Shadow Effects in Nanoindentation - Is It Possible to Extract Information of Every Point Within a Coating Substrate System by Contact Mechanical Testing?

Saxonian Institute of Surface Mechanics

N. Bierwisch, N. Schwarzer

Sächsisches Institut für Oberflächenmechanik

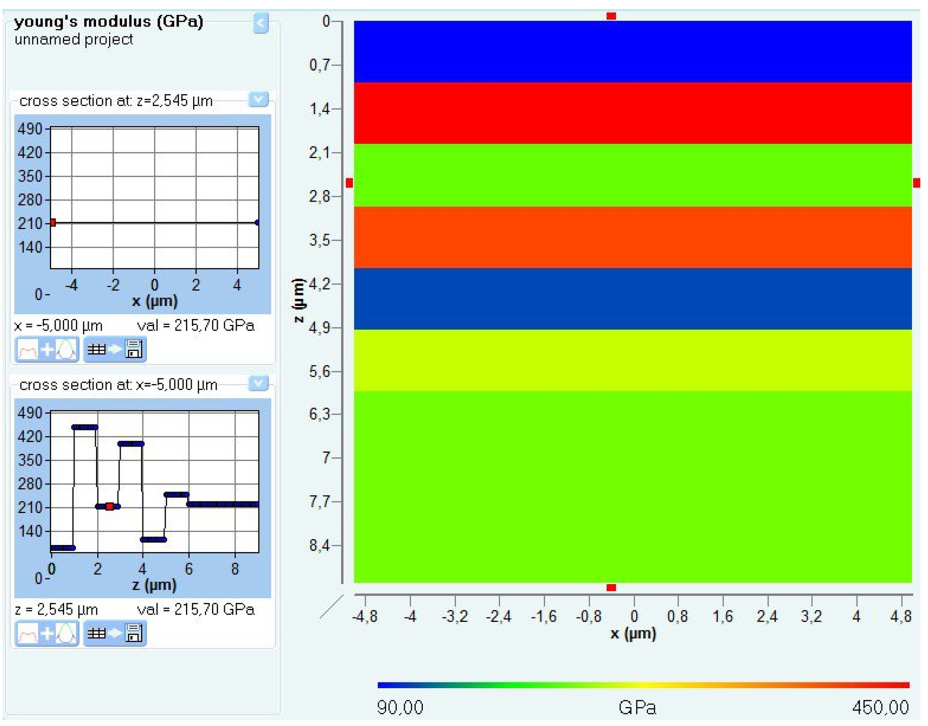
Motivation

Nanoindentation is a relatively cheap and non desctructive method for the generation of generic material paramters (e.g. young's moduls and yield strength). These generic parameters are needed in sophisticated models to analyze the material and to simulate and optimize the material performance for the expected application. During our work in this field we found out, that we deal nowadays with more complex material structures and it's getting more difficult to find the right test conditions to extract these generic parameters. Also we found out that some regions are shadowed by the material structure and properties. For these regions it's not possible to extract the information with mechanical contact experiments which only use normal loads.

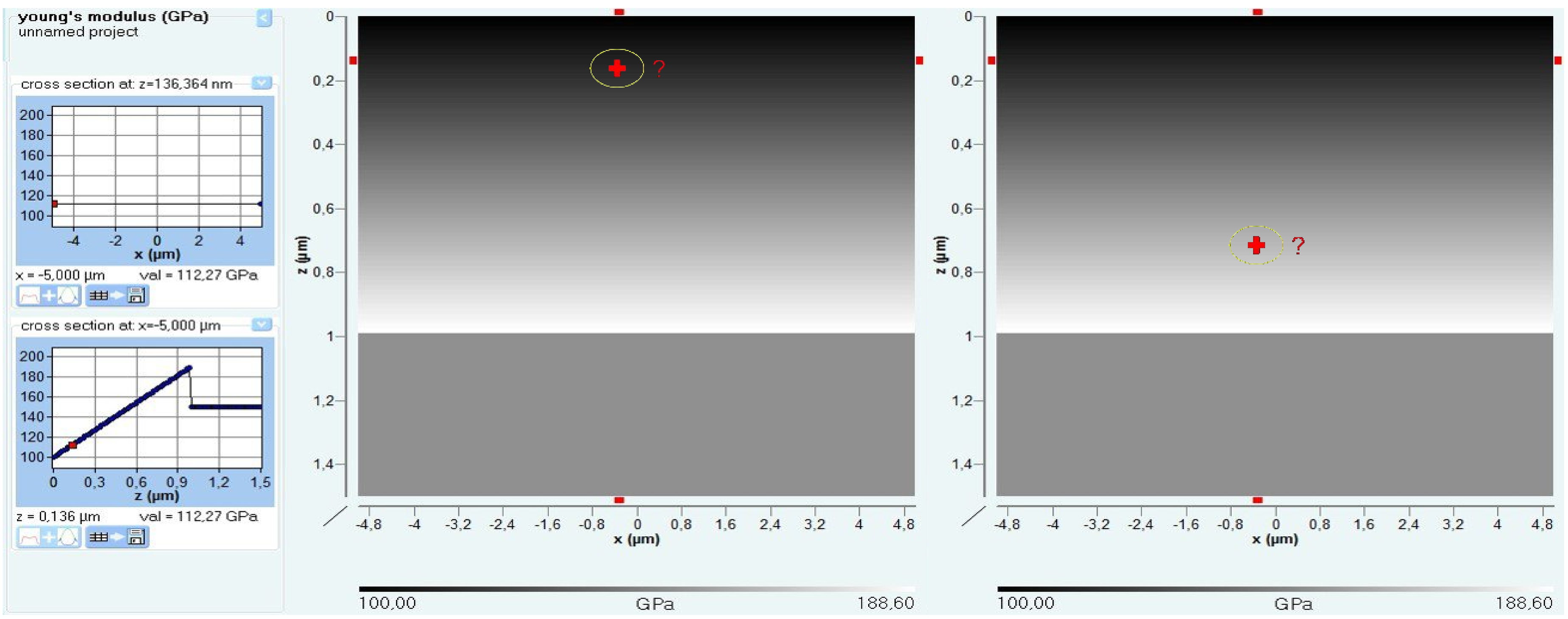
Complex material structures

As written in the motivation the structures become more complex to increase the application performance of new materials and material combinations.

The amount of used coatings is still increasing and more often the coatings itself are not homogeneous anymore. More and more gradient, composite or other micro structures are used.



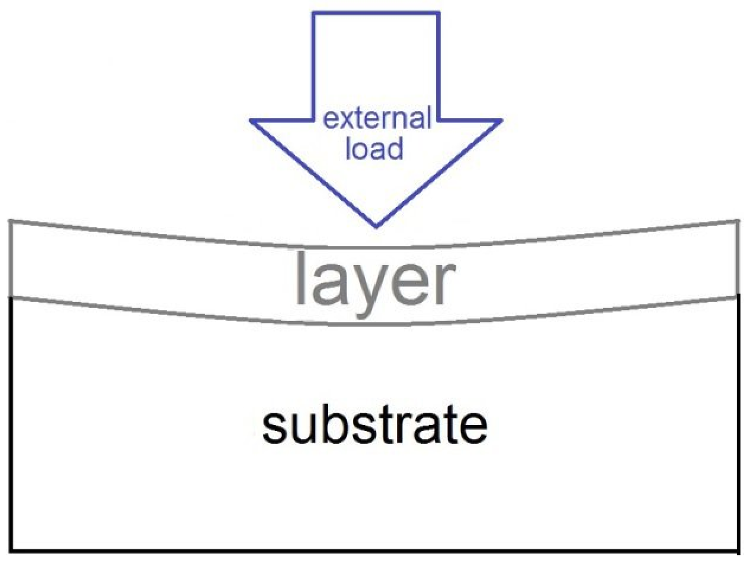
Complex multi layer stack on substrate

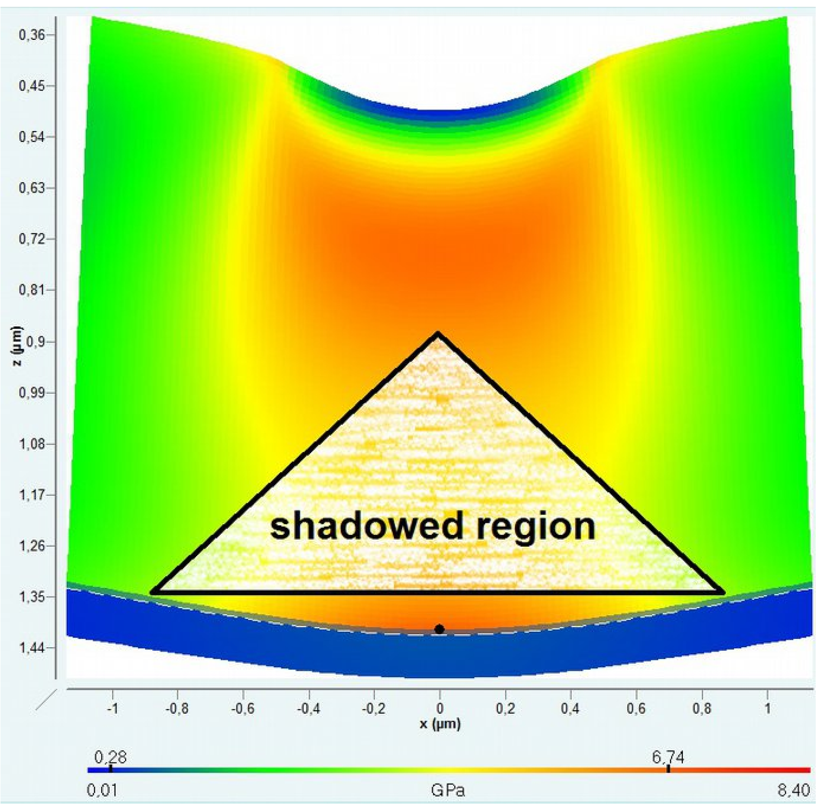


Extract information at different positions within a coating with gradient structure

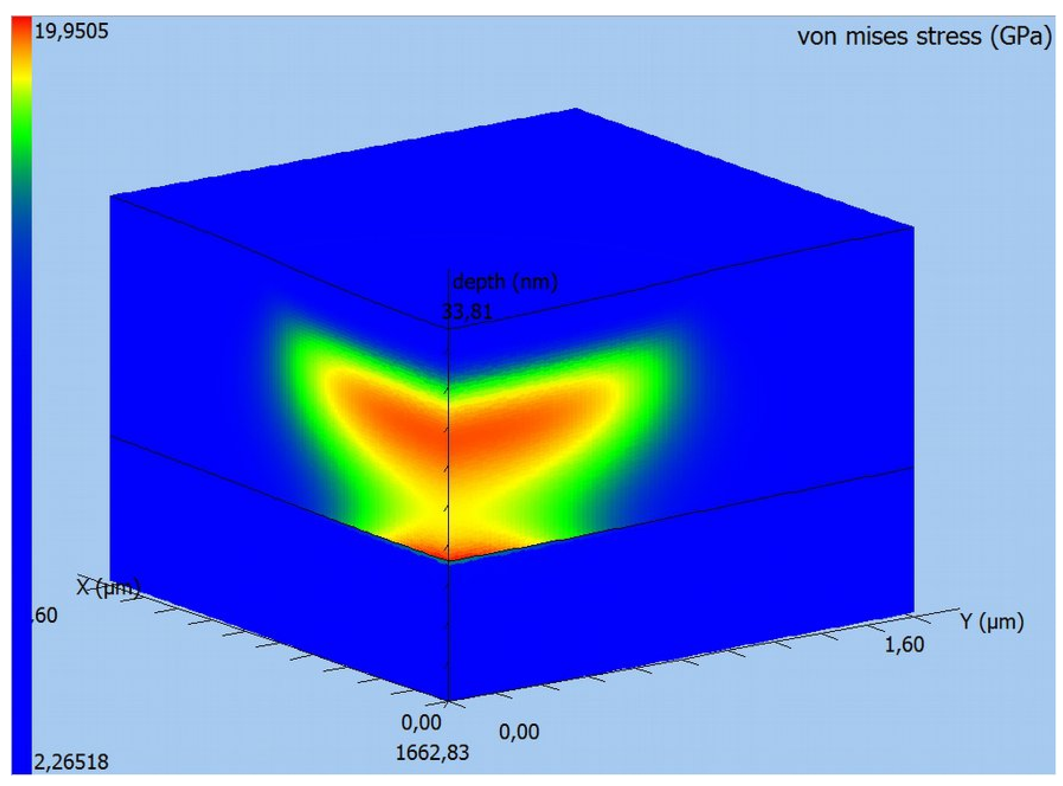
Eggshell shadowing

Often actual materials are protected by stiff coatings to increase their application performance. Applying an external load leads to a higher elastic deformation in the substrate and therefore the layer is bended. This leads to high stresses at the interface between the layer and the substrate. Because of this second maximum position, it's not possible to create the maximum von Mises stress at every position within the coating, because at a certant load the maximum at the interface becomes the global maximum.





AR coating on a polymer lens E-ratio: 70:4

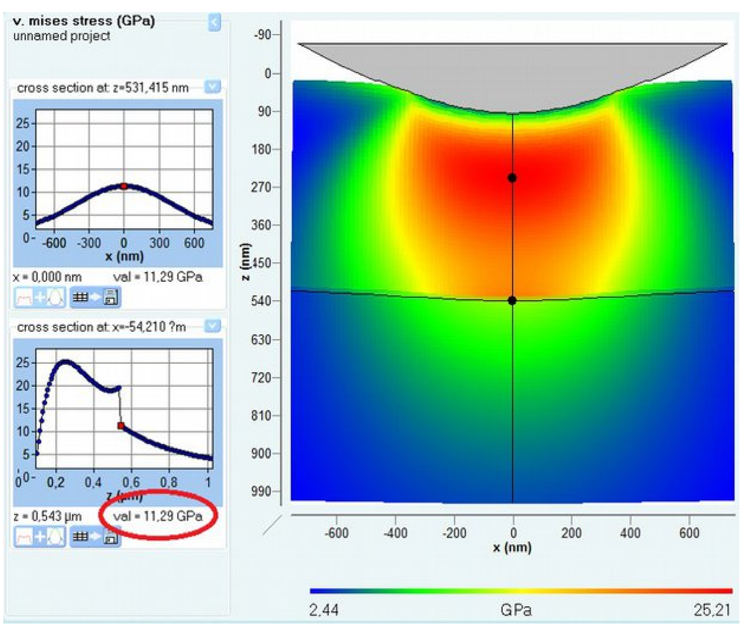


Hard metall coating on steel E-ratio: 590:221

Yield ratio shadowing

A second shadowing effect is created by the ratio of the yield strength of the different material components.

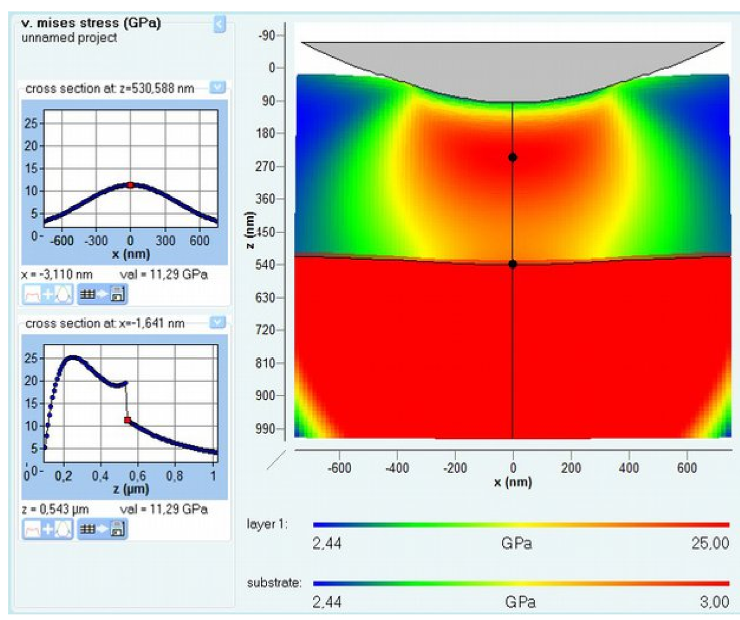
It's relatively easy to produce the critical stress value within the coating at a certain position, but often the critical value of the substrate is strongly exceeded.



On both figures we see the same stress distribution for a hard coating on a steel substrate. The yield strength values are 25 GPa for the coating and 3 GPa for the substrate. The maximum von mises is located at the centre of the coating and is slightly above 25 GPa. A second maximum value is highlighted in the substrate at the interface.

On the left side it's seem like a well designed experiment, but the maximum value in the substrate (11,26 GPa) is much too high.

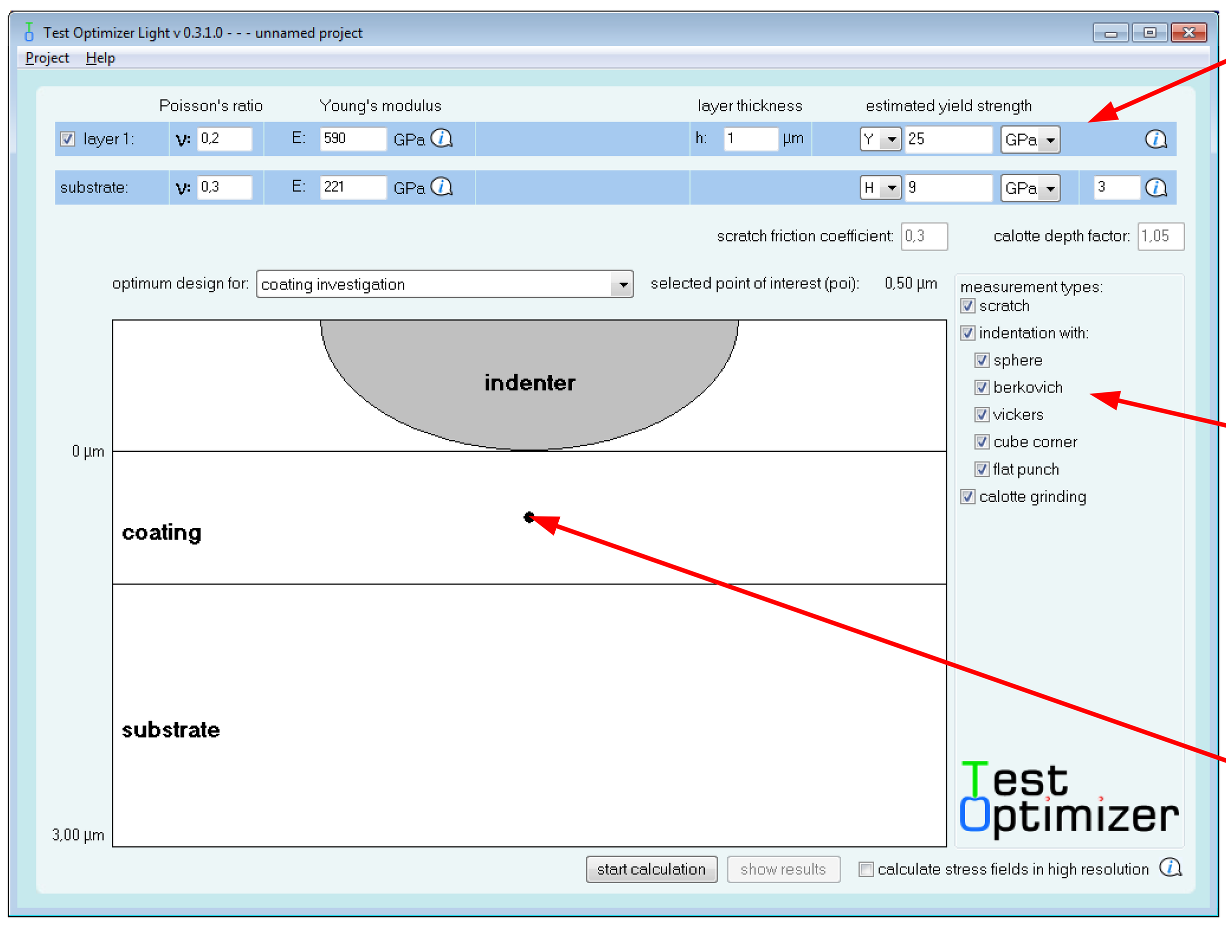
The right side uses a different color scale to demonstrate in which region the critical value of the substrate was exceeded.



Conclusion

It was shown that it's often not so easy to extract generic material parameters from complex material structures. Therefore it's difficult too find the correct experimental parameter extract these information.

SIO developed a small and easy to use software package named TestOptimizer [1], which calculates the optimum indenter and load parameter for different contact experiments.

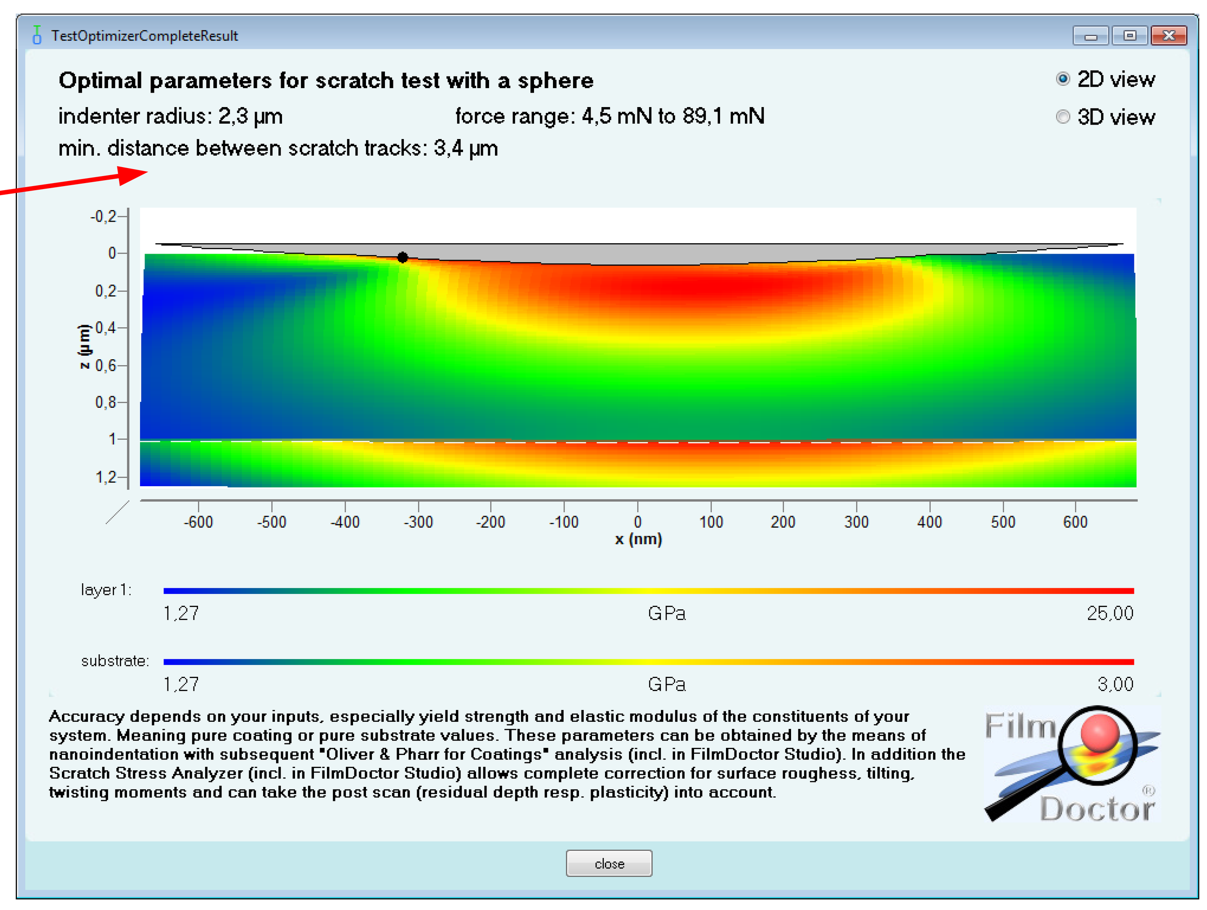


material definition

get optimum experimental parameters

select experiment types to be designed

define design goal according to your point of interest (POI)



Benefits

- ✔ Get locally resolved mechanical parameters
- ✔ Dimension tests to save time and costs
- ✔ Optimize your materials faster

References

[1] TestOptimizer – www.siomec.de/TestOptimizer

Test Optimizer

www.siomec.de