PROGRESSIVE METHOD OF OBSERVATION AND ASSESSMENT DURING CORROSION TESTS WITH ARTIFICIAL ATMOSPHERE

Radek Pavelka, Milan Brozek
Czech University of Life Sciences Prague
pavelkar@tf.czu.cz

Abstract. This article describes observation of corrosion resistance of different painting systems used for painting truck cabins and chassis. All testing contains 57 steel plates painted with 1, 2 or 3 layer systems, different chemical compositions and ways of application. Three representative samples were selected for the purpose of this article. Testing of corrosion resistance has been done according to EN ISO 9227 – Corrosion tests with artificial atmosphere – Salt spray test, which were extended by progressive observation and photos every 120 h until 1000 h. So every 120 h it has been assessed according to EN ISO 4627–1,2,3,4,5,8,10 and then from this observation characteristics of rusting, blistering, cracking, flaking and corrosion progression were created. Measuring and observation show very specific and interesting characters and different progression of all samples in different phases of test duration. According to these characteristics for each sample we can decide usability for the given conditions. Comparison of more painting systems can set a very precise picture and can make more precise analyses to find exact deviation between each other.

Keywords: corrosion, painting, salt spray, truck.

Introduction

Currently very high demands are made on car body and truck cabins or chassis, which can be achieved by years of proven and also newly developed technologies and technological processes using the highest quality materials. Painted body, and thus the coating must meet among other things ideal optical properties, weathering, and chemical attack, sunlight, but mainly it must meet long-term protection against corrosion [1].

There are many ways how to test corrosion resistance, which are necessary for paint producers for developing and improving paint and also for truck and cars producers for quality checking.

The most usable testing of corrosion resistance are cabinet tests. Cabinet corrosion tests have been used since the early 1900s as a means of evaluating the performance of coating as a quality control tool for monitoring process and in some cases, as a method for accelerating corrosive activity [2].

A cabinet corrosion test is one in which a test chamber is used to produce an environment that will cause the occurrence of a corrosion product on the test sample. Some common corrosive environments produced in a test chamber are salt fog, humidity, hot temperatures, cold temperatures, UV exposure and corrosive gases. These environments may be used individually or in combination with each other. Commonly used cabinet tests are ASTM B117 and others, BI103-01 for Ford Motor, DIN50017,18,21 for VW, GM4465P and another for General Motors, ISO 9227 and others as international standard, VDA 621-415 for automotive and others [2].

The most commonly used cabinet corrosion test is the Salt Spray (Fog) test. The salt spray test was adopted by ASTM in 1939 after considerable developmental work by the National Bureau of Standards. It has widespread use in many industries including automotive, aerospace, paints and coatings etc. Typically called a salt spray test it actually consists of fog produced by air atomization of 5 % sodium chloride solution and the cabinet temperature is maintained at 35 ºC. The test duration is typically in 24 h increments and can range from 24 h to 5000 h. Except for sample rotation and daily monitoring of collection rates, the cabinet should remain closed for the duration of the test [2].

As it is well known, the automotive sector has contributed on a large scale to achieving compliance with increasingly restrictive environmental legislation in the field of surface treatments and most especially, anti-corrosive coatings. It can currently be stated that the anti-corrosive protection of almost all automobile bodywork includes a cataphoretic primer [3]. Although cathodic electrocoating has been a mature technology for a number of years, research and development on this subject has not ended. The first lead free systems came onto the market only in the 1990s [4; 5], coinciding with the attempts to meet other challenges such as achieving further reductions in the volatile organic solvent content and lowering the curing temperature. At the beginning of the 21st century, most of the paints currently used in electrophoretic corrosion-protective OEM automobile coatings are epoxy-based materials that are internally cross-linked through urethane chemistry [6; 7].

At international level is cathodic electrocoating used for a primer coating automobile bodywork or truck cabin and as a primer for mounting parts or as a topcoat for substrates that are not visible in products after mounting. Current applications of cataphoresis in the automobile industry include: seat structures and rails, suspension components, brake components, shock absorbers, spiral springs, headlight casings, window supports, steering sets, clamps, pedal sets, air pipes, axles, jacks, compressors, fans, safety belt components, motor and suspension supports, and fixtures [8].

Materials and methods

The testing was done in corrosion cabinet acc. EN ISO 9227 – Corrosion tests with artificial atmosphere – Salt spray test by method NNS, which were extended by progressive observation and photo documentation every 120 h until 1000 h. So, every 120 h visually corrosion and blisters have been assessed and also according:

- EN ISO 4627-1 General information and designation system;
- EN ISO 4627-2 Assessment of degree of blistering;
- EN ISO 4627-3 Assessment of degree of rusting;
- EN ISO 4627-4 Assessment of degree of cracking;
- EN ISO 4627-5 Assessment of degree of flaking;
- EN ISO 4627-8 Assessment of degree of delamination and corrosion around a scribe;
- EN ISO 4627-10 Assessment of degree of filiform corrosion.

In order to achieve statistical processing and evaluation, each of the painting systems was sprayed on 5 testing panels (57 painting systems = totally 285 panels) and all these panels were measured five times (dry film thickness, gloss, adhesion) then each panel was exposed and evaluated, from the measured values averages were calculated. In this article only average values are described.

Steel panels from steel No. 1.0037 (according to DIN St 37-2) and steel S235JR (according to EN) dimensions 150 mm x 70 mm x 1.2 mm were used. The elemental composition of steel is presented in Table 1.

Table 1

Composition of the steel panels

Elements	Fe	C	Si	Mn	P	S	Cr	Mo	Co	Cu	Nb
Weight %	97.7000	0.1900	0.4150	1.9000	<0.0050	<0.0050	0.0260	0.018	0.0559	0.0429	0.0481

In the whole research 57 samples of painting systems were tested. For the purpose of this article three representatives of different painting systems have been selected.

- **Sample 2.** 2-layer: Primer cataphoresis coating KTL PPG Powercron 6200 + PPG PUR 1K Waterborne topcoat (ESTA application).
- **Sample 26.** 2-layer:Primer FEYCOPUR 610 - 2K PUR+FEYCOPUR 626 - 2K PUR Topcoat.
- **Sample 32.** 1-layer system: Mankiewicz – 2K PUR Monolyer 402-28 (spray application).

Results and discussion

This sample 2 was as well as others prepared on steel panels (see above). Cataphoresis coating has been applied at a paintshop for truck cabins at the company Avia Ashock Leyland in Prague, where cathodic systems are used based on modified epoxy resins containing amino groups from the company PPG named Powercron 6200. Panels were pre-treated with Zn-phospating what is included at this cataphoresis paint-line. The topcoat was painted with 1-layer Waterborne Topcoat from PPG applied with ESTA manual spraying. This system is there standartly used for cabins and some assembling parts for Avia trucks. In Table 2 there is measuring of dry film thickness and gloss.

Table 2

Sample 2 – dry film measuring

Paint (1^{st} / 2^{nd} layer)		KTL PPG Powercron 6200	PPG 1K Waterborne topcoat
Film thickness acc. EN ISO 2808, µm		24.6	67.1
Adhesion acc. ISO 2409, Gt		0	0
Gloss acc. ISO 2813	20º (60º)	18.9 (69.4)	85.7 (93.5)

All 5 painted panels of the sample 2 have been observed every 120 h, but for purpose of this article; in Fig. 1 you can see only selected photo documentation (every 240 h).

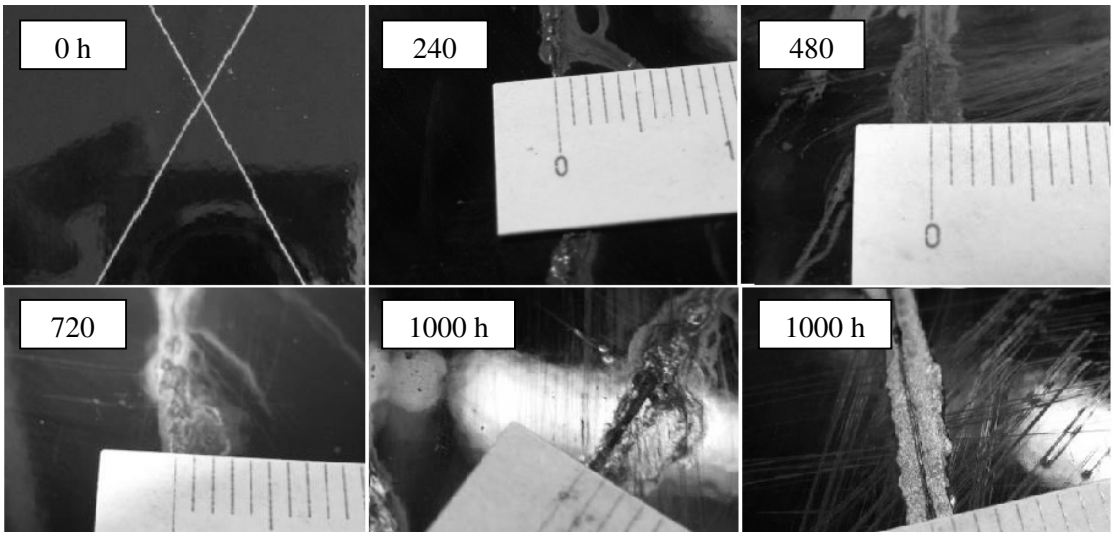

Fig. 1. **Photo documentation of sample 2**

Observation of this sample shows very stable results. First small blister at the cut was found after 600h, which was maximum 0.5 mm big. Then there was a small change after next 120 h and after 720 h it was measured 1.0 mm, and this was not changed until observation till 1000 h. Peeled paint was removed after exposition which uncovered steel substrate 1 mm from the cut to both sites. Detailed view shows filiform corrosion average 0.5 mm and maximally 1.0 mm from the cut. In Table 3 there are detailed recorded observations during exposition.

Table 3

Summary table of the observation results of sample 2

Assessment		Observing, h									
		0	**120**	**240**	**360**	**480**	**600**	**720**	**840**	**960**	**1000**
Corrosion at the cut, mm		0	0	0	0	0	0.5	1	1	1	1
Ø blisters, mm		0	0	0	0	0.5	1	1	1	1	1
EN ISO 4628-2	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-3	Ri	0	0	0	0	0	0	0	0	0	0
EN ISO 4628-4	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-5	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-10	L/M, mm	0/0	0/0	0/0	0/0	0.5/0.3	1/0.5	1/0.5	1/0.5	1/0.5	1/0.5

After 1000 h exposition the degree of delamination and corrosion around the cut according ISO 4628-8 was evaluated and the result can be seen in Table 4. In both ways of evaluation of the degree of delamination and corrosion the degree is 1 – very small. This and the other results confirmed that cataphoretic primer ensures very good corrosion resistance for very long exposition.

Table 4

ISO 4628-8 - Assessment of degree of delamination and corrosion around a scribe after 1000 h

Degree of delamination:						acc. pictures	Degree of corrosion :						acc. pictures
d_1 =	2	w =	0.1	d =	0.95	1	w_c =	1	c =	0.1	c =	0.45	1

The second painting system presented in this article as the sample 26 was painted on the same steel panels. The first primer layer from the company Feycolor Feycopur 610 has been painted by manual spraying at the paintshop for truck chasses components. The panels were cleaned with isopropanol without any other pre-treatment. The second topcoat layer was painted with Feycopur 626 as well from Feycolor sprayed with manual spraying. This system is not used for any painting of truck components, but was presented by the company Feycolor as a substitute of the cataphoretic coating system.

Table 5

Sample 26 – dry film measuring

(1^{st} / 2^{nd} layer)		FEYCOPUR 610 – 2K PUR	FEYCOPUR 626 – 2K PUR
Film thickness acc. EN ISO 2808, µm		94.7	170.4
Adhesion acc. ISO 2409, Gt		0	1
Gloss acc. ISO 2813	20° (60°)	0.9 (4.4)	32.1 (79.6)

All 5 painted plates of the sample 26 have been observed every 120 h, but for the purpose of this article, see in Fig. 2, only selected photo documentation (every 240 h):

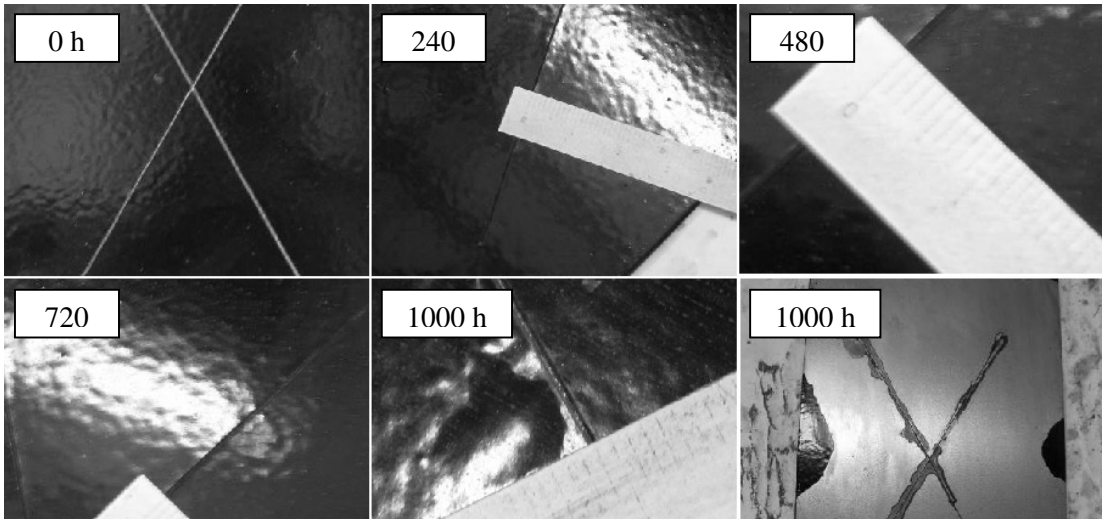

Fig. 2. **Photodocumentation of sample 26**

Observation of this sample did not show any corrosion during exposition. But blistering became to be critical only after 240 h, where the size of blisters was 3 mm what was changing and at the end it was more than 6mm.Then, after exposition peeled paint was removed, which very easy uncovered steel substrate almost on the whole panel. Uncovered steel substrate has enabled to evaluate filiform corrosion very easy which was average 5 mm and maximally 6 mm from the cut. In Table 6 there are detailed the recorded observations during exposition.

Table 6

Summary table of the observation results of sample 26

Assessment		Observing, h									
		0	**120**	**240**	**360**	**480**	**600**	**720**	**840**	**960**	**1000**
Corrosion at the cut, mm		0	0	0	0	0	0	0	0	0	0
Ø blisters, mm		0	0	3	4	5	5	6	6	6	6
EN ISO 4628-2	Vol./Size	0/0	0/0	2/4	2/4	2/4	2/4	2/5	2/5	2/5	2/5
EN ISO 4628-3	Ri	0	0	0	0	0	0	0	0	0	0
EN ISO 4628-4	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-5	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-10	L/M, mm	0/0	0/0	2/3	3/4	4/5	4/5	5/6	5/6	5/6	5/6

After 1000 h exposition the degree of delamination and corrosion was evaluated around the cut according to ISO 4628-8 and the result can be seen in Table 7. Evaluating the degree of delamination and corrosion acc. to the picture sample, it was degree 5 – very huge. This result shows very bad quality of corrosion resistance of this painting system. It is very sensitive to blistering what leads to corrosion gradation from the cut. This system cannot be in any case used as a substitute for cataphoretic coating.

Third painting system presented in this article as the sample 32 was painted on the same steel panels. It is only one layer paint from the company Mankiewicz named Monolyer 402-28. It has been painted by manual spraying at the paintshop for truck chasses components. The panels were cleaned with isopropanol without any other pre-treatment. This system is not used for any painting of truck components, but was presented by the company Mankiewicz as a substitute of the classical two layers

system to save the painting costs and has very good corrosion resistance near to cataphoretic coating systems.

Table 7

ISO 4628-8 – Assessment of degree of delamination and corrosion around a scribe after 1000 h

Degree of delamination:						acc. pictures	Degree of corrosion :						acc. pictures
d_1 =	64	w =	0.1	d =	31.95	5	w_c =	16	c =	0.1	c =	7.45	5

Table 8

Sample 32 – dry film measuring

Paint (1st / 2nd layer)		Mankiewicz– Monolyer 402-28
Film thickness acc. EN ISO 2808, µm		64
Adhesion acc. ISO 2409, Gt		0
Gloss acc. ISO 2813	20º (60º)	43.5 (83.5)

All 5 painted plates of the sample 26 have been observed every 120 h, but for the purpose of this article, see in Fig. 3, only selected photo documentation (every 240 h):

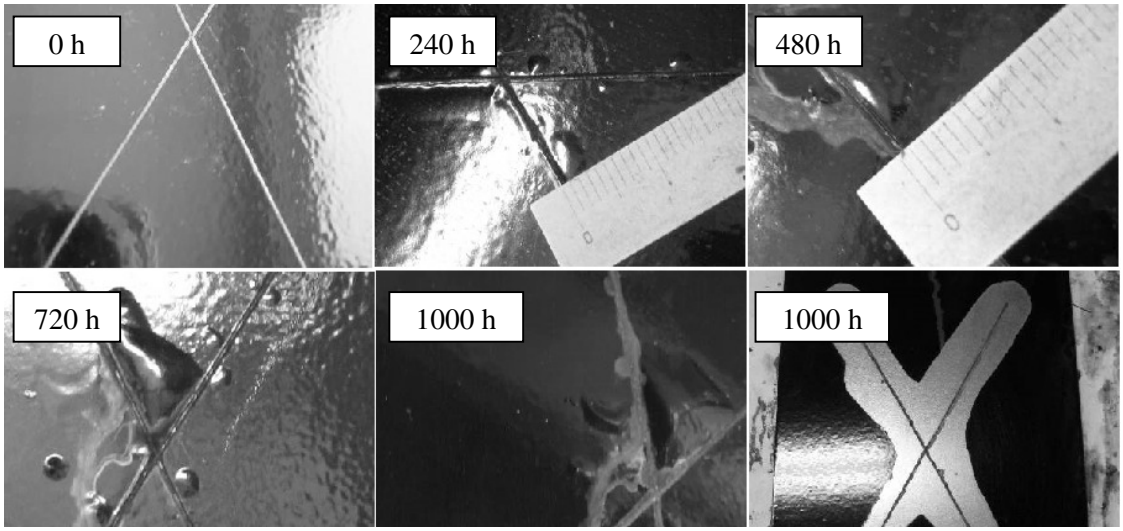

Fig. 3. **Photo documentation of sample 32**

Observation of this sample did not show any corrosion during exposition. But there was interesting blistering observation. It became to be critical only after 120h, where the size of blisters was 2 mm what was later changing and at the end it was 6mm, the same like in the previous sample 26. Then, after exposition peeled paint was removed, steel substrate was uncovered 6 mm to both sites from the cut (see Fig. 3). Then filiform corrosion was evaluated, which was average 4 mm and maximally 6 mm from the cut. In Table 9 there are detailed recorded observations during exposition.

Table 9

Summary table of the observation results of sample 32

Assessment		Observing, h									
		0	**120**	**240**	**360**	**480**	**600**	**720**	**840**	**960**	**1000**
Corrosion at the cut, mm		0	0	0	0	0	0	0	0	0	0
Ø blisters, mm		0	2	3	3	5	5	5	6	6	6
EN ISO 4628-2	Vol./Size	0/0	2/3	2/3	2/3	2/4	2/4	2/4	2/5	2/5	2/5
EN ISO 4628-3	Ri	0	0	0	0	0	0	0	0	0	0
EN ISO 4628-4	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-5	Vol./Size	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
EN ISO 4628-10	L/M, mm	0/0	1/2	2/3	2/3	2/5	2/5	3/6	4/6	4/6	4/6

After 1000 h exposition the degree of delamination and corrosion around the cut according ISO 4628-8 was evaluated and the result can be seen in Table 10. In both ways of evaluation of the degree of delamination and corrosion the degree is 1 – very small. This result shows very good quality of corrosion resistance of this painting system compared to the two layer system and compared to the

cataphoretic system. We cannot say that it is a substitute, but it can be used as a cheaper solution for parts with lower requirements.

Table 10

ISO 4628-8 – Assessment of degree of delamination and corrosion around a scribe after 1000 h

Degree of delamination:						acc. pictures	Degree of corrosion :						acc. pictures
d_1 =	18	w =	0,1	d =	8.95	1	w_c =	2	c =	0.1	c =	0.95	1

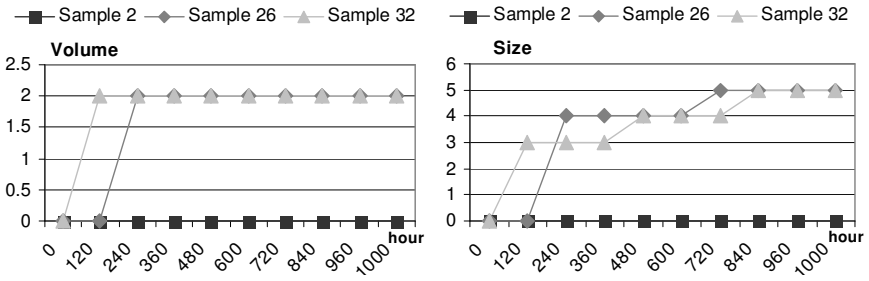

Fig. 4. **Observation characteristic of degree of blistering acc. EN ISO 4628-2**

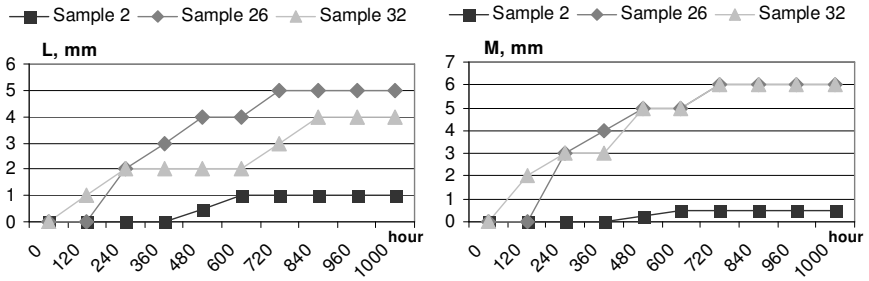

Fig. 5. **Observation characteristic of filiform corrosion acc. EN ISO 4628-10**

Conclusion

Measuring and observation of the degree of blistering reflected in Fig. 4 show very specific characters and different progression of all samples in different phases of test duration. There you can see that the volume of blistering is relatively stable from 120 h and is not growing. But the size of these blisters is growing fluently. Observation of filiform corrosion (Fig. 5) shows growing of the average and maximal size fluently step by step but it depends on the painting system.

According to these characteristics for each sample, resp. paint systems, we can decide the usability for the given conditions and we can see that degradation begins more at the start or end of testing. Comparing more painting systems you can set a very precise picture and you can make more precise analyses to find exact deviation between each other.

References

1. Reference Document on Best Available Techniques on Surface Treatment using Organic Solvents, August 2007, 655, pp. 164 [online] [2013-06-25] Available at: http://eippcb.jrc.ec.europa.eu/reference/BREF/sts_bref_0807.pdf
2. Baboian R.: Corrosion Tests And Standards: Application And Interpretation (2nd edition) ASTM International, 2005, 882, pp.130-131.
3. Almeida E.,Guide on anticorrosive protection in automotive industry, INETI, Lisbon 2000, pp. 79-97.
4. K. Kinberger, Ind.-Lackier-Betr. 59, 1991, 332 p.
5. Oberfläche + JOT 9, 1991, pp 30.
6. J.A. Laugal, G.E. Martin, D.L. St. Aubin, G.G. Wold, US Patent 5,348,635, (20 September 1994), to BASF Co.
7. L.P. Hack, J.W. Holubka, J. Coat. Technol. 72 (905), 2000, 61 p.
8. Almeida, E ; Alves, I; Brites, C; Fedrizzi, L; Cataphoretic and autophoretic automotive primers – A comparative study, Progress in organic coatings, 46 (2003), pp. 16-20.