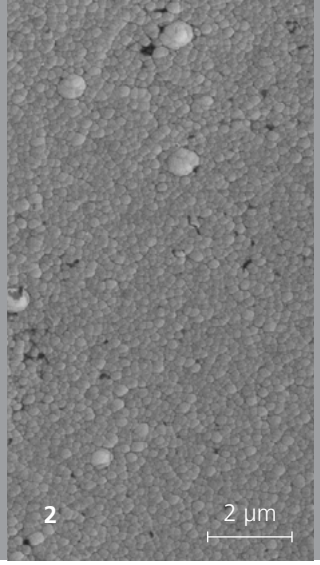
1



2

THERMALLY STABLE DLC COATINGS

Current developments in the automotive industry, such as higher power densities, downsizing or the use of low-viscosity oils, require the use of coatings with long-term stability which offer low friction coefficients and low wear rates even at temperatures up to 500 °C. The diamond-like carbon coatings (DLC coatings) currently established in industry, mostly hydrogenated amorphous carbon coatings (a-C:H coatings) but increasingly also hydrogen-free ta-C coatings, do meet requirements but only up to about 350 °C. One way of increasing the heat resistance of DLC coatings is to modify them by incorporating additional elements. As part of a development project in association with the company IHI Hauzer Techno Coating in Venlo, Netherlands, differently modified DLC coatings have been investigated at the Fraunhofer IST with regard to their mechanical and tribological properties up to 550 °C.

Coating preparation and high-temperature tests

In an initial step the modified DLC coatings were deposited by Hauzer Techno Coating in a Flexicoat® 1200 hybrid coating machine. The following technologies were used here:

- Arc evaporation
- Sputtering
- PACVD (plasma-assisted chemical vapor deposition) and
- Combinations of arc evaporation with sputtering and PACVD with sputtering.

Tungsten and silicon were used as modification elements for the a-C:H coatings and tungsten and hydrogen for the ta-C coatings. Following a four-hour annealing treatment at temperatures up to 500 °C in an ambient atmosphere, hardness, wear and friction coefficients were measured. Furthermore, with the high-temperature tribometer available at the Fraunhofer IST the friction coefficients could be measured directly at high temperatures, for example, at 450 °C in a normal atmosphere.

Assessment of different modified DLC coatings

The changes in coating hardness resulting from annealing are shown in the diagram (top) for six selected coating materials. Apart from the a-C:H coatings modified with tungsten (a-C:H:W), hardness rises or remains unchanged. Furthermore it is clear that the surface roughness of the coatings and also the friction coefficients fall slightly after annealing.

For all coatings considerably higher friction coefficients were measured at 450 °C than at room temperature (see diagram, bottom). Comparatively minor increases can be seen with the ta-C:H and a-C:H:W coatings. Both friction and wear are taken into consideration in application-oriented assessments of coating potential. In the light of these criteria the a-C:H:Si coatings, for example, which have the lowest friction coefficients at room temperature, are less suitable for high-temperature applications on account of their high rates of wear. The studies carried out yielded valuable information about the suitability of differently doped DLC coatings for highly stressed tribological pairs with thermal loads up to temperatures in the range of 500 °C.

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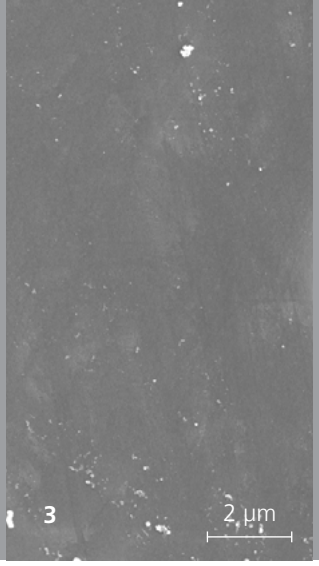
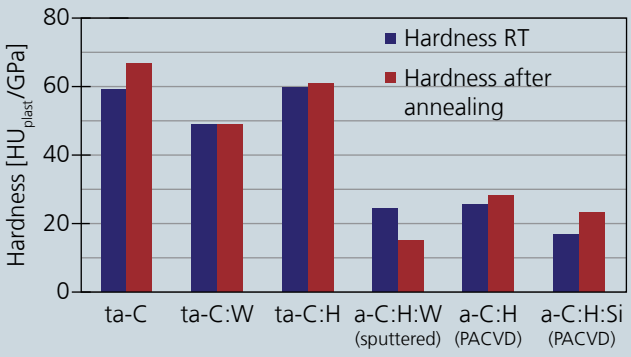


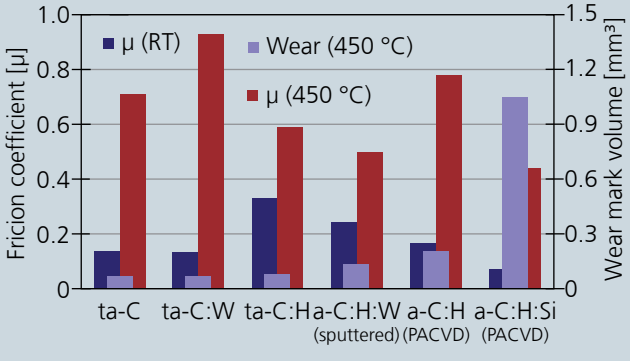
Outlook

The results of these investigations form a basis for being able to define friction- and wear-reducing DLC coatings for automotive components for use at higher temperatures. Further investigations are being prepared for development work, including tests under different load collectives, lubricated conditions, varied coating modifications and testing of the coatings on real components.

Comparison of layer hardness before and after annealing.



Fricion coefficients measured at room temperature (RT) and at 450 °C as well as the determined wear rates after the test.



1 *High-temperature tribometer at the Fraunhofer IST.*

2-3 *REM surface images of an a-C:H:W coating before (2) and after (3) annealing.*

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