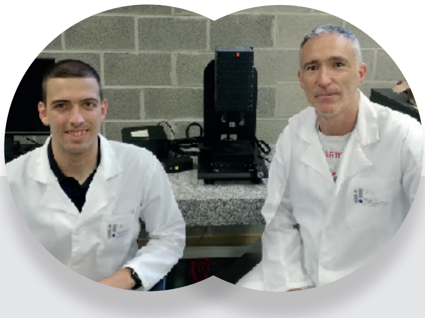
SENSOFAR METROLOGY

Surface characterization of tribological coatings: wear properties, thickness, and roughness

The Institute for Research in Advanced Materials and Mathematics (INAMAT2) is a multidisciplinary research institute that has common objectives such as the development, dissemination and transfer of knowledge from various fields. The materials engineering department has a long experience in studies related to coatings and the surface improvement of materials.

With the S mart 3D profilometer, it is possible to more precisely measure the volume loss of the wear tracks after the friction and wear tests, since it measures the real shape of the wear track.

Our research focuses on improving tribomechanical properties of Diamond-Like Carbon (DLC) coatings, deposited by the novel PVD technique High Power impulse magnetron sputtering (HiPIMS) with positive pulses on tool steels. These coatings are of great interest to the industry because of their extraordinary properties: excellent wear resistance, very low friction coefficient, great hardness, or biocompatibility. The aim of these studies was to improve the tribomechanical properties, such as, adhesive or wear resistance, of the DLC coatings on different steel substrates.



The Institute for Research in Advanced Materials and Mathematics (INAMAT2) from Public University of Navarre (UPNA) is a multidisciplinary research institute that brings together researchers from different scientific areas (Mathematics, Physics, Chemistry and Materials Science).

The study was carried out by Adrián Claver (left) and José Antonio García Lorente (right).

upna
INAMAT2
Institute for Advanced Materials and Mathematics

With the Sensofar´s 3D optical profiler we expected to better characterize the surfaces, with greater accuracy in the measurements and higher quality 2D and 3D images.

Coated and uncoated round and plane samples have been measured. Different steels and ceramics have been used as substrate and high-quality coatings, such as DLC, are deposited on them. In these samples we carry out friction and wear tests with a pin-on-disc tribometer and after that we measure the wear tracks.

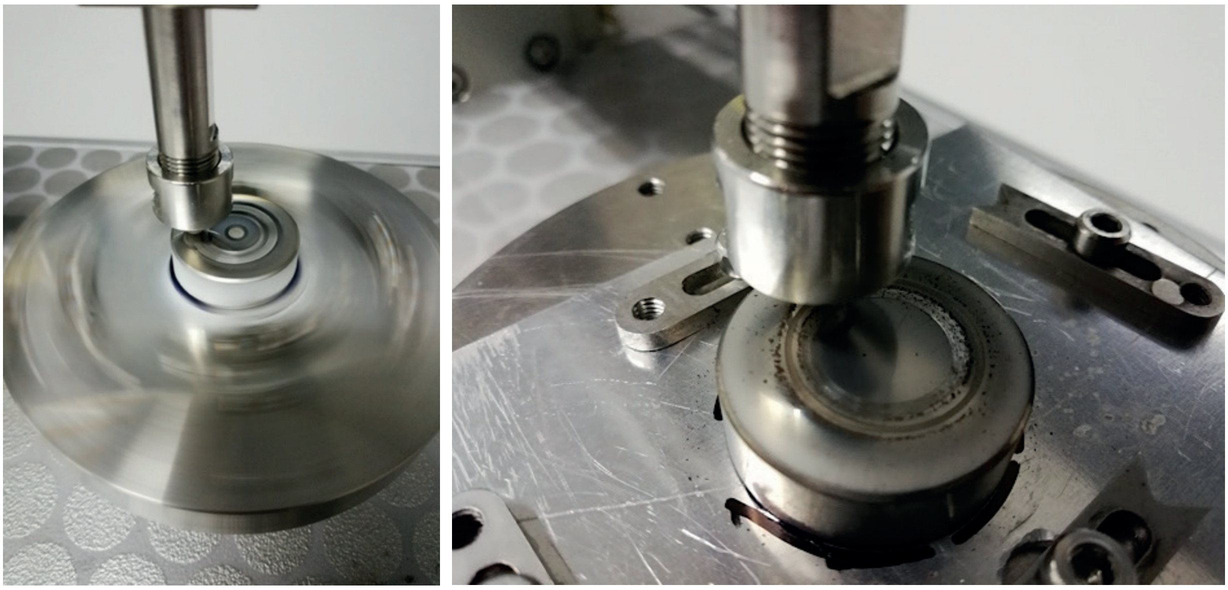


Figure 1. (a) Friction and wear tests being carried out on one of the samples. (b) Image of one of the samples after a friction and wear test.

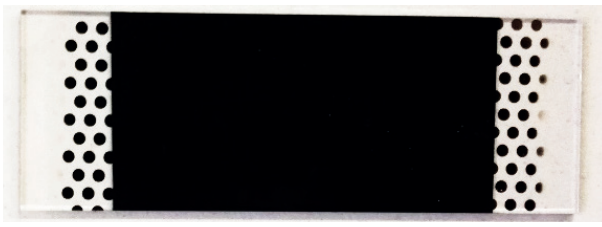


Figure 2. Sample used to determine the thickness of the coating.

There are many key parameters in studying the tribomechanical properties of a surface or a coating: nano-hardness, adhesion between the coating and the substrate, roughness, thickness of the layers or wear properties. With the S mart profilometer, we can measure the superficial roughness, the thickness of the coatings and the volume loss after the friction and wear tests, which is necessary to then calculate the wear coefficient.

In industrial applications wear resistance is a very important property since it can determine the correct performance and provide a longer life of the materials. Determining this value is not easy, since many factors intervene: there are changes in the wear mechanisms and both the pin and the disc suffer wear.

The characterization of the wear is not so simple, and with the Sensofar´s profilometer we are able to achieve the most realistic representation of the wear suffered during the friction in wear tests and to better measure volume loss.

Measurements

VOLUME MEASUREMENT

For the friction and wear tests we used 6 mm diameter alumina balls, with a surface maximum roughness of Ramax 0.050 µm and a hardness of around 1650 HV, and different samples of coated and uncoated tool steels as the disks. In the tests, the disks rotate against the pin under the following conditions: 40 N load, 200 rpm and 20,000 cycles, and the tests were repeated three times at 8, 10 and 12 mm (track radii) for each sample. As a result of this test, a wear track appears from which the volume loss is measured to determine the wear coefficient.

The volume loss, measured to later calculate the wear resistance, was measured using Confocal technology. The objectives were chosen depending on the width of the wear tracks, using the 5X and 10X ones for the uncoated samples, where the widest wear tracks were observed, and the 20X and 50X ones for the coated samples that presented the narrower tracks.

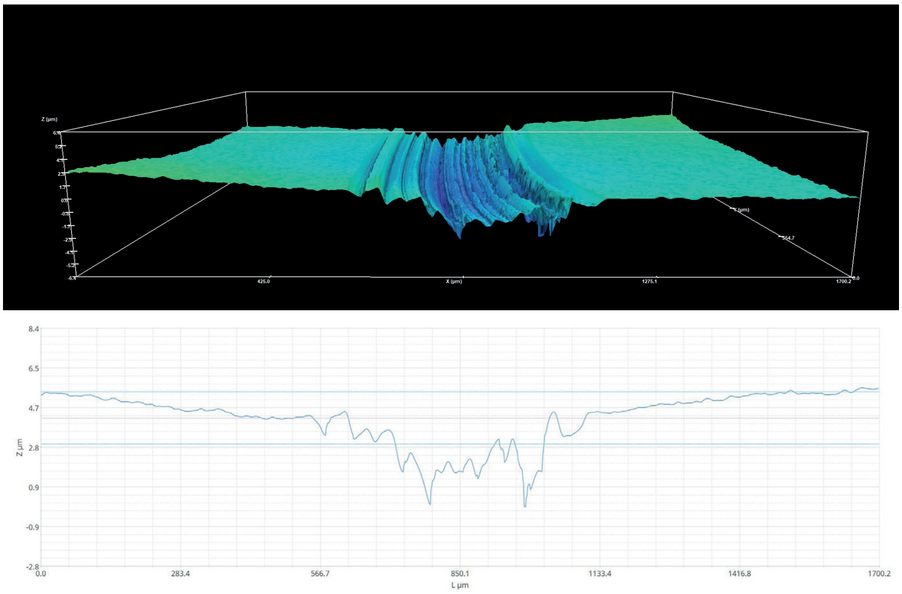


Figure 3. Measurements of the volume loss of the coating acquired by the S mart 3D optical profilometer (10X EPI).

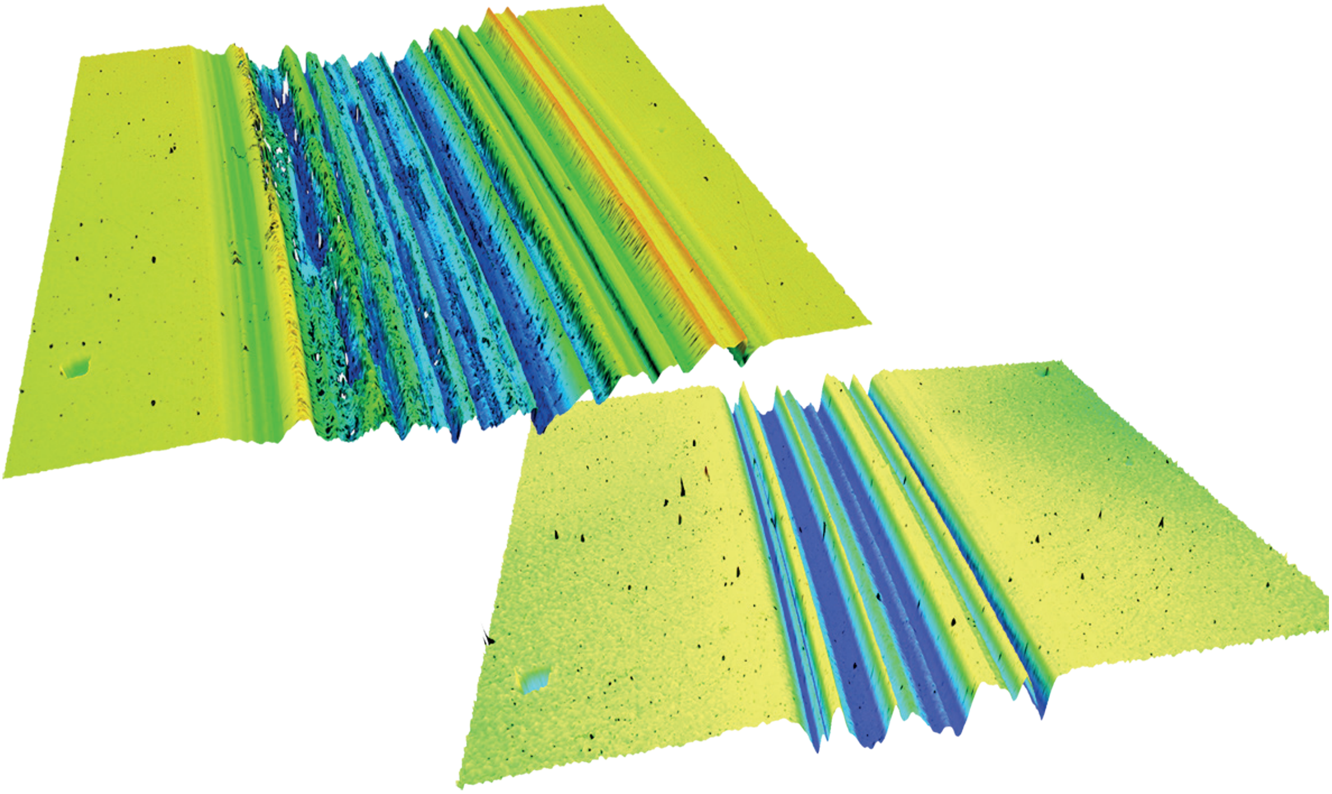
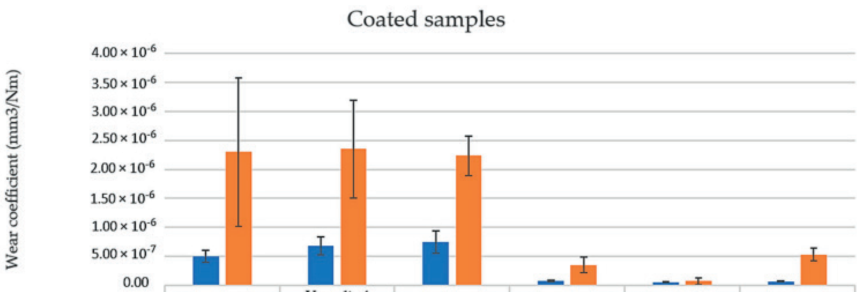


Figure 4. Image of the wear track of a (a) WC-C and (b) ta-C coated sample acquired by Confocal profilometer (10X brightfield objective).

The wear coefficient was determined in two ways to achieve the most accurate value; following the standard ASTM G99 and straight from the Confocal measures of volume loss. When Confocal profiler measurements are used directly, the measured volume loss value is extrapolated to the entire wear track and with that volume loss value the wear coefficient is calculated.



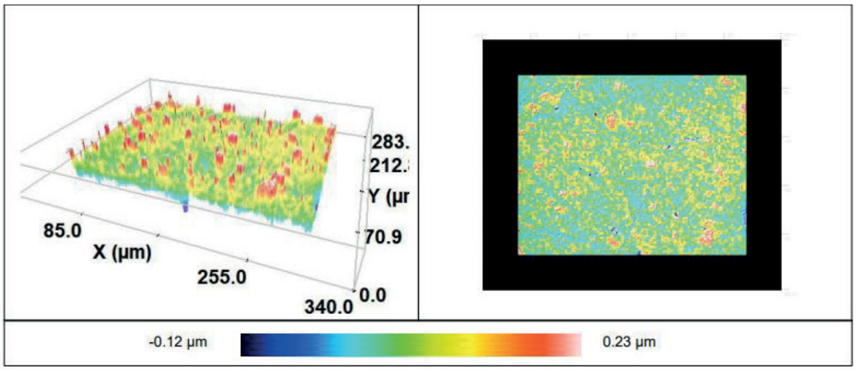
	Vancron WC:C	Vanadis 4 WC:C	K-360 WC:C	Vancron ta-C	Vanadis 4 ta-C	K-360 ta-C
Confocal measures	4.98×10^{-7}	6.79×10^{-7}	7.44×10^{-7}	7.59×10^{-8}	5.37×10^{-8}	6.72×10^{-8}
ASTM G99 measures	2.30×10^{-6}	2.35×10^{-6}	2.24×10^{-6}	3.51×10^{-7}	7.17×10^{-8}	5.29×10^{-7}

Figure 5. Comparative graph of the wear coefficient values obtained for each sample measured by standard ASTM G99 (orange plot) and Confocal (blue plot).

The main goal, to characterize the wear resistance of the coatings in the most accurate way, was achieved with the S mart 3D profilometer. Thanks to the fact that this profilometer measures the volume loss after the friction and wear tests taking into account the real shape of the wear track, it can be said that the wear coefficient values obtained by Confocal are lower and more realistic than those calculated following the standard ASTM G99.

THICKNESS AND ROUGHNESS MEASUREMENT

Moreover, it was possible to easily measure the superficial and profile roughness of the samples, then contrasting the values obtained by using two different technologies for measuring it, Confocal and Interferometry. In this way, it was possible to ensure the precision of the roughness values obtained. The substrate's roughness can be a determining factor in the adhesion between the coating and the substrate.



ISO 25178 / Height

Sa	2.8853 nm	Sq	4.7867 nm
Sku	205.4096	Ssk	3.0629
Smean	0.1369 nm	Sv	122.09 nm
Sp	226.31 nm	Sz	348.40 nm

Figure 6. Measurements of the superficial roughness (0.08 mm cut off) of a coated tool steel sample by Confocal microscopy with the 50X objective.

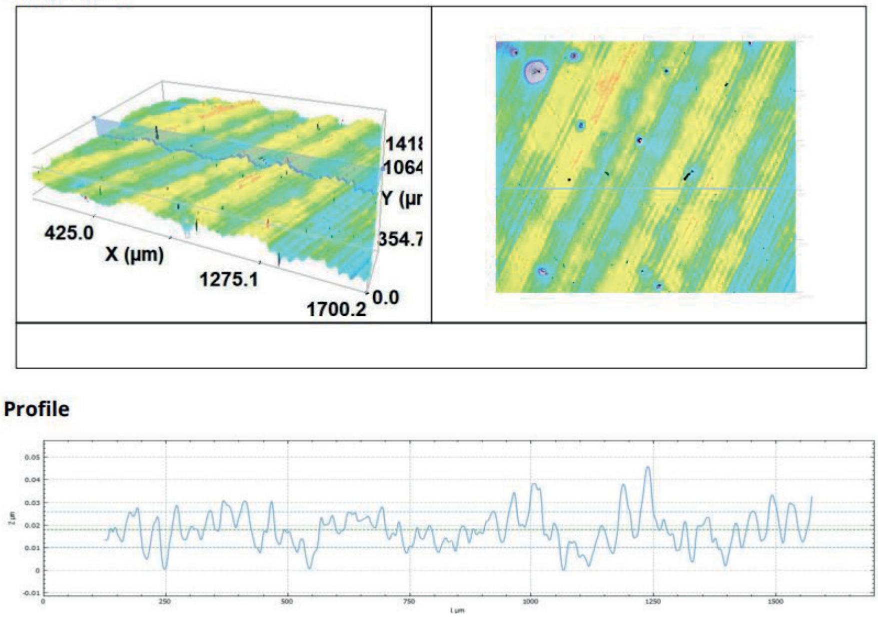


Figure 7. Measurements of the profile roughness of a coated tools steel sample by interferometry (10XDI).

Finally, the thickness of the coatings was measured in a fast and simple way. As well as for roughness, the thickness was measured both with Confocal and Interferometry in order to corroborate the results. The main advantage of this measurement is that it was possible to measure the thickness without the need for destructive testing.

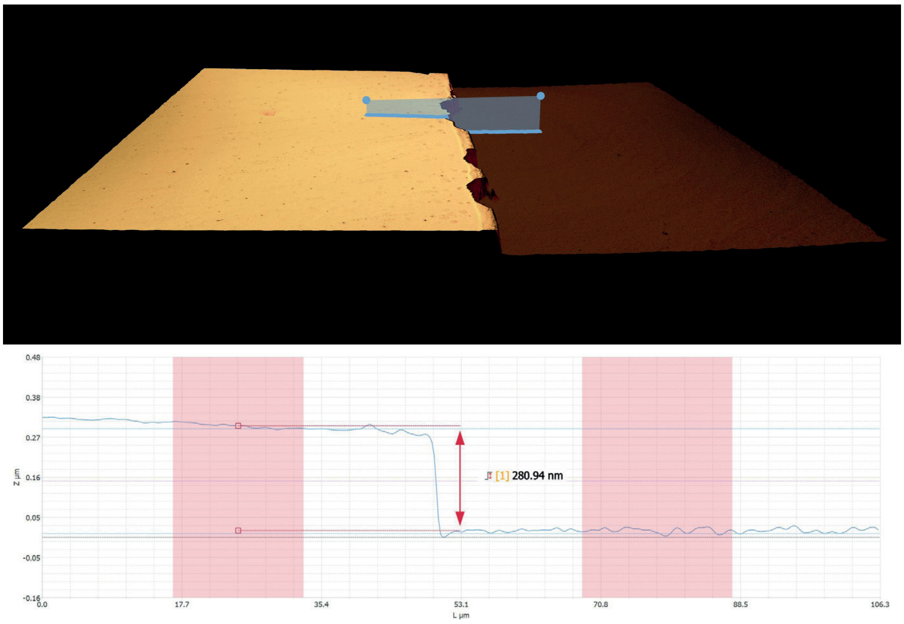


Figure 8. Measurements of the thickness of the coating acquired by the S mart 3D optical profilometer.

For the roughness and thickness measurements both Confocal (50X) and Interferometry (10X) were used. This way we tried to achieve the highest resolution in depth to obtain the most accurate values.

Conclusions

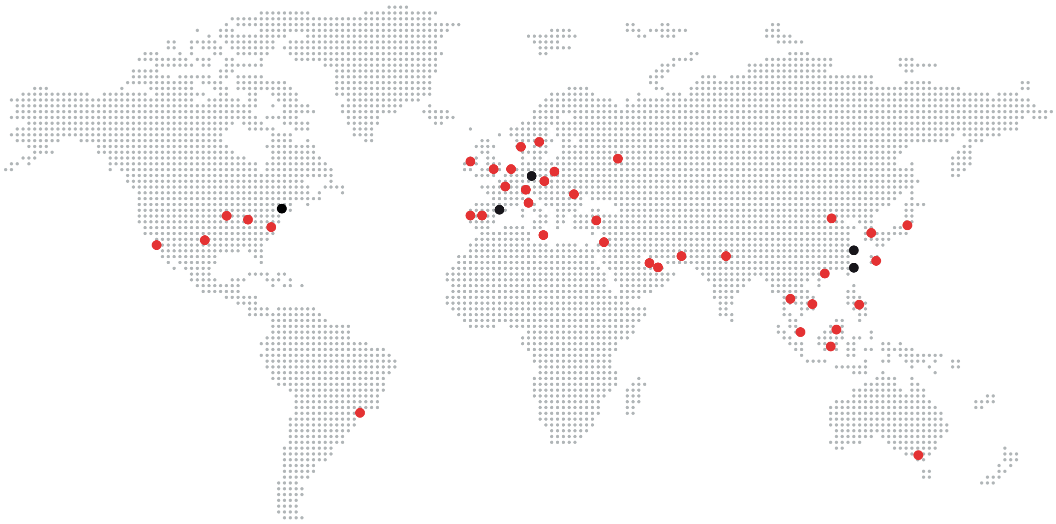
There are many parameters that are important to study the tribomechanical properties of a surface or a coating such as nano-hardness, adhesion between the coating and the substrate, roughness, thickness of the layers or wear properties. Sensofar's optical profiler can assess all these properties, as well as being more accurate than other methods of characterization. Finally, it should be noted that the versatility, speed and ease of use of the S mart profilometer gives us the option of using different techniques for corroborating the values obtained.

References

1.Claver A, Jiménez-Piqué E, Palacio JF, Almandoz E, Fernández de Ara J, Fernández I, Santiago JA, Barba E, García JA. Comparative Study of Tribomechanical Properties of HiPIMS with Positive Pulses DLC Coatings on Different Tools Steels. Coatings. 2021; 11(1):28.

2.García JA, Rivero PJ, Barba E, Fernández I, Santiago JA, Palacio JF, Fuente GG, Rodríguez RJ. A Comparative Study in the Tribological Behavior of DLC Coatings Deposited by HiPIMS Technology with Positive Pulses. Metals. 2020; 10(2):174.

SENSOFAR
METROLOGY



SENSOFAR is a leading-edge technology company that has the highest quality standards within the field of surface metrology

Sensofar Metrology provides high-accuracy optical profilers based on confocal, interferometry and focus variation techniques, from standard setups for R&D and quality inspection laboratories to complete non-contact metrology solutions for in-line production processes. The Sensofar Group has its headquarters in Barcelona, known as a technology and innovation hub in Europe. The Group is represented in over 30 countries through a global network of partners and has its own offices in Asia, Germany and the United States.

HEADQUARTERS

SENSOFAR METROLOGY | BARCELONA - Spain | T. +34 93 700 14 92 | info@sensofar.com

SALES OFFICES

SENSOFAR ASIA | SHANGHAI - China | T. +86 21 61400058 | info.asia@sensofar.com
SENSOFAR GERMANY | LANGEN - Germany | T. +49 151 14304168 | info.germany@sensofar.com
SENSOFAR USA | NEWINGTON (CT) - USA | T. +1 617 678 4185 | info.usa@sensofar.com

sensofar.com