- ✔ Find and avoid failure sources
- ✔ Ward off unjustified customer complaints

References:

[1] W.C. Oliver and G.M. Pharr, J. Mater. Res. 7, 1564 (1992)

[2] N. Schwarzer: "The extended Hertzian theory and its uses in analysing indentation experiments", Phil. Mag. 86(33-35) 21 Nov - 11 Dec 2006 5153 – 5767, Special Issue: "Instrumented Indentation Testing in Materials Research and Development"

[3] V. Linss, N. Schwarzer, T. Chudoba, M. Karniychuk, F. Richter: "Mechanical Properties of a Graded BCN Sputtered Coating with VaryingYoung's Modulus: Deposition, Theoretical Modelling and Nanoindentation", Surf. Coat. Technol., 195 (2005) pp 287 – 297

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See also our Scratch-Stress Analyser.