ASPECTS REGARDING THE APPLICATIONS OF THE NANOINDENTER IN THE CHARACTERIZATION OF ADVANCED MATERIALS

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ABSTRACT: The development of new materials is a research area with major implications in all fields, starting with the industry up to medical sciences. The ability to use these new materials in areas where their impact will be significant is largely dependent on the ability to precisely determine their characteristics in order to identify those characteristics that are either unique or has a better value. The paper aims to present the applications of the nanoindenter in identifying mechanical characteristics of materials with an example of characterization for an alloy used in the medical field.
KEYWORDS: indentation, mechanical characteristics, advanced materials, nanoindenter.

1. INTRODUCTION

The term advanced materials can be used for all new materials or for all existing and modified materials that can obtain superior performance for at least one characteristic that is critical for the considered application [1].

In the actual economic development model based on a knowledge economy, studies have shown that advanced materials are an important strategic priority within all major knowledge economies [2].

Application of the new advanced materials in any field of the industry can be realized only after a full characterization of all the characteristics. In some field such as medicine other aspects must be investigated such as biocompatibility.

The paper will present the main characteristics of the Agilent G200 Nano indented with is available in the SMARTMAT Advanced Materials Research Infrastructure at the University of Oradea.

The SMARTMAT Laboratory is a research infrastructure developed widen HU-RO SMATMAT project realized in the framework of the Hungary-Romania Cross-Border Co-operation Programme 2007-2013 (www.huro-cbc.eu), and is part-financed by the European Union through the European Regional Development Fund, Hungary and Romania

The laboratory has activities in the field of advanced materials and is intended to serve as many researchers activities as possible. The main activities that can be carried out are the determination of a wide variety of properties for surfaces using nanoindentation, scratch testing, atomic force microscopy (depending on the type of tip used, there are a multitude of characteristics that can be studied) [3].

2. MAIN CHARACTERISTICS AND APPLICATIONS OF THE G200 NANO INDENTER

The nanoindenter is designed to realize precise mechanical testing for a micro-to-nano range of loads and displacements [4].

Figure 1. G200 nanoindenter set-up at the Smartmat laboratory

The nanoindenter can be used for determinations of Young’s modulus and hardness, measurement of deformation. Also some other specific testing is possible, namely frequency-specific testing, quantitative scratch and wear testing, integrated probe-based imaging, high-temperature testing [4].

The main fields of application of the nanoindenter are [4]:

- Semiconductor, thin films;
- MEMs (wafer applications);
- Hard coatings, DLC films;
- Composite materials, fibers, polymers;
- Metals, ceramics;
- Lead-free solder;
- Biomaterials, biological and artificial tissue;

Table 1. G200 Nanoindenter specifications.[4]

Characteristics	Value
Displacement resolution	< 0.01 nm
Total indenter travel	1.5 mm
Maximum indentation depth	> 500 μm
Load application	Coil/magnet assembly
Displacement measurement	Capacitance gauge
Maximum load (standard)	500 mN
Indentation placement - Useable surface area	100 mm x 100 mm
Position control	Automated remote
Positioning accuracy	1 μm
Microscope - Video screen	25x (x objective mag.)
DCM II Indentation Head Option	
Displacement resolution	0.0002 nm (0.2 picometers)
Range of indenter travel	70 μm
Typical leaf spring stiffness	~100 N/m
Typical damping coefficient	0.02 Ns/m
Typical resonant frequency	120 Hz
Lateral stiffness	80,000 N/m
Loading capability - Maximum load	30 mN (13 gm)
Loading capability - Load resolution	3 nN (0.3 μgm)
Time per indentation	Standard < 5.0 sec
LFM Option	
Maximum lateral force	> 250 mN
Lateral resolution	< 2 μN
Maximum scratch distance	> 100mm
Scratch speed	100 nm/s up to 2 mm/s
High Load Option	
Maximum force	10 N
Load resolution	≤ 1 mN
Maximum indentation depth	≥ 500 μm
Displacement resolution	0.01 nm
Frame stiffness	≥ 5 x 106 N/m
NanoVision Option	
X-Y scan range	100 μm x 100 μm
Z scan range	Indentation head dependent
Positioning accuracy	≤ 20 nm
Resonant frequency	> 120 Hz

The nanoindenter has a data acquisition function with a fundamental data acquisition rate is 12.5 kHz. The acquired data is stored and averaged using an electronic buffer and recorded at a rate of up to 500 Hz [4].

The measurements made with the equipment are compliant with international standards, ISO 14577[4]. ISO 14577 is an international standard that governs instrumented indentation [5]. Part 1of the standard describes the test method and analysis used to determined hardness and other material parameters. Part 2 prescribes procedures for verifying the performance of the testing instrument, and Part 3 prescribes the requirements for reference materials [6].

3. MEASUREMENTS OF ALLOY USED FOR MEDICAL IMPLANTS

This paper present the stages of measurements for an alloy used for medical implants. The composition of the alloy is Co 61.1% Cr 27.8% W 8.5% Si 1.7% MN <0.5%.

Figure 2. The sample of material used for the test.

In order to realize the test, the sample presented in figure 2 has to be mounted on a sample tray. The sample tray contained up to for samples and is actuated by the motion system.

The system is designed for positioning the specimens under the microscope and indenter tip.

In figure 3 is presented the sample tray mounted on the motion system. On the sample tray the material to be tested is mounted.

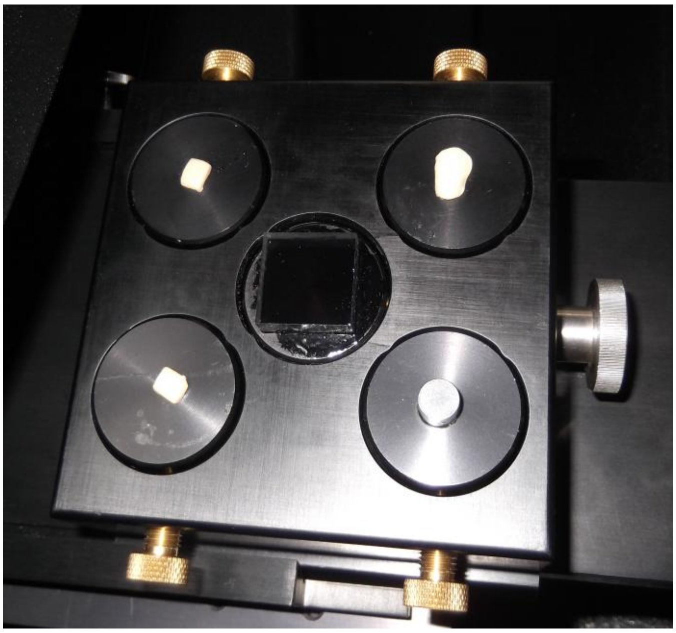

Figure 3. The sample of material used for the test.

In the center position of the sample tray, the reference sample provided by the manufacturer is located.

The measurements are made using the NanoSuite software. The image of the sample is acquired using the CCD camera of the nanoindenter.

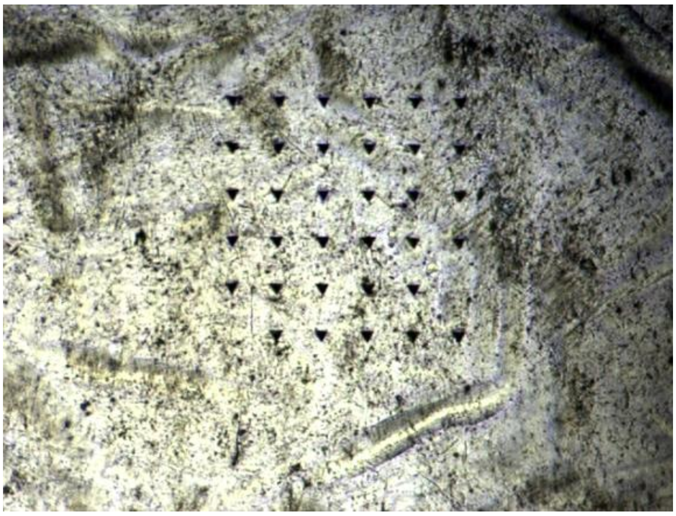

Figure 4. Indentation on the tested material.

In table 2 the modulus and hardness at max load are presented, for the test material.

Table 2. Measured modulus and hardness

Test	Modulus At	Hardness At
1	****	****
2	238,252	7,074
3	241,81	7,026
4	247,402	6,578
5	249,815	6,654
6	236,15	6,728
7	****	****
8	246,152	6,765
9	253,743	6,782
10	252,502	6,898
11	250,29	6,676
12	239,512	6,569
13	244,654	6,556
14	242,08	6,654
15	250,508	7,147
16	261,422	7,537
17	247,697	6,578
18	237,762	6,459
19	250,098	6,901
20	243,227	6,417
21	265,587	7,174
22	229,51	6,358
23	242,41	6,901
24	245,5	6,561
25	257,653	7,423
26	249,372	6,658
27	243,241	6,533
28	235,893	6,845
29	246,829	6,482
30	231,574	6,126
31	251,328	7,014
32	242,102	6,414
33	249,208	6,72
34	234,681	6,487
35	247,38	6,762
36	239,123	6,747
Mean	245,425	6,741
Std. Dev.	7,937	0,3
% COV	3,23	4,45

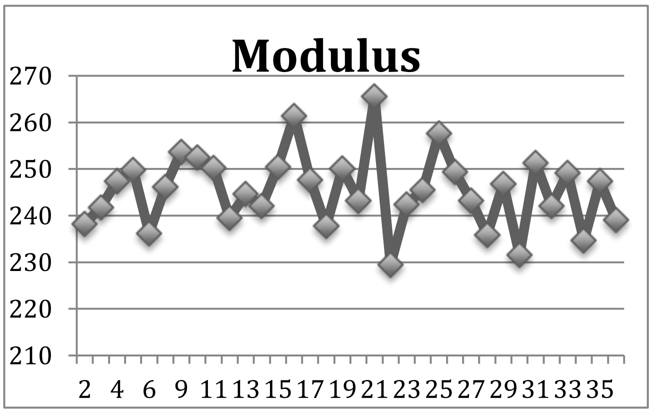

Figure 5. Modulus value for the measurements (except test1 and 7)

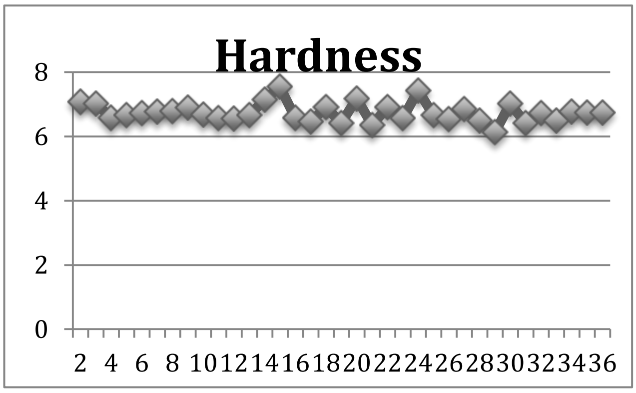

Figure 6. Hardness value for the measurements (except test1 and 7)

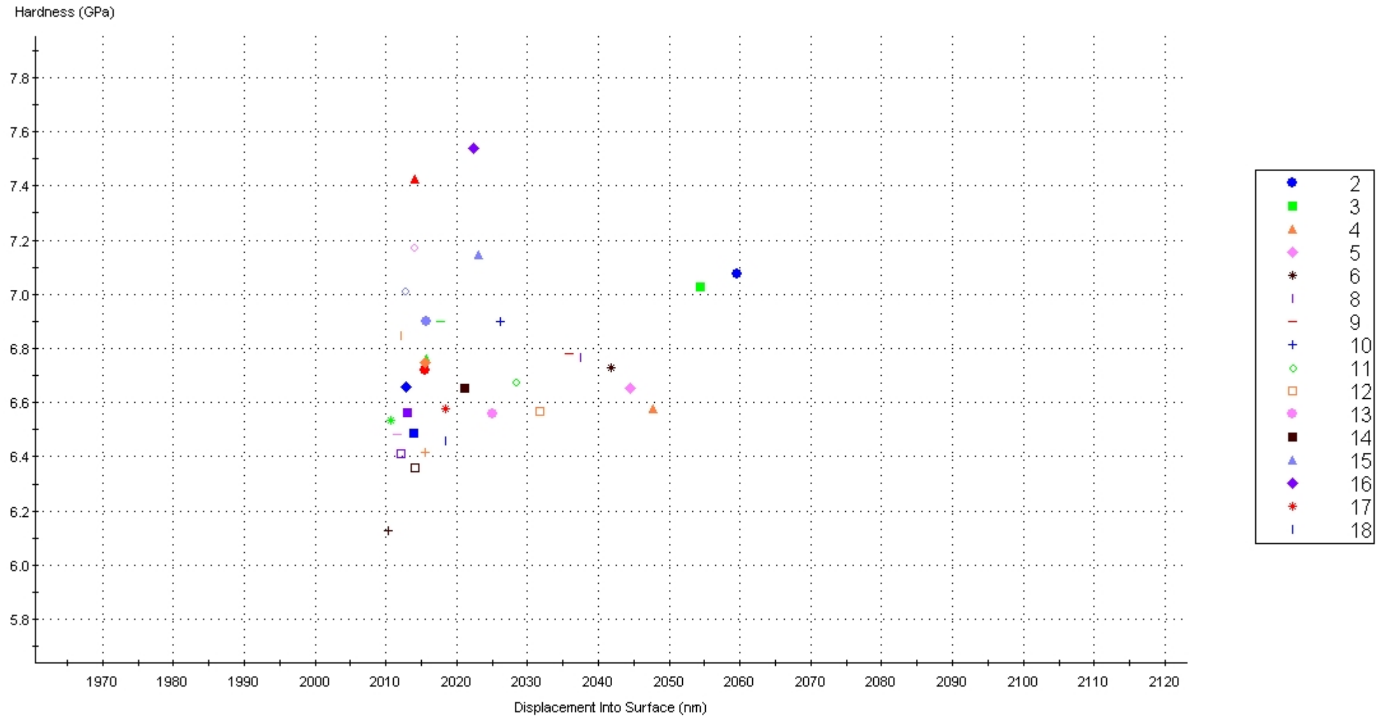

Figure 7. Hardness versus displacement into surface

In figure 7 the hardness of the test sample is presented relative to the displacement into surface. In figure 8 the modulus of the test sample is represented relative to the displacement into surface.

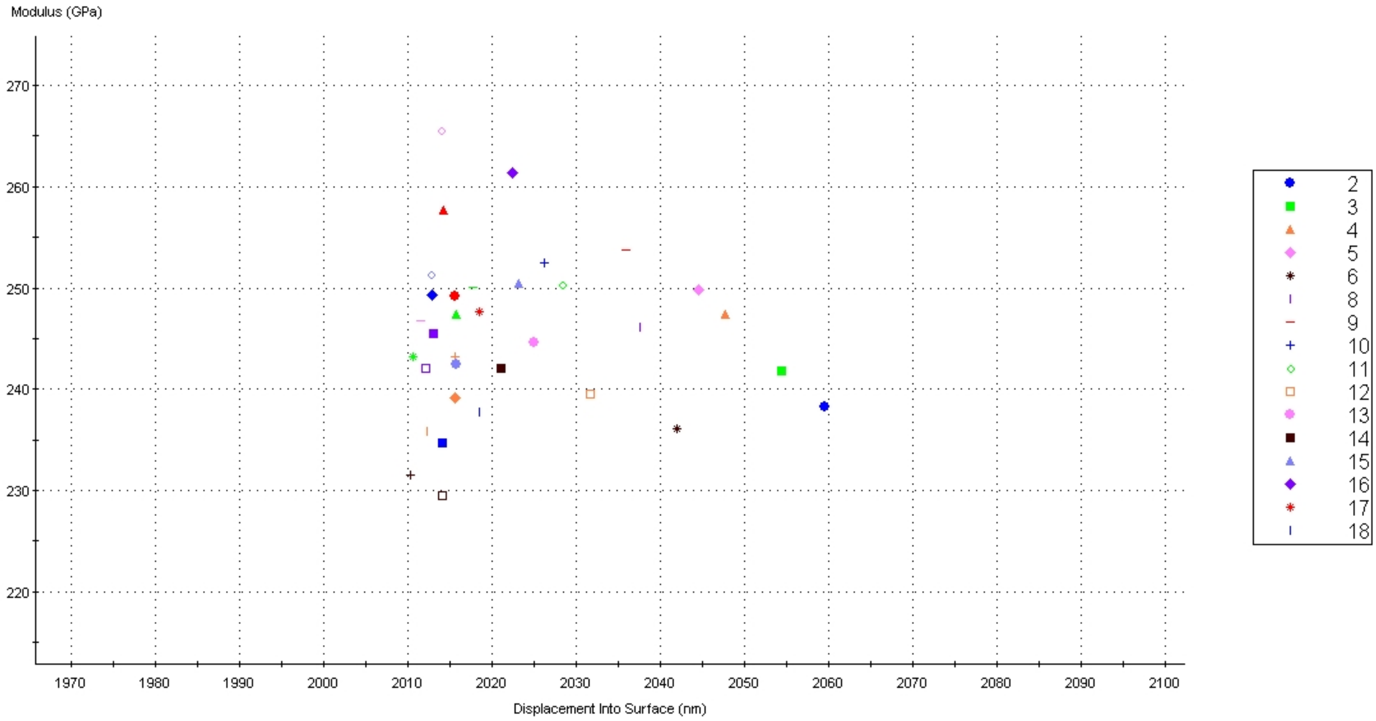

Figure 8. Modululs versus displacement into surface

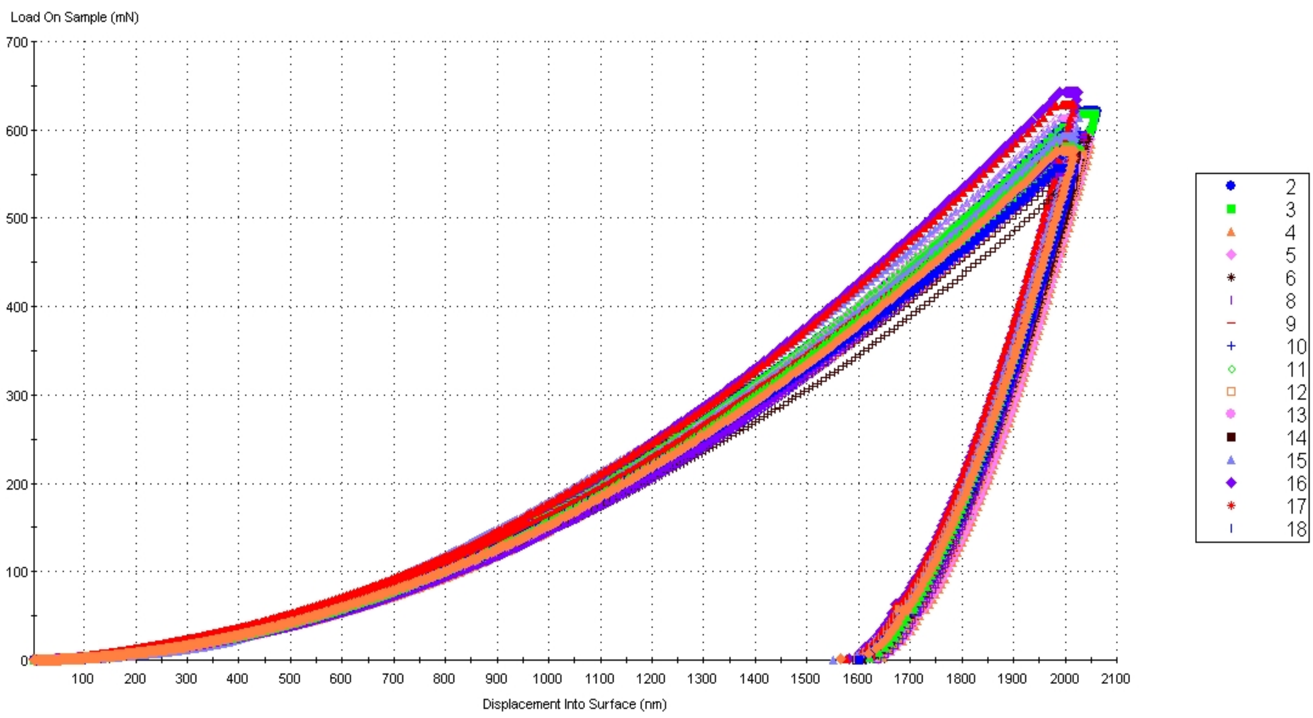

Figure 9. Load versus depth for the analyzed material.

4. CONCLUSION

As described in the paper the nano-intender is a tool for mechanical characterization of materials. The measurements done with this tool are important in determining with a high degree of precision the mechanical proprieties of materials, being thus an important tool in the research of advanced materials.

The test realized are according with an internationally recognized standard (ISO 14577).

The precision of the test is appropriate, as can be observed in Table2. For the modulus test, the standard deviation (7.937) represents 3.23 % of the mean value for the measurements (245,425).

For the hardness test the standard deviation (0.3) represents 4.45 % of the mean value for the measurements (6.741).

Another very useful mechanical characterization method that can be accomplished whit the nano-indenter is the Scratch Test. The method is useful for evaluating different coatings and wear testing.

5. ACKNOWLEDGEMENTS

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