

PVD/PACVD Technology and Equipments of Hauzer Techno Coating

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As a company that plays a major role in the manufacturing industry, we urgently need to reduce emissions of CO₂ and other gases by improving the efficiency of internal combustion engines, and to reduce waste produced at manufacturing sites by improving manufacturing processes, in order to maintain and improve the rapidly deteriorating global environment. The essential technologies required to implement these measures are surface modification technologies that use the hard coating methods of Physical Vapor Deposition (hereinafter called PVD) and Plasma Assisted Chemical Vapor Deposition (hereinafter called PACVD).

A leading supplier of industrial PVD/PACVD hard coating systems, Hauzer Techno Coating B.V. (Hauzer) in the Netherlands, celebrated its 25th anniversary since foundation in 2008 and joined the IHI group in April of the same year. Hauzer is highly regarded by automobile manufacturers around the world, especially for its Diamond Like Carbon (hereinafter called DLC) coating, which is increasingly applied to automobile parts. In addition, the company has been contributing to improving fuel efficiency in the automobile industry. This article introduces the applications, coating technologies, and product lineup of the Flexicoat® series, the mainstay of Hauzer's products.

1. Applications

PVD/PACVD hard coating technologies are used for vapor deposition of hard thin films composed of metals or ceramics on product surfaces. Hauzer sells its coating systems mainly in the three markets of tribological component coatings, tool coatings, and decorative coatings.

1.1 Tribological component coating market

The automobile industry is the largest market in which Hauzer's systems are used, with coatings applied to the surfaces of engine-related components.

The use of hard coatings is rapidly increasing in the automobile industry for the purpose of improving environmental performance. Hard coatings are mainly used to reduce friction losses to improve and maintain fuel efficiency (low-friction property), and to enable components with a high load resistance, which are typified by high-pressure injection (>160 MPa, common rail injection), which is indispensable to clean diesel engines (high hardness and high resistance to wear).

Conventionally, CrN coatings are used as hard coatings

for reducing the friction losses of piston rings and other components. DLC coatings are rapidly spreading in applications where harder films are required.

Clean diesel engines are popular in Europe and achieved by common rail injection. These components must have high load resistance, and thus require the use of DLC, which offers high resistance to wear and a low coefficient of friction, for protecting component surfaces.

With the accelerated trend toward lower fuel consumption and downsizing (lower displacement volume) triggered by exhaust control, there are stricter demands for engine components, as well as expanding applications for coatings. Hauzer has focused on coatings for automobile components for many years and has maintained excellent sales performance in the industry for its products, especially its DLC coating systems.

Figure 1 shows examples of coatings on automobile parts, **Table 1** shows the main types of coatings for tribological components, and **Table 2** shows applications of coatings for automobile parts.

1.2 Tool coatings

Coatings are mainly applied to cutting tools and molds. Some examples of applications of tool coatings are shown in **Fig. 2**. Tool coatings have advanced as functional coatings for improving the service life and processing performance of tools to achieve reduced processing costs



Fig. 1 Example applications of coatings for automobile parts

Table 1 Types of coatings for tribological components

Item	Unit	Carbon coating				Nitride coating	
		Me-DLC	DLC	Me a-C	a-C	CrN	TiN
Process	—	PVD/PACVD	PACVD	PVD	PVD	PVD	PVD
Hardness	HV 0.05	800 - 2 200	1 500 - 3 500	1 500 - 2 500	2 000 - 4 000	2 000 - 2 200	2 000 - 2 200
Coefficient of friction	—	0.1 - 0.2	0.02 - 0.1	0.05 - 0.1	0.02 - 0.1	0.4	0.5
Internal stress	GPa/ μm	0.1 - 1.5	1 - 3	1 - 3	2 - 6	0.1 - 1	0.5 - 2
Thickness	μm	1 - 10	1 - 3	1 - 5	1 - 3	1 - 40	1 - 8

Table 2 Applications of coatings for automobile parts

Position	Target component	Type of coating
Diesel injection	Pressurization pump	Me-DLC
	Valve	DLC
	Injection	CrN
Cam shaft	Cam shaft	Me-DLC
	Follower	DLC
	Tappet	CrN a-C
Piston	Upper piston ring	CrN, DLC/Me-DLC
	Piston pin	DLC/Me-DLC
Crankshaft	Journal bearing	AlSn alloy, AlPbSi alloy

1.3 Decorative coatings

Dry hard coatings have been widely used for decorative purposes as they provide product surfaces with a high-quality appearance and high resistance to wear, and also increase the service life of products. In recent years, there has been increasing demand to replace electrolytic plating, which requires waste fluid treatment, with dry processes that have less impact on the environment in consideration of environmental protection. Hard coatings are widely applied to familiar products, such as wristwatches, writing tools, door knobs, faucets, eyeglass frames, and cellular phones (**Fig. 3**).

Demand is also increasing for decorative coatings on plastics. Conventional coatings on plastics require electrolytic plating processes for the basecoats in order to improve adhesion of the surface films. This system prevents a full shift to dry processes and does not allow coating of materials other than ABS plastics.

In order to solve these problems, Hauzer developed its DLC basecoat technology, which requires no plating in the basecoat,⁽¹⁾ and began selling systems that enable full dry coatings. Hauzer DLC basecoats have enabled coating of various kinds of plastic materials, not only ABS plastic.

Hauzer also introduced CROMATIPIC™ (trademark of Sidasa UCG in Spain) into its lineup. This is a Cr coating process using Hauzer's products for the basecoating of plastics in cooperation with Sidasa UCG. It is also a full-



Fig. 2 Example applications of tool coatings

and improved processing quality. These days there are diversified demands for tools to reduce cutting oils by utilizing dry cutting, to switch to water-based cutting oils, or to be compatible with mist cooling as environmental measures at processing sites.

Metal nitride coatings mainly using AlTiN or TiN have long prevailed as coatings for tools. These days oxide coatings that mainly use Al₂O₃ are attracting a lot of attention for the processing of difficult-to-cut materials and for improving the speed of cutting.

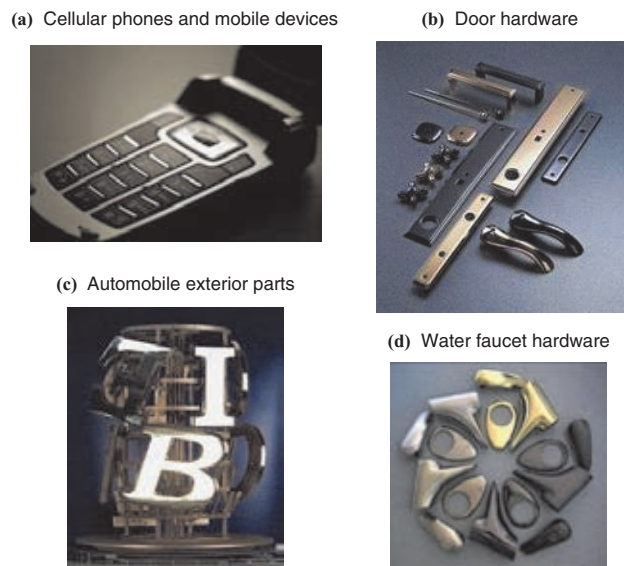


Fig. 3 Example applications of decorative coatings

dry process, which can be applied to basecoats on any plastic material. It is also environmentally friendly and significantly improves product design flexibility.

2. Coating technologies

Hauzer provides coating processes using the arc discharge method, the sputtering method, and the PACVD method which supplies materials as gas. The company is continuously developing new processes, such as Dual Magnetron Sputtering and High Power Impulse Magnetron Sputtering plus (HIPIMS+), as technologies derived from the sputtering method, and offering these technologies to markets.

This article introduces the Dual Magnetron Sputtering technology for Al_2O_3 coating and the HIPIMS+ technology that Hauzer's own unique leading-edge technology.

2.1 Dual Magnetron Sputtering

Al_2O_3 coating is carried out by sputtering the aluminum target and supply oxygen into the coating chamber to cause a reaction and apply a coating of oxide. During this process, ordinary DC sputtering or DC pulse sputtering is problematic in that the target surface is oxidized as the process advances, preventing long-time stable operation.

In contrast, the Dual Magnetron Sputtering method applies an AC bias voltage of several tens of kHz to a pair of targets with two cathodes. The two cathodes are alternately sputtered to repeat oxidization and etching on the target surface. This prevents development of oxidization and enables consistent coating of Al_2O_3 . This method also enables continuous coatings of up to 5 μm . **Figure 4** shows an example of this method.

2.2 HIPIMS+

The arc discharge method enables high-speed coating and excellent film adhesion due to a high ionization ratio in the processing space, but causes droplets of the target materials to scatter and accumulate in a particulate state resulting in defects in the films. In contrast, sputter coatings produce very smooth films, although they offer a low coating speed and poor adhesion due to a low ionization ratio. Conventionally, either of these processes has been selected by comparing their merits and demerits in accordance with the application requirements.



Fig. 4 Dual Magnetron Al_2O_3 coating insert

As a means to solve these problems, Hauzer developed its HIPIMS+ technology.

HIPIMS technology is attracting attention around the world as a technology that produces dense films by applying high-energy pulse bias voltage in the sputtering process. Although ordinary HIPIMS technology caused a strong etching effect in the coating process, it was very difficult to achieve a higher coating speed than that of conventional sputtering methods.

Hauzer therefore developed a technology that achieves a coating speed comparable to arc coatings by improving the HIPIMS technology by adding pulse waveforms and frequencies control in combination with unique patented technologies, in collaboration with Sheffield Hallam University in the U.K. and other advanced research institutes in Europe, and commercialized a product that adopts the technology known as HIPIMS+ in 2008.⁽²⁾

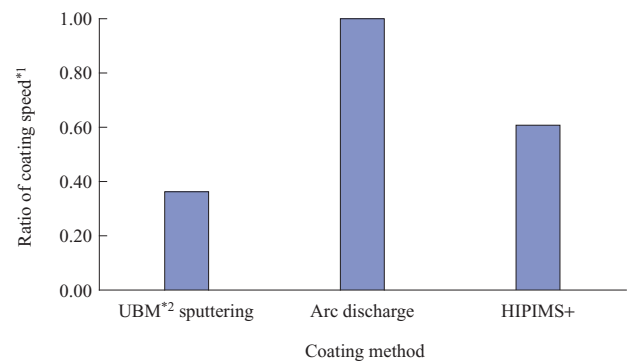
This technology features a very high ionization rate as well as a high composition ratio of both metal ions and reactive gas ions. This enables high-dense smooth coating with excellent adhesion and no defects at a high coating speed.

Figure 5 shows a comparison of coating speeds among sputtering, arc discharge, and HIPIMS+. **Figure 6** shows the composition ratios of ionic species (compared to DC sputtering). A comparison of the compositions of ion species between HIPIMS+ and DC Magnetron Sputtering shows high ratios of metal ions ($\text{Ti}^+/\text{Ti}^{++}$) and reactive gas ions (N^+). **Figure 7** shows the appearance of the plasma on the cathode surfaces.

2.3 Hybrid processes

A hybrid process combines sputtering, arc discharge, and PACVD technologies in a single equipment. Hauzer was the first company to formulate this process⁽³⁾ and release it onto the market.

Hauzer's coating systems enable continuous coating of multi-layer films by combining not only arc discharge, sputtering, and the PACVD processes, but also the latest technologies such as Dual Magnetron Sputtering and HIPIMS+. This is one advantage of Hauzer's products.



(Notes) *1 : Ratio when the coating speed of the arc discharge method is 1
*2 : Unbalanced Magnetron Sputtering

Fig. 5 Ratio of coating speed (sputtering, arc discharge, and HIPIMS+)

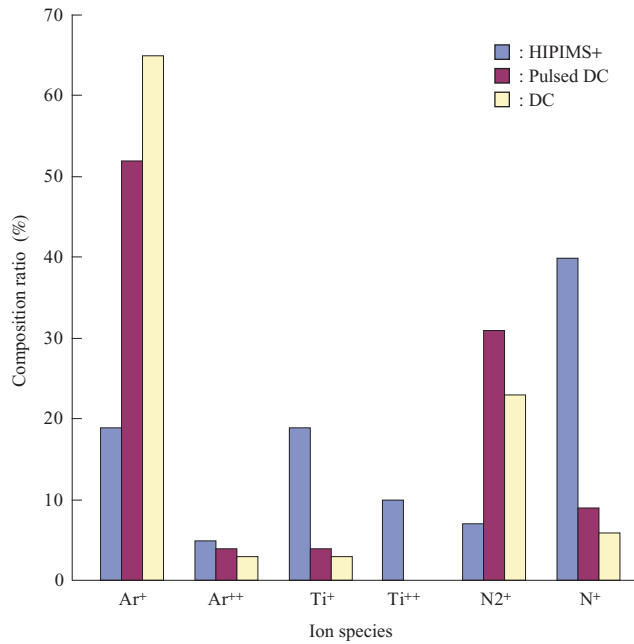


Fig. 6 Composition ratios of ion species (compared to DC sputtering)

(Note) Data provided by Sheffield Hallam University

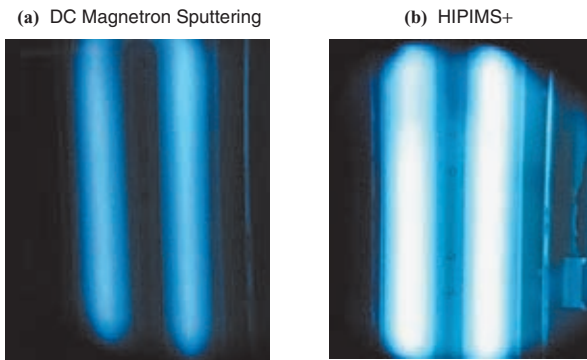


Fig. 7 Plasma on cathode surfaces

3. Flexicoat® series coating systems

Hauzer offers a series of systems with different processing capabilities suitable for mass production to enable customers to select the most appropriate system for the size and production volume of their products (Table 3).

These systems adopt platform design and their basic design is common to all models. Each system is configured with Hauzer’s uniquely developed coating source, power supply, heater, sample fixing method, and other

specifications suitable for customer applications. The name Flexicoat is derived from the high flexibility of the process design. Almost all processes can be combined in any system in this series.

3.1 Flexicoat® 850 (Fig. 8)

Flexicoat® 850 is the model with the smallest capacity in the series and has an effective coating capacity determined by a table diameter of 500 mm and a effective height of 500 mm, as well as all the features of the Flexicoat® series. The Flexicoat® 850 has a chamber made of four walls on which heaters, circular-arc cathodes, square-arc cathodes, and sputtering cathodes, vacuum equipment, and pressure gauges are mounted as necessary.

3.2 Flexicoat® 1000 (Fig. 9)

Flexicoat® 1000 is suitable for high-performance coatings on cutting and forming tools that are relatively large in size or produced in large volumes.

An arrangement of six cathodes can be adopted while the effective coating capacity is determined by a large octagon-shaped chamber with both a table diameter and effective height of 650 mm.

3.3 Flexicoat® 1200 (Fig. 10)

Flexicoat® 1200 has the same basic system configuration as Flexicoat® 1000, but with an effective capacity of $\phi 650 \times 850$ mm; thus it has a higher production capability than Flexicoat® 1000 by approximately 30%.

Flexicoat® 1200 is the main model used for coating tribological components. It is also used for coating large tools and molds, as well as for decorative coatings in the manufacturing of a wide variety of products in small quantities.

3.4 Flexicoat® 1500 (Fig. 11)

Flexicoat® 1500 is the largest system among the standard Flexicoat® models, with an effective capacity of $\phi 900 \times 1\,500$ mm. As a standard model it is the largest system in the industry, and in recent years we have seen an increase in the quantities shipped resulting from its application in the mass production of decorative components, automobile components, and large tools.

3.5 Turnkey solution (Fig. 12)

To lower the technical barriers for customers who have never used PVD/PACVD systems, a total package of PVD/PACVD processes is also provided as a turnkey solution. The turnkey package contains a series of processing equipment for stripping (necessary for tool coating), washing, coating, quality control (microscopes and measuring instruments for adhesion, film thickness, and so on) and post-treatment (as necessary), operational know-how, and operational training.

Table 3 Lineup of systems in the Flexicoat® series

Model	Flexicoat® 850	Flexicoat® 1000	Flexicoat® 1200	Flexicoat® 1500
Load diameter (mm)	500	650	650	900
Load length (effective) (mm)	500	650	850	1 500
Load mass (kg)	250	500 - 1 000	500 - 1 000	900 - 3 000
Number of cathodes (-)	4	4 - 6	4 - 6	4 - 6



Fig. 8 Flexicoat® 850



Fig. 10 Flexicoat® 1200



Fig. 9 Flexicoat® 1000



Fig. 11 Flexicoat® 1500

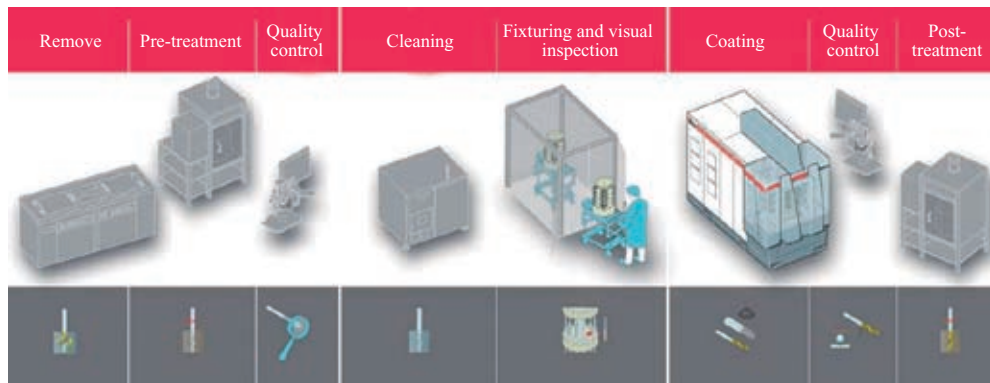


Fig. 12 Turnkey solution

4. Conclusion

This article has introduced a range of applications and technologies for Hauzer’s products, in particular, the Flexicoat® series. Although the coating processes are not visible from the final products, they are expected to continue growing in the future as essential technologies for reducing the fuel consumption of automobiles, waste at manufacturing sites, and the environmental effects.

We would like to contribute to reducing the burden on the environment in the industrial world by utilizing Hauzer’s leading-edge coating technologies.

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