NEW RESULTS: HiPIMS TA-C RESISTS CAVITATION WEAR

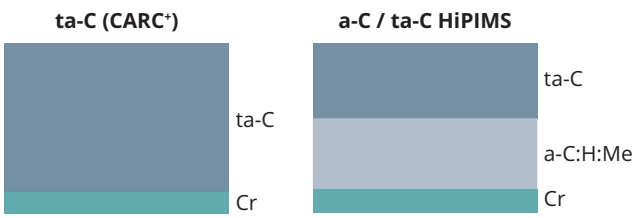
Tetrahedral amorphous carbon (ta-C) coating, a hydrogen-free diamond-like carbon (DLC) coating, is in growing demand in the automotive industry. Compared to hydrogenated DLC coatings, hydrogen-free DLC coatings have increased thermal stability and improved mechanical and tribological properties in combination with low-viscosity oils, which is important in certain automotive applications. New test results show that ta-C coating applied by HiPIMS, smoother than ta-C applied traditionally, has excellent cavitation wear resistance and adhesion. Ruud Jacobs, Process Manager Tribological Coatings, says: “From a technical perspective, we consider the HiPIMS carbon coating to be one of the best – if not the best – performing coatings available.”

Bubbles That Create Shock Waves

HiPIMS ta-C, the hydrogen-free DLC coating of choice for applications that require smoothness, is undergoing regular tests in various applications such as tappets, diesel and gasoline injectors and fuel pumps. The wear and lifetime results have been very promising. In this new test, focused on adhesion and cavitation wear resistance, Robert Bosch GmbH Powertrain Solutions tested HiPIMS ta-C on roller shoes from a diesel pump.

In the test, an ultrasonic sonotrode was used to create cavitation in the centre of the roller shoe bore. Cavitation occurs when gases dissolved in liquid create bubbles. When pressurised, the cavitation bubbles collapse, generating violent microjets or shock pressure waves characterised by high velocities, pressures and temperatures. The resulting microimpacts on the surface lead to plastic deformation of the substrate surface, forming undulations (waviness) on the surface that damage the coating. The typical lifetime of hard coatings with the used test parameters is 90 to 900 min.

	ta-C (arc)	ta-C HiPIMS
Thickness [µm]	0.1 + 0.9	0.6 + 0.7
Roughness Ra [µm]	0.08	0.01
Roughness Rp [µm]	1.0	0.08
Hardness HV 10mN	2000 - 6500	4000
Adhesion (HrC)	1 - 2	1 - 2
Sp3 content	Up to 65%	30 - 40%



Excellent Adhesion and Cohesion

HiPIMS ta-C on the roller shoes showed extremely good adhesion and cohesion in the complex shape of the roller shoe bore. As can be seen in the pictures below, failures start mainly at substrate failures (probably caused by micron-scale non-metallic inclusions). The coating surface shows typical undulations caused by plastic deformation of the substrate underneath the coating. The coating, which has to follow the undulations, is additionally stressed by the bending. After 1080 minutes of cavitation testing, most of the HiPIMS ta-C coating was still intact on the substrate surface. Dr. Ulrich May from Robert Bosch GmbH Powertrain Solutions: “The coating performance is excellent and should open opportunities for other types of applications, too.”

↑ Overview of cavitation damage zone after 270 min. exposure time. Failed area is very small.

↑ Overview of cavitation damage zone after 720 min. exposure time. More and bigger delaminations. Undulations in the coated areas are clearly visible.

↑ Overview of cavitation damage zone after 1080 min. exposure time. Failed areas coalesce.

Increasing HiPIMS Productivity with Larger Batches

These excellent test results are another good reason to invest in HiPIMS ta-C. However, compared to ta-C by CARC+ technology, the HiPIMS process has a lower deposition rate. Increasing the batch size and using specialised fixtures for the most efficient loading can both give a significant boost to HiPIMS productivity, for smooth, droplet-free results in a manageable process time. Now, HiPIMS technology is also available on the Hauzer Flexicoat® 1500, the largest batch-coating system in the Hauzer portfolio. The required cathode power density and the recipe that was developed in the Hauzer Flexicoat® 1200 system have been expanded to the Flexicoat® 1500. This is another important step towards optimising HiPIMS ta-C to a competitive production process.

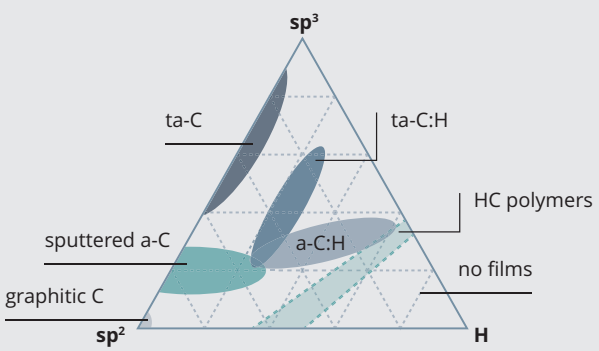
Hauzer Flexicoat® 1500.

From Hydrogenated DLC to Smooth Ta-C

Low friction and high wear resistance have always been very important properties when it comes to coatings for the automotive industry. Extremely high volumes of valve train components, piston system parts and fuel injection components are routinely coated with diamond-like carbon (DLC) coatings.

- **1990s.** Introduction of the 'classical' hydrogenated DLC coatings (a-C:H/a-C:H:Me) as tribological coatings for engine parts.
- **2000s.** Growing demand for hydrogen-free DLC coatings, in particular the amorphous carbon (a-C) and tetrahedral amorphous carbon (ta-C) coatings. For some applications, especially for those where friction reduction counts, hydrogen-free DLC coatings have superior properties to hydrogen-containing DLCs.
- **2010s.** Hydrogen-free DLC coatings taken into mass production. The first application was a thin ta-C layer on mechanical tappets, produced in Hauzer Flexicoat® 1500 machines equipped with sputter cathodes for the adhesion layer and circular arc (CARC) cathodes for the highly sp3-hybridised carbon top layer. Other applications followed, requiring different thicknesses (up to 30 micrometres for piston rings) and a wide range of sp2/sp3 ratios. Because the deposition method results in droplets, post-coating surface treatment is nearly always mandatory to get to the desired smoothness.

The solution to the high roughness of traditionally deposited ta-C is HiPIMS technology, the droplet-free alternative. Hauzer offers HiPIMS ta-C in a Hauzer Flexicoat® 1200 machine with sputter cathodes that can run pulsed DC magnetron sputtering for the adhesion layer and a HiPIMS cathode for the hard ta-C top layer.



J. Robertson, Materials Science and Engineering, 2002 (129-821)

Diamond-like carbon (DLC) coatings come in many varieties, classified by their ratio of sp3-bonded carbon (diamond), sp2-bonded carbon (graphite) and hydrogen. The more sp3-bonded carbon in a coating, the harder it usually is. Tetrahedral amorphous carbon (ta-C) is a hydrogen-free carbon coating with high sp3/sp2 ratio (on the left side of the triangle.)