

Test Optimizer

–

Design of Contact Experiments for Coated or Treated Surfaces

Marcus Fuchs, Norbert Schwarzer

Saxonian Institute
of Surface Mechanics

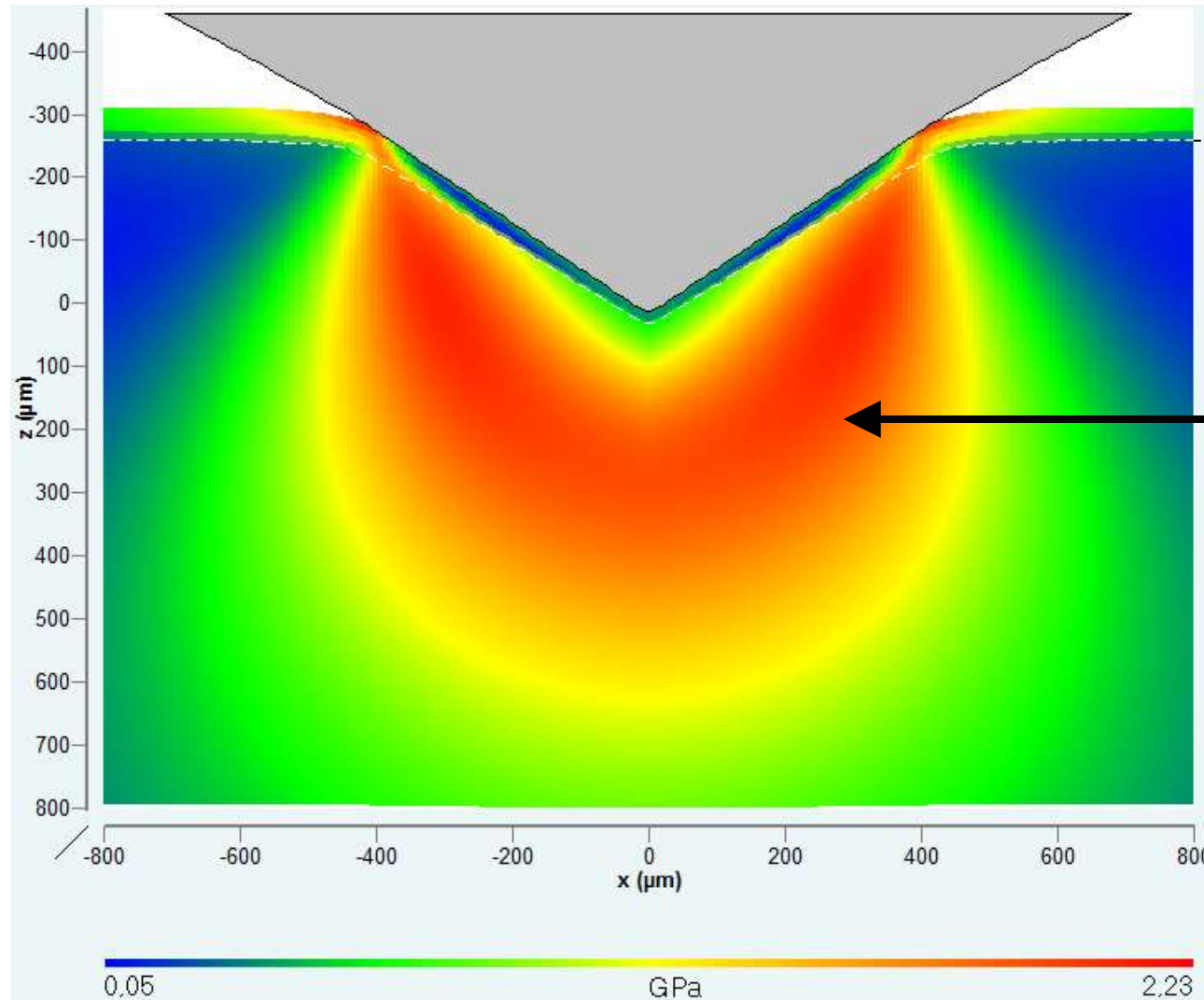
Tankow 2
18569 Ummanz
Germany

Test
Optimizer



Why shall I design my contact experiments?

Example: Rockwell hardness test HRC on 20 μm TiN coating



20 μm TiN
steel substrate

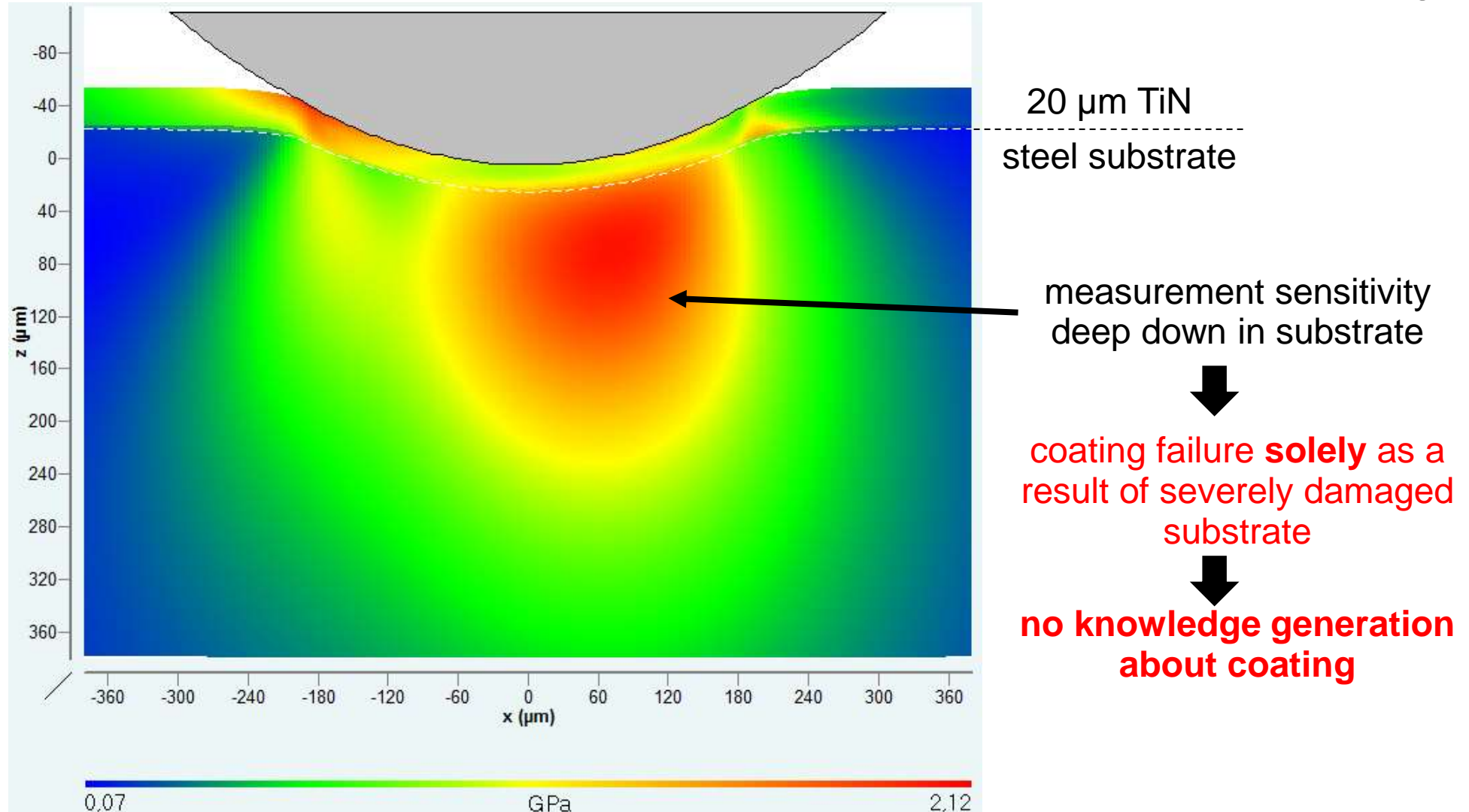
99.3% of measurement sensitivity **in substrate**



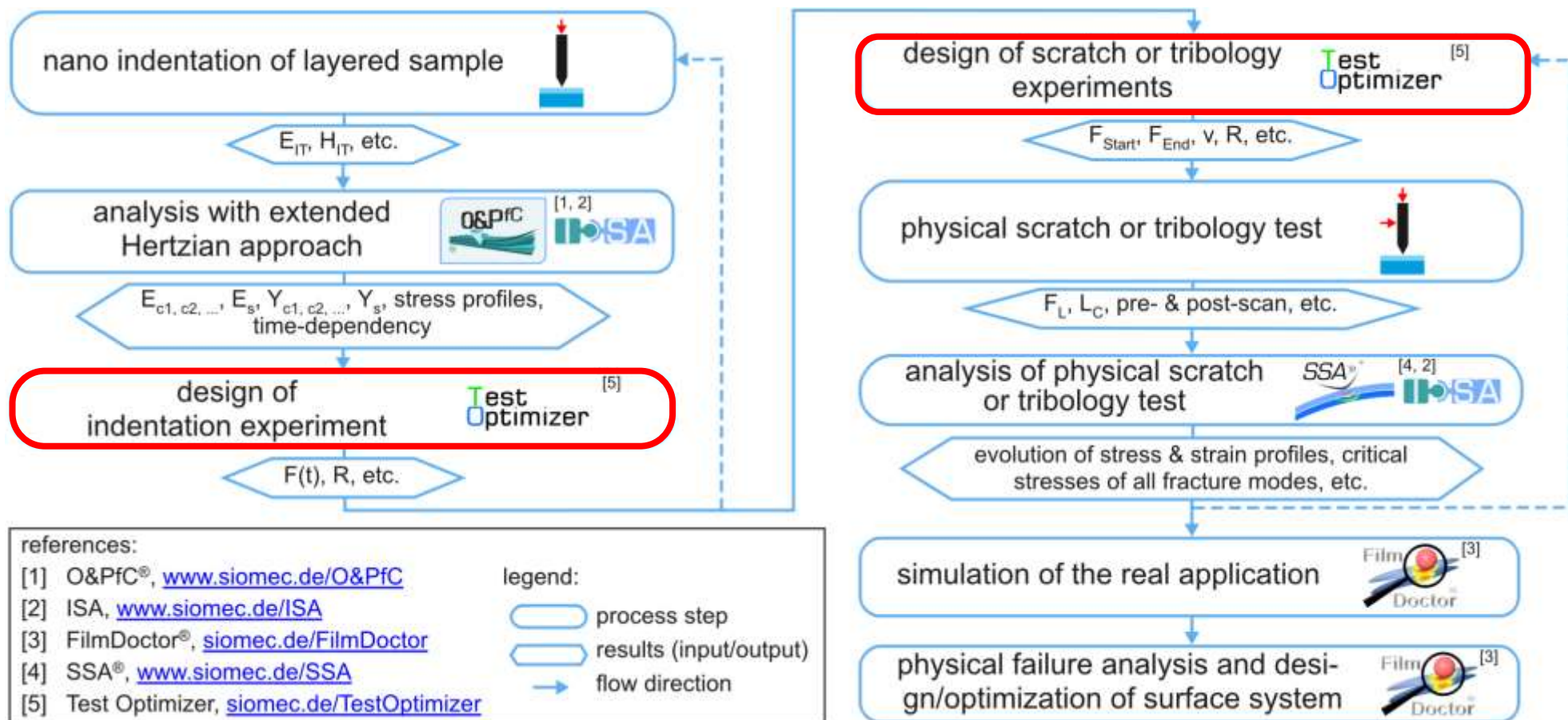
Only **0.7%** coating information!
Worse on thinner or multi-layer coatings!

Why shall I design my contact experiments?

Example: Scratch test as per DIN EN 1071-3 on 20 μm TiN coating



... requires properly designed experiments:





How do I design my contact experiments?

3 simple steps:

1st step:
material definition

2nd step:
aim of investigation

The screenshot shows the Test Optimizer CSM v 0.2.0.7 interface. The top section is titled 'Project Help' and contains a table for material properties:

| | Poisson's ratio | Young's modulus | select from database | layer thickness | estimated hardness and constraint factor | |
|--|-----------------|-----------------|----------------------|--------------------|--|-----|
| <input checked="" type="checkbox"/> layer 1: | ν : 0.2 | E: 400 GPa | user defined | h: 1 μm | H: 30 GPa | 1.5 |
| substrate: | ν : 0.3 | E: 200 GPa | user defined | | H: 30 GPa | 1.5 |

Below this is a section for 'optimum design for: coating investigation' and 'selected point of interest (poi): 0.5 μm '. A diagram shows a semi-circular indenter on a coating layer of 1.00 μm thickness, which sits on a substrate. The vertical axis is labeled with 0 μm , 1.00 μm , and 3.00 μm .

On the right, the 'measurement types' section is checked:

- scratch
- indentation with:
 - sphere
 - berkovich
 - vickers
 - cube corner
 - flat punch
 - calotte grinding





At the bottom, there are buttons for 'start calculation', 'show results', and a checkbox for 'calculate stress fields in high resolution'.

Test
Optimizer

3rd step: types of experiments to be dimensioned

1st step: Material Definition

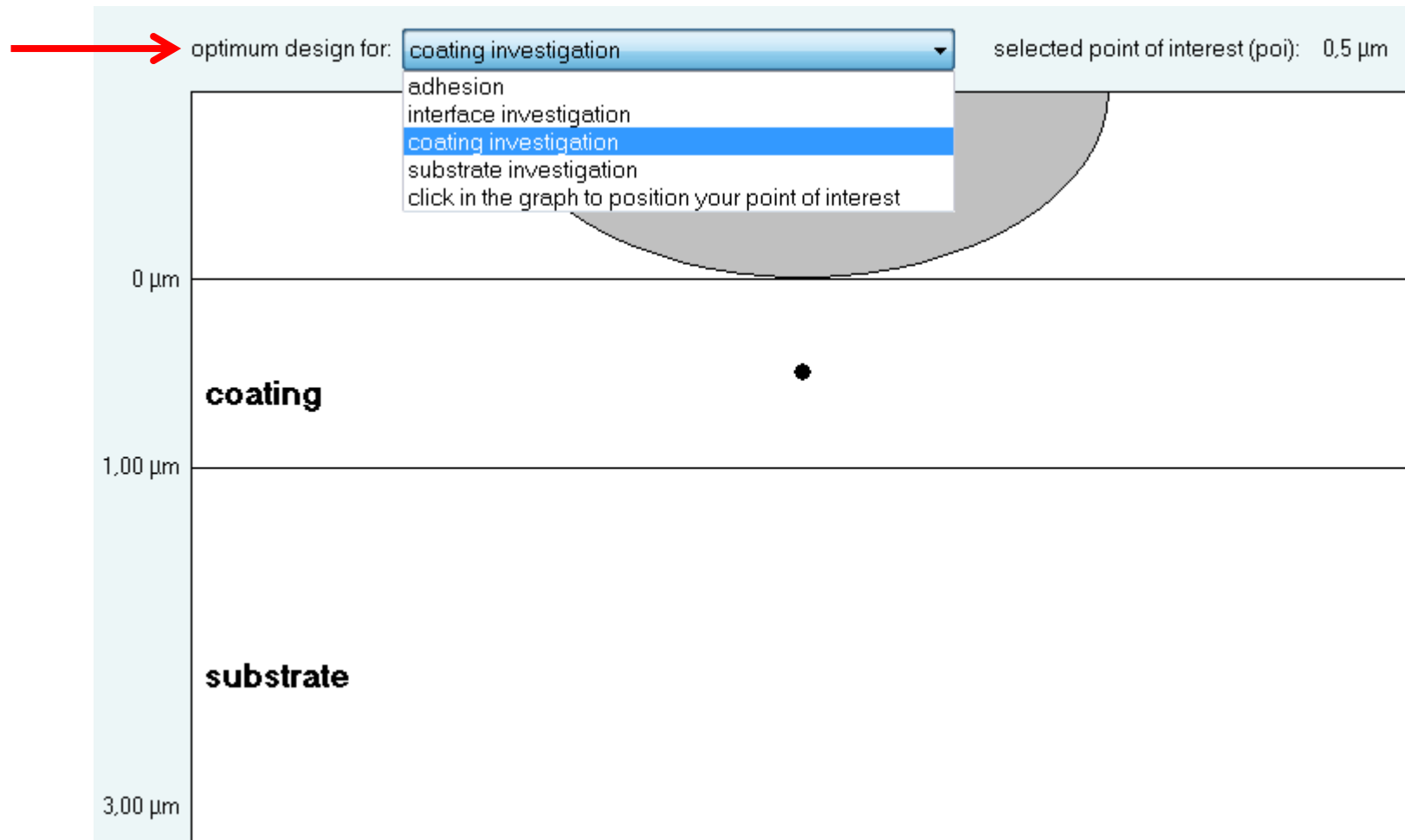
- mechanical properties of coating and substrate:
 - enter as far as known (from literature)
 - select (similar) material from provided database
 - estimate them

| | Poisson's ratio | Young's modulus | select from database | layer thickness | estimated hardness and constraint factor | | | |
|--|-----------------|--|----------------------|--------------------|--|----|-----|---|
| <input checked="" type="checkbox"/> layer 1: | ν : 0.2 | E: 400 GPa  | user defined | h: 1 μm | H | 30 | GPa | 1.5  |
| substrate: | ν : 0.3 | E: 200 GPa  | user defined | | Y | 20 | GPa |  |

- choose whether you want to enter hardness H and constraint factor C or yield strength Y which are related under $H = C \cdot Y$

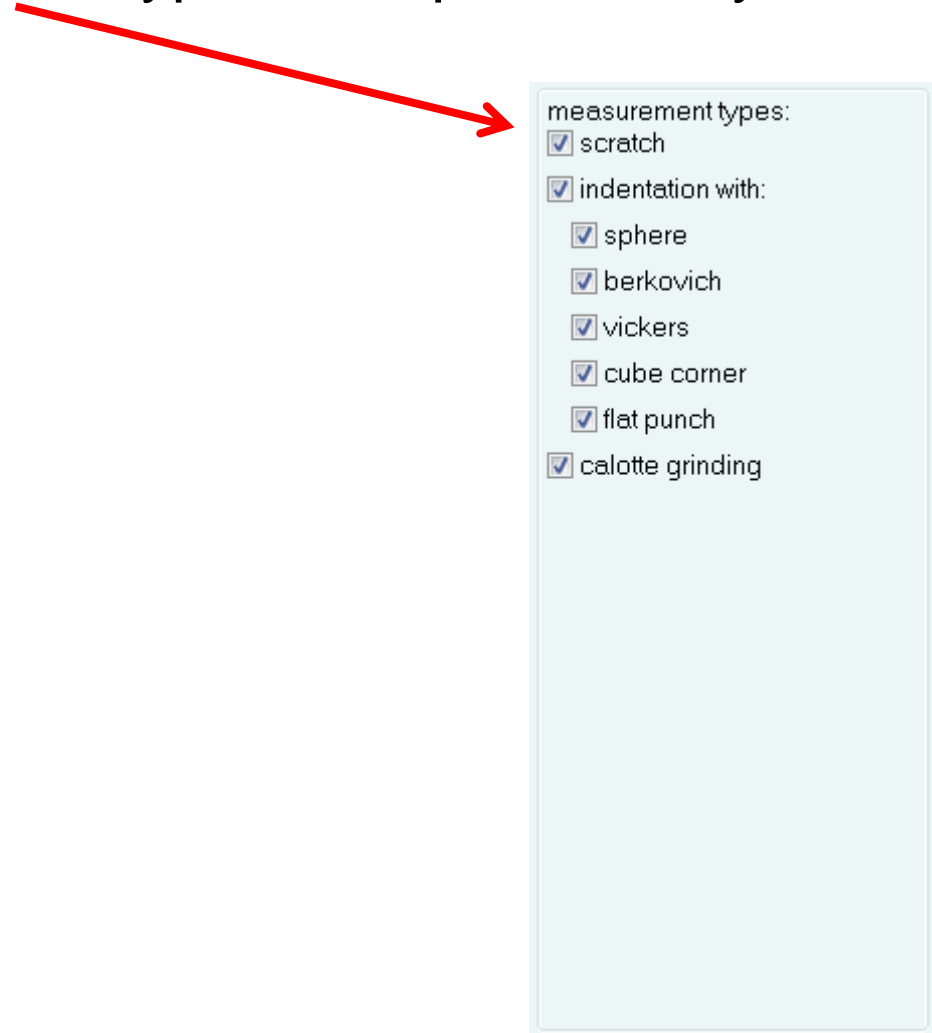
2nd step: Aim of Investigation

- select which point of your sample is of interest for you (POI)
- the experiments will be dimensioned to investigate this region



3rd step: Types of Experiments

- select the types of experiments you want to have dimensioned

A screenshot of a software interface showing a list of measurement types. A red arrow points from the text 'select the types of experiments you want to have dimensioned' to this list. The list is titled 'measurement types:' and contains the following items, each with a checked checkbox:

- scratch
- indentation with:
 - sphere
 - berkovich
 - vickers
 - cube corner
 - flat punch
- calotte grinding



Example: 1 μm TiN coating on steel substrate

Result: Dimensioned Scratch Test

theoretically optimum key parameters

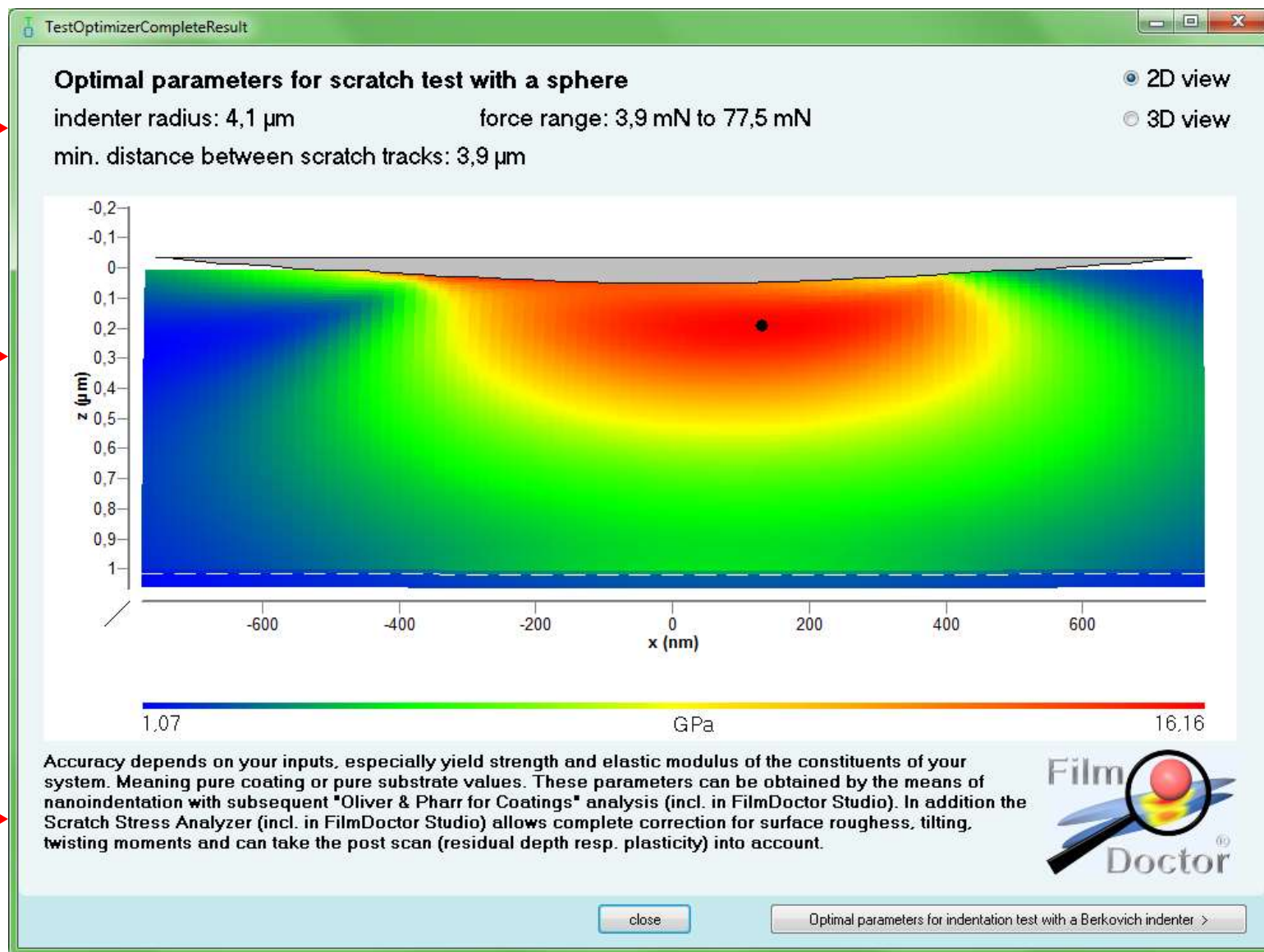


estimated sensitivity profile



well-designed for coating investigation

hints

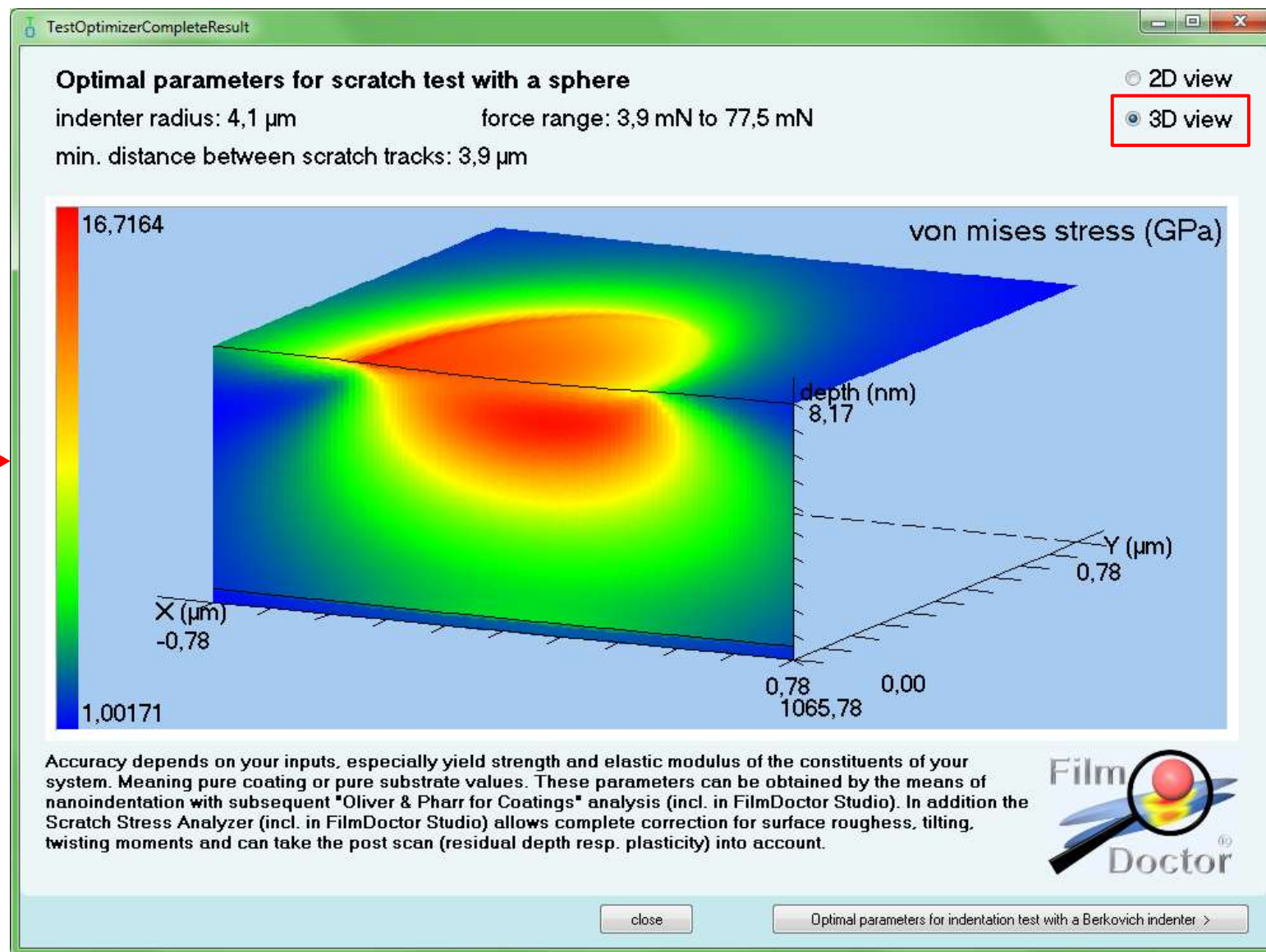




Example: 1 μm TiN coating on steel substrate

Result: Dimensioned Scratch Test

3D view →





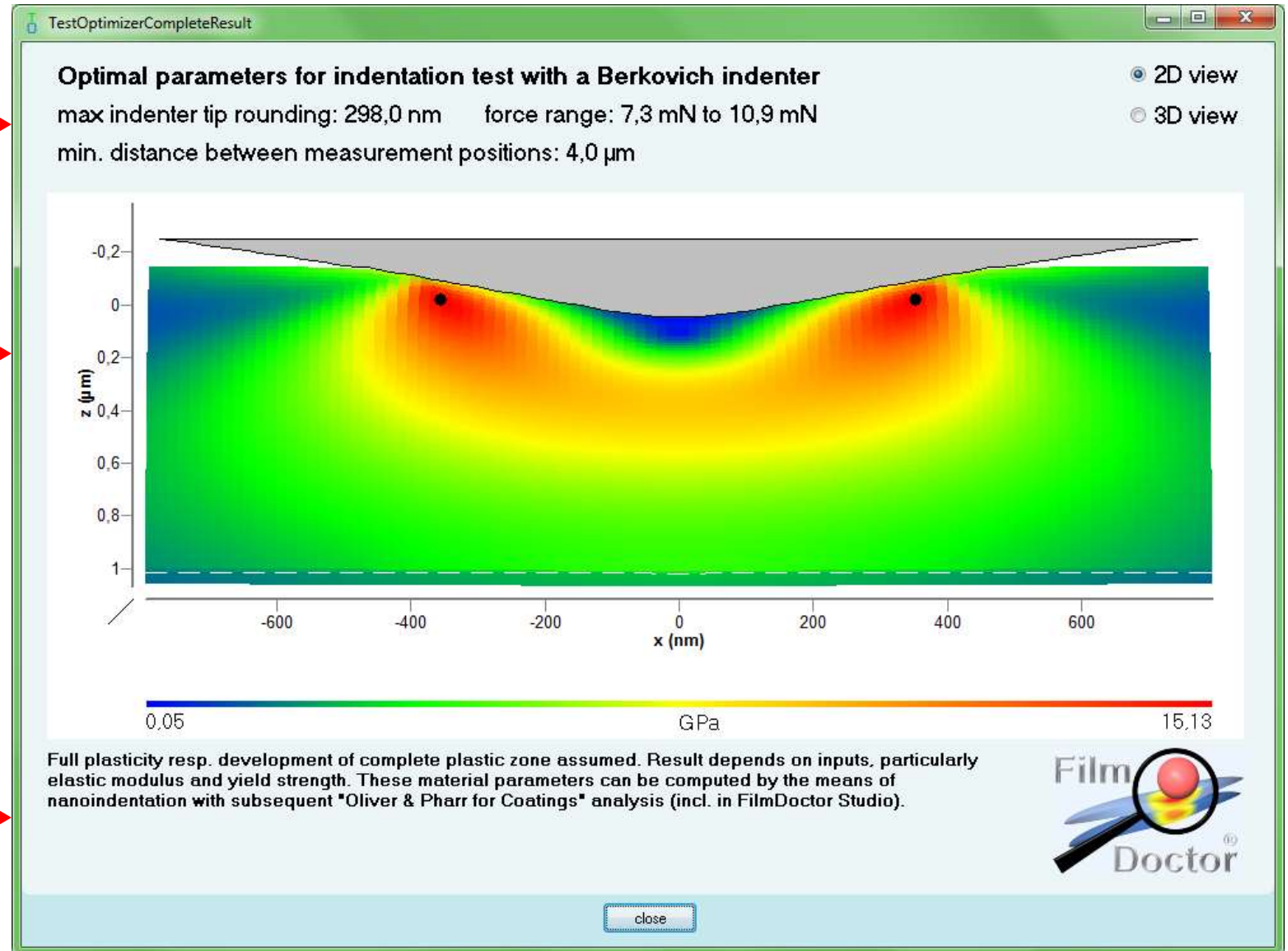
Example: 1 μm TiN coating on steel substrate Result: Dimensioned Indentation Test

theoretically optimum key parameters

estimated sensitivity profile

well-designed for coating investigation

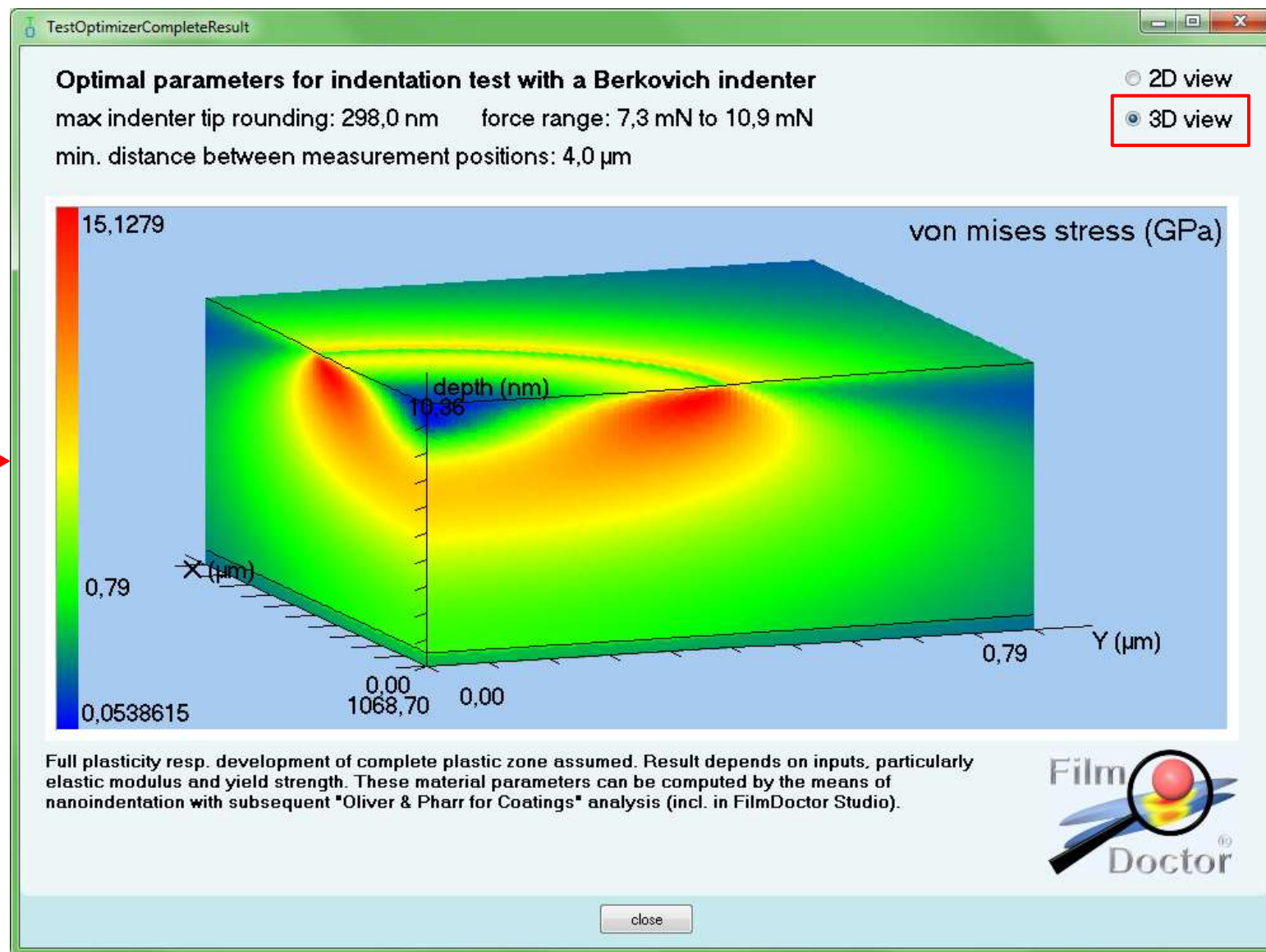
hints





Example: 1 μm TiN coating on steel substrate

Result: Dimensioned Indentation Test



3D view →

- design of contact experiments is crucial for investigation of treated/coated surfaces
- Test Optimizer allows quick & easy design of
 - scratch tests
 - indentation measurements
 - sphere
 - Berkovich
 - Vickers
 - cube corner
 - flat punch
 - calotte grinding on coatings
 - **as thin as 0.1 nm**
 - **with up to 100 layers**

The logo for Test Optimizer features the word 'Test' in black with a green 'T' and a blue 'O'. Below it, the word 'Optimizer' is in black with a blue 'O'. Small red dots are placed above the 'i' and 'z' in 'Optimizer'.

- [1] N. Schwarzer, J. Phys. D: Appl. Phys., 37 (2004) 2761-2772
- [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] N. Schwarzer, G. M. Pharr: „On the evaluation of stresses during nanoindentation with sharp indenters”, Thin Solid Films, Vol. 469-470C pp. 194-200
- [4] D. S. Stone, (1998) Elastic rebound between an indenter and a layered specimen, J. Mater. Res., Vol. 13, No. 11, 3207 – 3213
- [5] N. Schwarzer: "Arbitrary load distribution on a layered half space", ASME Journal of Tribology, Vol. 122, No. 4, October 2000, 672 – 681
- [6] N. Schwarzer, T. Chudoba, G. M. Pharr: „On the evaluation of stresses for coated materials during nanoindentation with sharp indenters”, Surf. Coat. Technol (2006), Vol 200/14-15 pp 4220-4226
- [7] N. Schwarzer, T. Chudoba, F. Richter, Surf. Coat. Technol., Vol 200/18-19 (2006) pp 5566-5580
- [8] V. Linss, N. Schwarzer, T. Chudoba, M. Karniychuk, F. Richter: "Mechanical Properties of a Graded BCN Sputtered Coating with Varying Young's Modulus: Deposition, Theoretical Modelling and Nanoindentation", Surf. Coat. Technol., 195 (2005) pp 287 - 297
- [9] T. Chudoba, N. Schwarzer, V. Linss, F. Richter: „Determination of Mechanical Properties of Graded Coatings using Nanoindentation”, proceedings of the ICMCTF 2004 in San Diego, California, USA, also in Thin Solid Films (2004): 469-470C pp. 239-247
- [10] R. Puschmann, N. Schwarzer, F. Richter, S. Frühauf, S. E. Schulz: "An applicable concept for the indentation of thin porous films", proceedings of the NanoMech 5, 7-9 September 2004 in Hückelhoven, Germany, also in Z. Metallkd. 96 (2005) 11, 1-6
- [11] N. Schwarzer: „Modelling of the mechanics of thin films using analytical linear elastic approaches“, Habilitationsschrift der TU-Chemnitz 2004, FB Physik Fester Körper, www.siomec.de/pub/2007/013 and <http://archiv.tu-chemnitz.de/pub/2004/0077>
- [12] N. Schwarzer: "Effect of lateral displacement on the surface stress distribution for cone and sphere contact", Phil. Mag. 86(33-35) 21 Nov - 11 Dec 2006 5231 – 5237, Special Issue: Instrumented Indentation Testing in Materials Research and Development"
- [13] N. Schwarzer, „Short note on the potential use of a rotating indenter with respect to the next generation of nanoindenters”, Int. J. Surface Science and Engineering, Vol.1 2007 2/3, pp. 239-258
- [14] N. Schwarzer, Some Basic Equations for the Next Generation of Surface Testers Solving the Problem of Pile-up, Sink-in and Making Area-Function-Calibration obsolete, JMR Special Focus Issue on "Indentation Methods in Advanced Materials Research", J. Mater. Res., Vol. 24, No. 3, March 2009, 1032 – 1036
- [15] N. Schwarzer, Basic Equations for the Next Generation of Surface Testers for the Case of an Elastic Indenter and a Layered Samples, online archive of the Saxionian Institute of Surface Mechanics, www.siomec.de/pub/2008/001
- [16] M. Fuchs, G. Favaro, " Physical characterization of coated surfaces, Part II: Scratch Test", Application Bulletin No. 38 of CSM instruments, free download at: www.csm-instruments.com/en/Physical-characterization-of-coated-surfaces-Part-II-%3A-Scratch-Test
- [17] N. Schwarzer, Q.-H. Duong, N. Bierwisch, G. Favaro, M. Fuchs, P. Kempe, B. Widrig, J. Ramm, Optimization of the Scratch Test for Specific Coating Designs, Surface and Coatings Technology, volume 206, issue 6, year 2011, pp. 1327 – 1335