

INDUSTRIAL PLASMA SOLUTIONS



耐摩擦涂层在汽车零部件上应用 WUXIFUEL INJECTION CONFERENCE

Date: 17-1-2019 豪泽涂层:夏永文,张宁

CONTENT

- Introduction Tribology and PVD coatings介绍摩擦和PVD涂层
- Hystorical review tribological coatings回顾耐摩擦涂层的应用历史
- Coating developments新涂层的开发与应用



IHI HAUZER TECHNO COATING

- Design, assembly and commissioning of PVD/plasma equipment and turn key solutions设计装配调试PVD等离子体设备和交钥匙方案
- Development of process, hardware, application and pilot production 研发新的工艺,硬件,新的应用并可进行导入生产
- 3 Competence Centres in Europe & Asia在欧洲和亚洲的3个研发中心
- > 470 Systems installed worldwide全球超过470台的安装使用
- > 34Years experience in PVD technology 超过34年的PVD经验
- 120 Employees (> 40% engineers)120名员工

COMPANY HISTORY

2015 400 machines delivered worldwide

2013 Introduction of CARC⁺ technology

2011 Competence Centre in Yokohama, Japan

2008 IHI Group, Japan, the new owner of Hauzer

2000 PVD equipment independent

1969 Heat treatment shop



2017

Opening Cromatipic[®] plant in Barcelona, Spain

2014 Start production Triboliner[®], inline platform

2012 Launch of Hauzer Metalliner[®], inline platform

2010 Competence Centre in Shanghai, China

2003 Competence Centre in Venlo, The Netherlands

1983 Development of PVD technology



4

TRIBOLOGY



DLC COATINGS: REDUCED FRICTION



HAUZER

PVD PHYSICAL VAPOR DEPOSITION





HAUZER

PVD COATING PROCESS



Technology: Arc

Arc Plasma



Technology: Magnetron Sputtering

DC sputter plasma



5% metal ions

HAUZER

Introduction PVD/PACVD technology and Tribology

Technology: Plasma Assisted Chemical Vapour Deposition (PACVD)

e

e⁻

e



HAUZER



e⁻

e⁻

11 11 BROUP

HAUZER

12

IHI GROUP



TYPES OF DLC

Type of DLC coatings

IHI GROUP

TA-C = TETRAHEDRAL AMORPHOUS CARBON





HAUZER



13

TYPES OF DLC sp³ (diamond) \bigcirc ħ a-C:H polymens sp² (graphite) Η Sputter DLC CARC PACVD LASER ARC H- content 0% 0% > 0 % > 15% **Structure** High sp 3 High sp3 Graphite or sp2 + sp3 sp2 + sp3 Surface Rough (polish) Rough (polish) Smooth Smooth Hardness Hv > 3500 Hv > 3500 graphite (soft) Hv > 2000 Hv > 2500 Hv 0,01 HAUZER

14



	CARC	LASER ARC	Sputter DLC	PACVD
H- content	0%	0%	> 0 %	> 15%
Structure	High sp 3	High sp3	sp2 + sp3	sp2 + sp3
Surface	Rough (polish)	Rough (polish)	Smooth	Smooth
Hardness Hv 0,01	Hv > 3500	Hv > 3500	Hv > 1000	Hv > 1000

HAUZER



		LAJÉR ARC	Sputter DLC	PACVD
H- content	0%	0%	> 0 %	> 15%
Structure	High sp 3	High sp3	Graphite or sp2 + sp3 sp3	
Surface	Rough (polish)	Rough (polish)	Smooth	Smooth
Hardness Hv 0,01	Hv > 3500	Hv > 3500	graphite (soft) Hv > 2500	Hv > 2000
HAU	IZER		16	





	CARC	LASER ARC	Sputter DLC	PACVD
H- content	0%	0%	> 0 %	> 15%
Structure	High sp 3	High sp3	Graphite or sp2 + sp3	sp2 + sp3
Surface	Rough (polish)	Rough (polish)	Smooth	Smooth
Hardness Hv 0,01	Hv > 3500	Hv > 3500	graphite (soft) Hv > 2500	Hv > 2000

HAUZER

Plasma-CVD Plasma generation: Pulsed Bias Micro Wave RF





cracked due to plasma

deposition of H/Si containing DLC

	CARC	LASER ARC	Sputter DLC	PACVD	
H- content	0%	0%	> 0 %	> 15%	
Structure	High sp 3	High sp3	Graphite or sp2 + sp3	sp2 + sp3	
Surface	Rough (polish)	Rough (polish)	Smooth	Smooth	
Hardness Hv 0,01	Hv > 3500	Hv > 3500	graphite (soft) Hv > 2500	Hv > 2000	
HAUZE	R	18			

OVERVIEW OF COATINGS FOR AUTOMOTIVE APPLICATIONS

	Carbon-Based Coatings				Nitrides	
	Me-DLC (WC-C:H)	DLC a-C:H	doped DLC a-C:H-X	a-C Sputtered C	ta_C	CrN
Method	PVD/PACVD	PACVD	PACVD	PVD	PVD	PVD
Hardness (HV0.05)	800-2200	1500- 3500	1500-2500	2000-4000	3000 - 7000	2000-2200
Coeff of friction	0.1-0.2	0.05- 0.15	0.05-0.1	0.05-0.1	0.02-0.1	0.4
Internal Stress (Gpa/µm)	0.1-1.5	1-3	1-3	2-6	1-3	011
Thickness (µm)	1-10	1-3	1-3	1-30	1-3	1-40
Industrial use	+++	+++	+++	+++	++	+++
Mass Production	+++	+++	+	+++	+	+++

HAUZER

HYBRID COATER FOR TRIBOLOGICAL COATINGS



Hystorical review tribological coatings



CRN AND THE FIRST METAL CONTAINING DLC'S 1970-1995

1970-1985



Turbocharged direct injection Diesel engine





Fiat Croma 1986

HAUZER





	Carbon- Based Coatings	Nitrides	
	Me-DLC (WC-C:H)	CrN	
Method	PVD/PACVD	PVD	
Hardness (HV0.05)	800-2200	2000 - 2200	
Coefficient of friction	0.1-0.2	0,4	

22

TURBOCHARGED DIRECT DIESEL INJECTION

Requirements:

- pressure > 2000 bar
- exact fuel metering
- tight closing of the fuel valve
- high speed for multiple injections
- lubrication only by fuel
- high lifetime
- low cost



Challenges:

- pressure > 2000 bar
- low power consumption
- light weight
- Iow noise
- high lifetime
- Iow cost

by fuel



	Carbon- Based Coatings	Nitrides	
	Me-DLC (WC-C:H)	CrN	
Method	PVD/PACVD	PVD	
Hardness (HV0.05)	800-2200	2000 - 2200	
Coefficient of friction	0.1-0.2	0,4	







ADVANTAGES OF DLC COATING

Advantages:

- High density, high hardness of coatings
- Designed for extreme loads
- Very good adhesion
- Thin films (2 to 5 µm), suited for parts with low tolerances
- Low process temperature
- Well controlled adjustment of process parameters and coating quality
- High rate deposition



HAUZER

EXAMPLE: INJECTOR

Parts: Coating: Thickness: Function: Equipment: Needle and orifices W-C:H + DLC/CrN 1 – 3 μm Reduction wear F1000/F1200







HAUZER

HIGH VOLUME PRODUCTION – LOW COSTS





HAUZER

HAUZER REFERENCE LIST:

All major suppliers for common rail injection systems use Hauzer Technology In-house Coating technology: Robert Bosch Delphi Caterpillar Denso Continental Job Coating

Denso

Continental

HAUZER

27

TYPICAL PVD/PACVD PRODUCTION CELL



HYDROGENATED AMORPHOUS CARBON



NEW EMERGING APPLICATIONS新兴的应用



HYDROGEN FREE AMORPHOUS CARBON COATINGS. 2005 – CURRENT无氢非晶碳膜

Limitations of a-C:H含氢非晶碳膜的局限

- Operating temperature resistance工作温度受限
- Resistance to certain oil additives对添加有添加剂的润滑油耐磨性差

	Carbon-Based Coatings				Nitrides	
	Me-DLC (WC-C:H)	DLC a-C:H	doped DLC a-C:H-X	a-C	ta-C	CrN
Method	PVD/PACVD	PACVD	PACVD	PVD	PVD	PVD
Hardness (HV0.05)	800-2200	1500- 3500	1500-2500	2000-4000	3000 - 8000	2000 - 2200
Coefficient of friction	0.1-0.2	0.05-0.15	0.05-0.1	0.05-0.1	0.02-0.1	0,4



LIMITATIONS HYDROGENATED DLC - a-C:H 1. TEMPERATURE RESISTANCE

Temperature Resistance of most common DLCs < 300 °C.

- SP3 bonds convert to SP2 bonds due to hydrogen desorption

(graphitization)



Effect of temperature on wear performance of hydrogenated DLC film

Richardson D.: "Review of Power Cylinder Friction for Diesel Engines" Journal of Engineering for Gas Turbines and Power Vol. 122, October 2000



LIMITATIONS HYDROGENATED DLC - a-C:H 1. TEMPERATURE RESISTANCE

Temperature Resistance of most common DLCs < 300 °C.

Example : Top piston ring (compression ring) in turbo diesel engine. Operating temperature up to 250°C



LIMITATIONS HYDROGENATED DLC - a-C:H 2. MO-DTC RESISTANCE

Engine oil is containing MoDTC, a friction modifier which reacts in a tribochemical reaction to MoS2



However, **a-C:H wears in engine oils containing MoDTC additives** in combination with high contact pressures especially in mixed or boundary lubrication, due to:

- Chemical reaction, leading to graphitization of the a-C:H
- Formation of MoO3 and FeMoO3, leading to abrasive wear of the a-C:H

LIMITATIONS HYDROGENATED DLC - a-C:H 2. MO-DTC RESISTANCE

DLC wears in engine oils containing MoDTC additives in combination with high contact pressures especially in mixed or boundary lubrication, due to:

- Formation of MoO3 and FeMoO3, leading to abrasive wear of the a-C:H

- Chemical reaction, leading to graphitization of the a-C:H





Comparison of DLC surface appearances after 1.8×10⁶ cycles sliding test under oil w/ and w/o MoDTC

Analysis of wear behavior and graphitization of hydrogenated DLC under boundary lubricant with MoDTC Itto Sugimoto, Fumiaki Honda, Kenichi Inoue Wear, Volume 305, Issues 1–2, 2013, 124–128



TA-C: PISTON RINGS



H free DLC

Nitride layer (optional)

Base material



TA-C PISTON RINGS: SCUFFING RESISTANCE



Source: Innovative Carbon Coating concepts for Piston Rings, MAHLE GmbH

HAUZER

37

Tribological coating developments

TA-C ON VALVE LIFTERS



Tribological coating developments

TA-C ON PISTON PINS





New piston concept with low compression height



New MAHLE Steel Piston and Pin Coating System for Reduced TCO of CV Engines, SAE International Journal of Commercial Vehicles - V125-2EJ 39



Tribological coating developments

TA-C ON DIESEL INJECTION NEEDLES





	1 μm ta-C	1 μm ta-C
	as coated	polished
Ra	45 nm	10 nm
Rz	380 nm	230 nm
Rp	300 nm	25 nm
Rv	70 nm	200 nm



TA-C: PISTON PINS / DIESEL INJECTION



Competitor ta-C vs Competitor a-C:H (source: Mahle)





HAUZER

AUTOMOTIVE COMPONENTS WITH APPLIED COATING



HAUZER

Valves Piston **Piston rings**

Con rod

Crankshaft



00 µm

12.07.2013 000011

x 44

PC-high

42



INDUSTRIAL PLASMA SOLUTIONS



THANK YOU FOR YOUR ATTENTION

夏永文 13651839063