# Radiation Curable Protective Coatings: Innovative and Feasible Solutions for the Steel and Aluminium Industry

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## Introduction

Nowadays, the UV technology is a well established technology for coatings on wood, flooring, furniture, printing inks and paper coatings and electronic applications. UV coatings are well known systems for providing exceptional mechanical properties and highly crosslinked systems.

Also the ecological aspect of the UV technology, being a solvent free technology, is even becoming more important in times of restrictive legislation for organic solvent emissions.

In the field of the metal coating market, UV curable coatings become more and more important. There are many reasons for which an UV curable coating is needed on metal: the main attributes of the coating are the protection against corrosion, chemical damage and mechanical degradation. When protection against mechanical damage is considered, properties like hardness and flexibility are important.

However its use in metal coatings is still relatively limited due to the fact that basic properties like corrosion resistance, flexibility and adhesion to metal are not yet fulfilled.
The aim of this paper is to present the parameters which have to be considered to achieve properties like adhesion, corrosion protection and flexibility.

Within Cytec Surface Specialties, focussed developments have lead to tailor made UV curable products which deal with the specific needs of formulators active in the metal area.
These resins are already commercial available.

## Evaluation methods for mechanical properties of UV coatings on metal substrates

**Cross-hatch adhesion (ISO & DIN 2409)**

Adhesion is the most important property of paint but also one of the most difficult to achieve with a radiation curable system applied to metal. It is assessed by enscribing a square pattern into the paint, applying adhesive tape to the pattern and pulling it off swiftly. Adhesion is quantified by counting squares remaining in six scores scale. 100% of the square remaining corresponds to class 0. More than 65% of the scare removed corresponds to class 5.

**Resistance to salt spray (ASTM B117, ASTM B368 & ASTM G85)**

Steel corrodes fastest in coastal areas and at sea because of the salts dissolved in the water. This led to the development of the hot salt spray test used to evaluate corrosion. Despite numerous studies that indicate that the results have no relationship to actual performance and optimisation for salt spray may actually act against good outdoor durability, the test is still considered as an industry standard by many companies when assessing resistance to accelerated corrosion.

The B117 test requires that a coated panel is placed in a chamber which is kept at 35°C and into which a fog of 5% sodium chloride solution is continuously sprayed. The panels are set at an angle of 60° to the horizontal. A scribe is often put on them to stimulate damage to the coating and one edge is left unprotected which mimics actual building practise. A bend can also be included. Test time is about 1500 hours with evaluation every 250 hours.

Performance is assessed on number and size of blister, which are apparent after a fixed length of time, the distance reached from the scribe by delamination and also the amount of corrosion products formed.

The B368 test is an accelerated version of the B117 using copper acetate as accelerating agent. Test time is about 240 hours.

The G85-98 test describes a method of cyclic accelerated corrosion known as the prohesion test. This test relates more closely to long term natural exposure than do the conventional salt spray, humidity or sulphur dioxide tests. The prohesion test usually uses an electrolyte of 0.4% ammonium sulphate and 0.05% sodium chloride.

It also uses electrolyte spray at ambient temperature, dry off at elevated temperature, and rapid cycling between spray and dry conditions.

**Resistance to cracking on bending (T-bend test EN 13523-7)**

This test is carried out on a thin strip of coated substrate, the end of which is folded through 180°. A vice is used to ensure that a 180° fold is achieved by compressing the two sides together. The metal is repeatedly folded over itself until the coating no longer cracks (expressed as *"without cracks"*) or until the coating no longer delaminates (expressed as "*without delamination*"). The result is quoted as 0T, 0.5T, 1T and so on.

**Resistance to cracking on rapid deformation (ISO/DIS 6272 – ASTM D 2794))**

It involves dropping a hemi-spherical striker of specified diameter and weight through various heights so that it hits the unpainted side of the metal causing an indentation in the form of a dome. In order to pass the test the cured coating must deform without cracking (expressed as "*without cracks*") when view through a x10 magnifier or must still adhere on the support after a cross cut (expressed as "*without peeling*"). The greater the height to which it is possible to raise the striker before the coating cracks the better the flexibility and adhesion.

**Slow drawn deformation-Erichsen cupping device (ISO & DIN 1520)**

This method evaluates the resistance of a coating to cracking and or detachment from a metal substrate when it is subjected to a gradual deformation by indentation under standard conditions. A die having a hardened and polished surface and a sample holder with a retaining ring are the heart of a cupping tester. The indenter that contracts the test panels is of hardened polish steel and forms a hemisphere of 20 mm diameter. The indenter is pushed through the steel from behind. The result is expressed as the indenter displacement (mm) before the coating starts cracking or detaching from the substrate.

One problem with this test is the interdependence of apparent flexibility on adhesion and hence how the coating fares during and after the test can not be used as a measure of flexibility or adhesion individually.

A more severe variant of this test proceeds in a crosshatch area.

## Chemistry

Urethane backbones bring flexibility and consequently adhesion, while epoxy backbones are known to give excellent corrosion resistance. Based on this know-how, a portfolio of different chemistries was developed for use in UV metal coatings. Urethane acrylates exhibit excellent adhesion and flexibility. Epoxy acrylates show excellent reactivity, hardness and corrosion resistance. We also developed a polyester acrylate which exhibits a good compromise between flexibility and corrosion resistance. In figure 1, some of the most important properties of our UV metal grades are summarized.

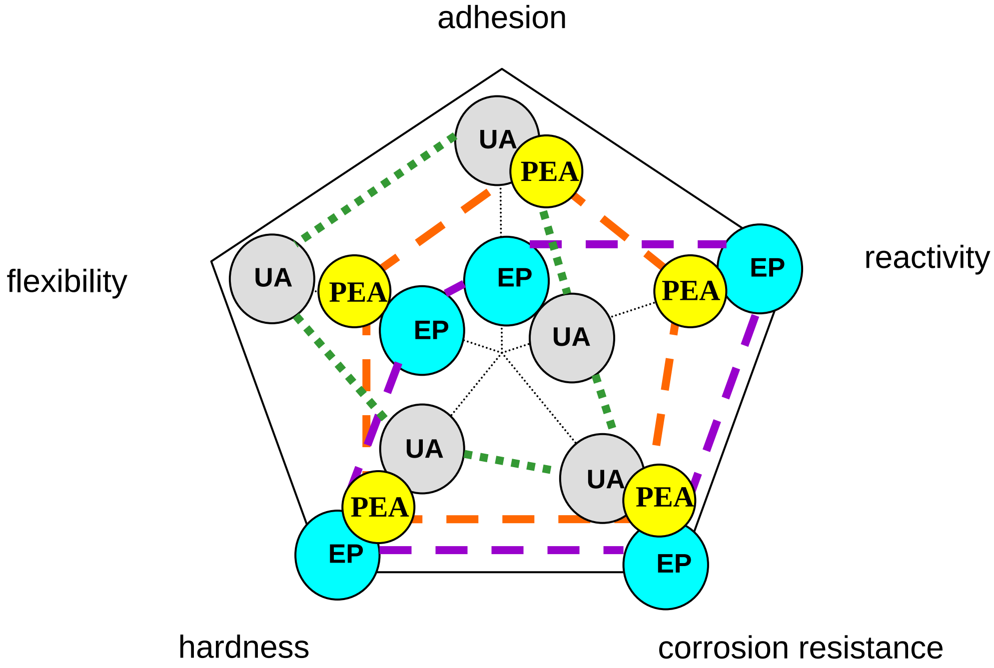


Figure 1: main characteristics.

The main properties of our UV resins for metal are listed in table 1.

| Resin | Viscosity (mPa.s at 25°C) | Mw | Functionality |
|---|---|---|---|
| EP 1 | 3500 | 550 | 2 |
| PEA 1 | 19500 | 2800 | 2 |
| UA 1 | 81500 | 2000 | 2 |
| UA 2 | 23014 | 2000 | 2 |
| UA 3 | 21090 | 2700 | 2 |
| UA 4 | 15200 | 2600 | 2 |

Table 1: product description: EP stands for epoxy acrylate, PEA for polyester acrylate and UA for urethane acrylate.

To optimise the flexibility, we have developed a urethane acrylate with an elongation of 158% (UA 3). This high elongation is also reflected in the T-bend test, resulting in a 0T score (cracks) and a 0.5T score (adhesion)
On the other hand we have also developed high reactive epoxy acrylates which exhibit excellent corrosion resistance (EP 1).
Pictures of these results will be showed during the presentation.

The different products that we have developed, enable UV coating formulators to optimise their coating systems according to the end use requirements.
To reach the requirements of e.g. a UV primer (see table 2), combinations of the above mentioned products can be made. Viscosity of the formulations can be adjusted with reactive diluants, like IBOA, phenoxyethyl acrylate, urethane monoacrylate, etc.…

| | |
|---|---|
| Substrate | HDG |
| cleaning step | Alkaline |
| Application | roller |
| thickness DFT | 5 µm |
| MEK resistance | >60 DR |
| paint viscosity | as low as possible |
| Adhesion | Tape |
| T bend (no cracks) | T bend 0 |
| T bend (no loss of adhesion) | T bend 1 |
| reverse impact (adhesion) | 18 J |
| corrosion resistance | 500h |
| Overcoatability | sb stoving |

Table 2: technical targets for a UV primer for buiding application.

These targets can be reached through a combination of UA 3, EP 1, IBOA, photoinitiator and an acidic methacrylated adhesion promoter.

## Conclusion

UV curing technology for industrial coatings has been established for decades. The advantages in terms of performance and processing are very well known.

In metal applications, the use of UV technology has been rather limited. Within Cytec Surface Specialties, focussed developments have led to tailor made epoxy-, polyester and urethane acrylates which deal with the specific needs of formulators active in the metal area. These specific needs are adhesion, corrosion resistance, flexibility, reactivity and hardness.

Our radiation curing products enable coating formulators to optimise the coating system and to achieve the balance of coating properties.