Third party submission of information on alternatives for
Applications for Authorisation

NON-CONFIDENTIAL

Legal name of submitter(s): Oerlikon Balzers Coating Germany GmbH
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1. ALTERNATIVE ID AND PROPERTIES

Technical alternative:

Oerlikon Balzers has developed an innovative breakthrough technology that is an alternative to traditional functional chrome plating with decorative character, which is a "suitable economically and technically viable alternative" under REACH. The information provided in the Analysis of Alternatives conducted by the CTAC Consortium, is based on very old technologies and a lot of progress has been achieved since. This does not provide for an accurate assessment of alternative technologies developed by Oerlikon Balzers.

Oerlikon Balzers’ ePD™ (embedded Physical Vapour Deposition (PVD) for Design parts) is a combined technology of UV coatings and the vacuum metallisation in the nanometer range and replaces the entire electroplating process including pre-treatment and post-treatment.

It is primarily used in the automotive sector to metallise parts like airbag-emblems, car mirrors, radiator grills etc., and can also be used in sanitary applications such as shower heads, or in food applications such as coffee machines.

The metallisation effect in ePD™ is sandwiched between two layers of UV lacquer.

ePD™ technology can be applied to a wide range of standard types of commercial plastics with a melting point of 50°C or higher, and those that are suitable for a paint application. This opens a wide door for engineers to use tailor-made plastic types for each application, including ABS, PC, PC/ABS, PC, PC/PBT, PC/PET, PA, TPE, etc. In comparison, only four types of plastic substrates can technically be coated in the common electroplating process.

Once the material is cleaned using snow-ice, the first lacquer layer, the primer, is sprayed onto it. This UV “base coat” serves to equalise irregularities on the surface of the injection-moulded plastic substrate.

On top of the base coat comes the actual PVD, which uses batch or the more efficient inline magnetron sputtering deposition technology in a vacuum chamber for a stable coating with high nanostructure density – with no harmful ions left behind. The PVD layer does not use any metal derivatives, chromium trioxide or other substances of very high concern (SVHCs).

The PVD sputtering technology has been well established in the industry for over 30 years. The innovation of sputtering on plastics is simply based on further development of the process. For the standard PVD process, only elementary chrome and other non-toxic metals are used for a “chrome” look and argon as a process gas. For advanced colours or functionalities, elementary metals like gold, stainless steel, aluminium are processed. The additional process gases nitrogen or acetylene are also used in a nano range. The limited use leads to effective volumes of less than i.e. one gas bottle per year per machine. This means that ePD™ uses a very limited amount of resources. The typical thickness of PVD coatings lies between 50 and 200 nm, which is multiple times thinner than stated in the Analysis of Alternatives submitted by CTAC.

To protect the metallised coating, a final one-component monocular UV lacquer (top coat) is applied which is colourless and extremely durable, stable and fast-drying. The technology cures 3D coatings and can handle complex geometries such as the “5D” mirror housing of cars (including inside) or complex shower heads. The one component technology enables ePD™ to recycle oversprayed lacquer and re-use it again. This will also protect resources and avoid waste. The UV lacquers for ePD™ are not based on the same components as other mostly thermal curing
SUBMISSION OF INFORMATION ON ALTERNATIVES

Wet lacquers, but on a different chemistry and curing technology\(^1\). All UV substances used are registered (no SVHCs) under REACH and none are considered as endocrine disruptors.

Oerlikon Balzers is located worldwide and provides a PVD coating service in over 110 plants in 32 countries but the business model is to provide the ePD™ equipment with the corresponding technology. The big advantage of the technology is its "green" aspect with simplified permission procedures (no gas emissions, waste water or solid waste).

Waste and emissions during production
The complete ePD™ process produces a very low amount of emissions.

The PVD process is vacuum based and free of any gaseous or solid waste. Residual target materials can be completely recycled or disposed of as standard metal waste.

The UV application is exceptional for a painting process. As an advanced function, a UV lacquer recycling unit is implemented in the paint booth and the off-gas system. The off-gas only contains small volumes of VOC, which are below legal limits or can be eliminated by post-combustion. A mid-term plan is to replace the VOCs by 100% solid content of the UV coatings.

ePD™ can be used for all shapes/geometries. The parts can be very small (i.e. design trims, buttons, etc.) up to large parts (1.2 m) i.e. automotive front grills or bumper trims. The size limitations depend on the equipment dimension. Even larger parts (bigger than 1.2 m) are technically suitable. PVD equipment for other applications with a form factor >2 m have already been built in the past.

Applications
The ePD™ technology can be utilised for a number of purposes typically covered by chromium trioxide containing coating solutions.

Example applications are:

- automotive interior design
- automotive exterior design
- consumer electronics design
- medical devices design
- sanitary and household design
- cosmetics design
- white goods.

The technology can also be applied to a broad scope of new features raising the value of the end product by combining design with functionality.

Automotive sector
The functions of ePD™ in the automotive sector include a large number of surface properties and more than conventional metal plating technology. Useful new functions can be integrated into ePD™ coated parts, and are therefore attractive to designers, manufacturers and end users.

\(^1\) This is part of the INUBIA patented technology - Only some machine parts are patented. The process itself is not IP protected, but the know-how is protected in the process and combination of PVD and UV lacquer.

[0032-03] [ePD™] [7 October 2015]
Beyond the classic chrome colour, ePD™ also offers a large variety of colour options, from mirror chrome to dark chrome and many other colour shades, giving more flexibility in design. As the ePD™ colour is only generated by the PVD layer (not by lacquering) the purely metal-based colour is extremely stable unlike electroplating which is generated through a chemical process. The PVD process is controlled by a computer process which monitors vacuum data, electrical current and voltage and gas pressure. Colour differences can be extremely accurately controlled by adjusting these physical inputs.

- ePD™ coatings provide enhanced corrosion resistance – ePD™ coated parts withstand mud and aggressive salts, a very important feature for automotive exterior plastic metallisation. Conventional electroplating technology currently does not provide this. ePD™ has been proven to be resistant even to "Russian mud", which contains highly corrosive salts, typically used to thaw ice on roads in Russia and Canada. This will help to save resources, due to durable parts up to the end of life of the vehicle.

- Laser etching allows controlled coating removal for day/night design or, for example, for light emitting buttons, which can have, letters or icons laser-etched into them.

- The inbound and outbound radar transparency of metallised plastic parts is now possible, for example, for safety distance control solutions integrated into the front grills of cars or lane departure warning sensors in the exterior trim.

- The integration of capacity sensing technologies in metallised plastic components offer attractive design solutions, such as door handles responding to touch or electronic control panels and sliders.

- The thin PVD ePD™ coatings of ePD™ can be made translucent for light sources beneath the coated part. At night and when dark, coated parts – that look metallic during the day – can provide signal lighting or back lighting.

- ePD™ can be adjusted with selective PVD layers which do not block GPS, radio and mobile phone waves. This enables the automotive industry to eliminate the antennas (mostly on the roof) with the effect to improve the cw-value to reduce the fuel consumption.

The above-mentioned properties can clearly also be applied to electronics, sanitary and white goods.

**Electronic**

Some of the uses in the electronic sector include design elements for coffee machines, mobile phones, and microwaves.

**Sanitary**

Uses in the sanitary sector include showerheads, accessories, shaver and toothbrush housings etc.

**Medical**

Uses include hearing-aid housings (medical devices) etc.

**White goods**

White goods uses include design elements for washing machines; oven handles, etc.

**Cosmetics**

Cosmetic uses include very small parts such as mascara or lipstick housing.

**Other**

In terms of applications other than surface treatment, the paint lines of the integrated ePD™ equipment can also be used to apply different UV lacquers for different applications. However, it is not recommended to mix applications due to cross contamination, but as fall back solution this would be an option.
Substances used

UV lacquer:

The combination of substances used in the UV-lacquer do not contain any SVHCs or other substances which are on ECHA’s candidate list. All the substances are registered under REACH. They will remain confidential for competitive reasons.

PVD layer:

Elementary Chrome  
Elementary Gold  
Elementary Aluminium  
Stainless Steel  
Argon  
Nitrogen  
Acetylene

The only possible exposure to the substances used in the UV lacquer will take place when containers are filled and placed in the paint-kitchen or during maintenance and cleaning. The process itself is fully automated and takes place in a closed booth/chamber with separate air conduction. No contact to human beings occurs in the standard process (state of the art for industrial paint application).

The readily coated ePD™ parts are classified like millions of normal painted parts that are produced every day. The metal layer is in the nano-range so the total amount of metal is far below any limit (i.e. can not be scaled). Due to this fact and the non-toxic property ePD™ parts are suitable for recycling.

2. TECHNICAL FEASIBILITY

ePD™ is a feasible alternative to functional chrome plating with decorative character also in terms of:

- Corrosion resistance,
- Chemical resistance,
- Wear resistance / abrasion resistance,
- Excellent health and environmental safety for finished articles²,
- Adhesion between coating and substrate,
- Sunlight resistance / UV resistance,
- Temperature resistance / heat resistance and
- Aesthetics

Oerlikon Balzers has developed a breakthrough technology and embedded it into the INUBIA I system, a fully integrated and automated machine for high-volume plastic metallisation in chrome look. Parts that have passed through the INUBIA I system have enhanced functionalities and properties such as extended durability through a special UV lacquer hardening process and full corrosion resistance. The design and colour combinations of this new technology are virtually unlimited.

² ePD™ finished articles contain no toxic substances contrary to chromium trioxide and an FDA is expected in the next 2-3 years after launching the sanitary market.
The use of the INUBIA I system performing ePD™ requires similar human resources as conventional metal plating technologies hence it is job neutral. The needed skills for the use of a conventional coating line are similar to those needed for the ePD™ system. Thus only a limited training for workers is needed to switch.

Material is cleaned using CO₂ snow-ice.

The ePD™ process involves a significant reduction of toxic waste from emissions of solvents, i.e. volatile organic carbon (VOCs).

ePD™ produces less emissions (GHG) in the production process compared to traditional metal plating and worldwide there is no requirement in view of the ePD™ process for extra CO₂ permissions.

ePD™ allows a significant reduction in the amount of raw materials use compared to traditional metal plating and enables the recycling of non-used coating material during the process.

The ePD™ process uses far less energy than comparable traditional metal plating.

ePD™ does not use any Substances of Very High Concerns (SVHCs).

The ePD™ process uses far less energy than comparable conventional coating technologies and involves a significant reduction of toxic waste.

The chromium used in the ePD™ process is zero valent and is harmless for human health and the environment.

**Pre-treatment**

[0032-03] [ePD™] [7 October 2015]
The ePD™ process will eliminate the need for etching during the pre-treatment of components or parts and therefore no use of chromium trioxide is required. The adhesion mechanism of PVD is based on plasma and does not need any chemical pre-treatment. The UV coatings are chemically bonding depending on the resin technology. Also no pre-treatment is needed. The etching process (as used in electroplating) is subject to a lot of quality issues which do not affect ePD™. This makes ePD™ a better alternative in this respect also.

**Functional requirements – automotive sector**

With regards to corrosion resistance, traditional chrome plating has seen many problems in the automotive sector for exterior parts in Russia, China, and Canada. ePD™ has successfully passed all kinds of corrosion tests (DIN EN ISO 9227 (incl. adhesion test afterwards)), VDA 233-102, etc.)\(^3\) in the automotive industry. Particularly winter salts combined with brake-pad dust create severe problems for a plated surface. ePD™ has unlimited corrosion resistance due to the fact that the PVD layer is not corrosive. The UV topcoat protects the PVD layer additionally but even with mechanical impacts like stone chipping no corrosion occurs. This is a huge innovation in the plastic metallisation business.

As a result of extended testing with clients in the automotive sector, the ePD™ technology has been approved as having “unlimited” (over 1 000 hours CASS test w/o damage) corrosion resistance. In comparison with decorative chrome plating based on chromium trioxide or trivalent chrome, ePD™ fulfils all specifications. In addition one must take into account that the corrosion tests in the specifications for “lacquer + PVD + lacquer” are much stronger than for plating. The CASS test is specified for a minimum of 500 hours for PVD/lacquer and often much less than 50 hours for electroplating. The statements in the Analysis of Alternatives (AoA) of CTAC regarding corrosion performance of chromium trioxide are therefore not adequately elaborated.

ePD™ applied on exterior parts in the automotive sector, is not aluminium based and therefore is corrosion stable in this respect.

In terms of chemical resistance, ePD™ has passed all OEM approvals for the automotive sector.

**Wear resistance / abrasion resistance**

The wear resistance has been approved for the automotive interior, exterior and sanitary industry.

**Excellent health and environmental safety for finished articles**

Due to organic coatings (UV layers) and a metal layer in the nano-range, no environmental liability occurs. Parts can be recycled like standard painted plastic parts.

**Adhesion between coating and substrate**

The adhesion of the UV primer is controlled by the resin technology. A physical/chemical adhesion mechanism assures the bondage, and therefore, unlike traditional plating, no adhesion problems occur especially after temperature cycling.

**Sunlight resistance / UV resistance**

The final UV resistance is controlled by the UV topcoat, which is stabilised by a UV-enhanced package. This package prevents the system from long-term degradation or yellowing. The tests are specified on methods required by weathering (Florida, Arizona, and Kalahari exterior test) or accelerated weathering simulations.

The UV-enhanced package for ePD™ coatings have been well established for more than 15 years. The current paint supplier is qualified for several automotive OEMs worldwide for the UV-head

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\(^3\) Please find a list of corrosion tests in the appendix.
lamp coatings on polycarbonate. This system replaces the glass headlamps with the much safer plastic surface.

**Temperature resistance / heat resistance**

ePD™ is highly resistant to temperature changes from -40°C to +80°C.

As to the aesthetics, ePD™ has already received design approval from one of the leading automotive manufacturers.

In addition, due to the thinner coating and the organic layer, better flexibility is achieved compared to electroplating. This ensures also an approved breaking behaviour of the system i.e. for airbag emblems. No critical breaking edges or catapulted particles occur (for example car manufacturers who produce passenger cars, bus and trucks changed the airbag technology 100% to ePD™ for this reason)

In conclusion, it can be stated that the Analysis of Alternatives conducted by the CTAC Consortium on Lacquer+PVD technologies does not represent Oerlikon Balzers’ ePD™ technology which is already a lot further developed. Below is the CTAC table for functional performance:

<table>
<thead>
<tr>
<th>Substrate compatibility</th>
<th>Corrosion resistance</th>
<th>Chemical resistance</th>
<th>Wear/abrasion resistance</th>
<th>Adhesion</th>
<th>Weather proof</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved</td>
<td>Approved</td>
<td>Approved</td>
<td>Approve for certain applications</td>
<td>General approval expected soon</td>
<td>Approved</td>
<td>General approval expected soon</td>
</tr>
</tbody>
</table>

Please see below the performance results of ePD™ according to various test results:

<table>
<thead>
<tr>
<th>Substrate compatibility</th>
<th>Corrosion resistance</th>
<th>Chemical resistance</th>
<th>Wear/abrasion resistance</th>
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<td>General approval expected soon</td>
<td>Approved</td>
<td>General approval expected soon</td>
</tr>
</tbody>
</table>

**Functional requirements – sanitary sector**

ePD™ also complies with the requirements for sanitary applications. The world's top three leading sanitary brands already approved ePD™ in the laboratory or in extended field tests. One extended field test in a hotel chain finalised the field test with a 100% positive result. Plans to proceed to production are at an advanced stage.

The Analysis of Alternative also states "potential alternatives must be authorised by public authorities before they can be considered technical alternatives. The testing procedures must demonstrate compliance with all regulations, and provide a safe product in contact with drinking water."

Approval for direct contact of the ePD™ surface with drinking water is planned after launching the first product platform. So far the ePD™ surface is separated (like the electroplated surface today) from the drinking water by a piping system or non-coated areas.

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4 Analysis of Alternatives (AoA), p.62
5 Analysis of Alternatives (AoA), p.6
Once again, the CTAC Analysis of Alternatives does not represent the latest developments in this sector as per the table below:

<table>
<thead>
<tr>
<th>Substrate compatibility</th>
<th>Corrosion resistance</th>
<th>Chemical resistance</th>
<th>Wear/abrasion resistance</th>
<th>Temperature change/heat resistance</th>
<th>Drinking water compliance</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depending on the deposited metal</td>
<td>Depending on the deposited metal</td>
<td>Not for UV lacquers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The performance results for ePD™ are:

<table>
<thead>
<tr>
<th>Substrate compatibility</th>
<th>Corrosion resistance</th>
<th>Chemical resistance</th>
<th>Wear/abrasion resistance</th>
<th>Temperature change/heat resistance</th>
<th>Drinking water compliance</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved</td>
<td>Approved</td>
<td>Approved</td>
<td>Approved</td>
<td>Approval for other OEMs expected soon</td>
<td>Approval for other OEMs expected soon</td>
<td>Not evaluated</td>
</tr>
</tbody>
</table>

**Functional requirements – cosmetics sector**

With regards to cosmetics, UV lacquer + PVD + UV lacquer already covers ~90% of the cosmetic packaging business. Nearly all lipstick, mascara housings and more are produced every year using UV lacquer + PVD (by thermal evaporation technology) + UV lacquer. It is already a worldwide standard. Although ePD™ can technically cover the cosmetics sector it has for now focused on the automotive and sanitary sector. Once the high-end products have been approved, approval for the cosmetics sector should not be an issue as long as the loading of parts into INUBIA system is fully automated. Therefore the below table produced by CTAC does not represent today’s reality:

<table>
<thead>
<tr>
<th>Substrate compatibility</th>
<th>Chemical resistance</th>
<th>Wear / abrasion resistance</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved</td>
<td>Approved</td>
<td>Approved</td>
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</tr>
</tbody>
</table>

Rather, the performance results for ePD™ are:

<table>
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<tr>
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<th>Chemical resistance</th>
<th>Wear/abrasion resistance</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved</td>
<td>Approved</td>
<td>Approved</td>
<td>Approved</td>
</tr>
</tbody>
</table>

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6 Analysis of Alternatives (AoA), p.65
7 Analysis of Alternatives (AoA), p.67
**Functional requirements – white goods**

In terms of white goods, ePD™ also covers all requirements. As tests were passed for the automotive, sanitary and cosmetics sectors, it is safe to assume that ePD™ complies with the requirements for white goods.

**General**

The Analysis of Alternatives conducted by CTAC also states "In addition to investment costs, the vacuum chamber must have a sufficient size for the respective parts (for example front grills, trim stripes, etc.) and accommodate the complexity of the parts. In general, the need for a vacuum chamber limits the size and the type of parts that can be coated. PVD, a line of sight process, is not suitable for complex geometries and large parts. The complexity and size of the parts to be coated with PVD has to be taken into account when planning the vacuum based process."\(^8\)

However, INUBIA I12 can cover more than 80% of all plated parts for decorative coating. It could technically also cover the largest parts, however the volumes of larger parts are currently not sufficient to justify the investment in a larger INUBIA system. It is technically feasible to enlarge its capacity if the opportunity arises.

Electroplaters have faced difficulties with certain shapes such as mirror caps for cars. There are only a few electroplaters left in this sector as quite a few of the mass treated mirror caps face problems due to changing climatic conditions, different surface tensions and density. The picture below demonstrates an electroplated field test part where the electroplating layer rolls up. What’s more, the outline is sharp like a knife and causes safety issues. ePD™ treated surfaces do not face these complications and ePD™ is in many ways a superior technology for complex shapes such as mirror caps.

To conclude, the ePD™ technology is technically feasible as an alternative to chrome plating.

**Other benefits**

ePD™ will tremendously expand design innovation and thereby improve competitiveness and the sustainability of the companies who make full use of it.

ePD™ would also greatly improve each client’s image as no SVHCs are used. This is vital at a time when society is becoming consistently more aware of the environment, pollution and hazardous substances.

Also, in terms of worker safety, ePD™ has benefits due to no worker exposure to any substances, as it is a closed system.

\(^8\) Analysis of Alternatives (AoA), p.68
The local community will also benefit from a cleaner technology in their water table and therefore favour it.

The lacquering process is state of the art worldwide with millions of plastic parts being produced every day. A demister system allows for the UV lacquer technology to recycle the lacquer that is left behind in the paint booth after the overspray, and in the off gas after cyclone aerosol.

Furthermore, energy consumption is reduced due to a very fast curing time in seconds (<30 sec) instead of minutes for thermal curing lacquer systems (~30 min oven drying at 80°C). In comparison, the electroplating process is much less efficient. Just for the metallisation process, there is an energy consumption of about 28-42 kWh/m² for the Cu-Ni-Cr process. The PVD layer is applied with about ~4.7 kWh/m².

The ePD™ technology also saves material resources. For a square metre of electroplating, about 3-7 g/m² of chromium, 223 g/m² of copper and 124 g/m² of nickel are used. This is in addition to co-chemicals like toxic boric acid etc. For a comparable surface area, the ePD™ technology ONLY requires ~2.1 g/m² of metal (chromium-based multilayer) without any additional co-chemicals. In total, this is a material saving of 98% of the metal.

Due to the plasma process, which occurs in a vacuum, no emissions are produced during the PVD process. Atmospheric air of the shop floor is pumped out of the chamber; the cooling system is a closed loop of water separated from any coating process just for cooling the cathode system or electrical units. The consumed elementary, pure target material can be recycled or re-used after sintering.

3. ECONOMIC FEASIBILITY

The substitution of a conventional coating line with an INUBIA I system applying ePD™ is economically feasible and attractive. The process is sustainable, innovative and the production can be guaranteed for long periods of time due to the durability of the INUBIA system and since it does not use any SVHCs that are subject to authorisation under the European Chemicals Regulation REACH, which is only granted for a certain period. The biggest cost efficiency is achieved by placing the ePD™ INUBIA lines on the site of the OEM (mostly sanitary) or Tier 1 and 2 level (automotive). The business model of Oerlikon Balzers for ePD™ is to supply the technology in the form of equipment and knowledge.

Investment costs

Commericially, customers would need to replace their existing chrome plating machines with the new ePD™ technology on INUBIA I.

The Analysis of Alternatives conducted by CTAC states that "no detailed quantitative analysis of economic feasibility was conducted. Indications were made stating that the operational costs for lacquer + PVD systems are up to 150% higher, and costs for a PVD metal coating (for example as additional coating on top of a chromium trioxide electroplated metallic chrome coating) are up to 50% higher compared to electroplating using chromium trioxide." The AoA also states "two PVD coating lines would be necessary to realise the same throughput of parts. The cost for the

9 Study by the Landesamt für Umweltschutz (environmental agency) in 2003 in cooperation with Zentralverband Oberflächentechnik e.V. (Germany’s central organisation for surface technology).

10 Analysis of Alternatives (AoA), p. 68
installation of one PVD coating line is estimated to be about 1 million Euros, resulting in investment costs (only for the PVD coating) of at least 2 million Euros. These high investment costs on the PVD technique do not yet cover costs for the set-up of adequate lacquer coating lines when changing to a lacquer + PVD + lacquer alternative, and further investment costs of at least 1 million Euro can be considered for this part.\end{note}

This greatly misrepresents the current state of play as 1) the cost of investment for customers to take up ePD™ would be equivalent to that of investment in chrome plating machines, and 2) a single INUBIA I6 or I12 system would suffice to realise the same throughput of parts as a traditional electroplating line (more on this below). Either way, the investment costs for any transition (including to Cr(III) for example - once it would become a viable alternative) will require investments to modify existing plating lines.

It is also possible to make stepwise investments\footnote{For example by starting with only one paint line instead of two. On that paint line you then apply the primer and the top coat. Although less efficient, it is a good option to reduce investments for a start-up.} – without negatively affecting the performance – to reduce the entrance barrier to the technology.

To compare the cost of ownership between electroplating and ePD™ is not reasonable on a 1:1 scale. A lot of previous and downstream processing steps have an impact on the pricing. OEMs and tier 1 businesses have analysed the cost of ePD™ in several projects, and generally concluded that ePD™ is price competitive. Depending on the geometry or size of the parts, either ePD™ or electroplating was slightly more cost efficient. However, overall they rate as equally cost efficient when the ePD™ technology is placed on site of the part supplier for in-house production.

Customers that would otherwise ship their parts to other locations for conventional electroplating will benefit from the on-site application of ePD™ technology, as it saves transport costs, minimises stocking, reduces logistics, allows for production on demand, and reduces CO2 and fuel consumption. In addition, it offers further coating choices to OEMs.

**Cost estimations**

The INUBIA I system with full automation based on UV lacquer technology is on the same cost level as conventional electroplating.

Even prospective clients have already clearly stated that ePD™ is cost competitive and, in some cases, huge savings can already be foreseen. The mentioned cost level (+150%) from the CTAC dossier reflects the “old” PVD+lacquering process using thermal 2K Polyurethane coatings and stand alone PVD batch machines. The ePD™ INUBIA lines consist of a multichamber PVD line and the fast-curing UV technology. Today cycle times of 35 seconds per coating unit (spindle) are achieved.

On top of that, huge savings are possible i.e. for moulding tools. Traditionally, different surface technologies are often used for the same part like body colour lacquering or chroming i.e. for automotive mirror caps depending on the edition. This means that for a small amount of parts, separate moulding tools for electroplating have to be built. In case of mirror caps, this implies that an extra amount of >200-300 TEUR can easily be spent for less than 30k of cars. All of the above therefore implies that ePD™ would be a cost-saving alternative.

**Timing**

The anticipated timeline to install ePD™ is estimated to be 18 months for machine assembling, installation and ramp-up.

**Human resources**

\footnote{Analysis of Alternatives (AoA), p. 68}
The use of the INUBIA I system performing ePD™ requires similar human resources as conventional metal plating technologies hence it is job neutral. This would include two operators for the machine and a certain amount of workers for loading, unloading, inspection and logistics. This is comparable to electroplating, except for the persons monitoring the baths and those that dispose of waste in the electroplating process. The process will have no adverse impact on job creation or losses and is *per se* job neutral. Workers can be easily trained to use the new technology on INUBIA I, as the required skills for the use of a conventional coating line are similar to those required for the ePD™ system.

**Volumes**

Through its short cycle times (spindle cycle time of around 35 seconds), ePD™ is suitable for high-volume mass production, therefore it is cost competitive with further upside potential to the conventional electroplating process.

The coating time of ePD, which includes the 3-layer application and cleaning, takes total ~50 minutes. The lower temperatures used do not lead to longer coating times as a higher film thickness is not required.

As the throughput of parts is 1:1 in comparison to electroplating, a 1:1 replacement of machines would suffice, and costs for installation of a single machine are in the same order as that of a large classical electroplating line.

In general ePD™ is available for all kinds of decorative plastic metallisation but, depending on the sizes and quantities of required parts, different machines are needed. For example: cosmetic packaging parts are very small but really high volumes are needed (easily >20 Mio pcs/a); sanitary parts are much larger but also require large volumes (> 3 Mio/a); the automotive exterior can have very large parts (>1.2 m) but sometimes with low volumes.

**Methodology**

To determine the economic impact and feasibility of ePD, Oerlikon Balzers did a very detailed cost of ownership calculation for customised demo parts focused on material and energy consumption. Potential customers added the local labour costs for all involved human resources, the customised depreciation, facility, logistic and raw material costs. At the end of this process, the total cost for an ePD™ coated part was available which is directly comparable with existing electroplating numbers. In some cases, advanced consideration was also taken for additional processes like assembling, moulding tool manufacturing etc.

The results coming in from major OEMs and Tier 1 companies was that the cost efficiency for ePD™ is in general on the same level as electroplating. The differences were related to the part design and the more or less better loading efficiency on racks for electroplating or spindles for ePD™. In some cases, a huge cost saving for ePD™ can be seen, in other cases a clear cost advantage for electroplating is discovered.

**4. HAZARDS AND RISKS OF THE ALTERNATIVE**

ePD™ technology is fully in line with the technology trend of cleaner and leaner production and the EU’s innovation strategy by offering an integrated solution consisting of the technology, the equipment, the materials, and the training for use and maintenance. It thus promotes a more holistic life cycle approach across the value chain of commerce from the raw materials stage to the end-of-life options of the parts.

ePD™ will significantly improve material efficiency and safety, eliminate worker exposure to SVHCs and reduce the negative impact on the environment. The new technology is more sustainable than conventional chrome plating as it saves resources and consumes less energy. It also includes no hazardous substances such as boric acid and produces low emissions (no toxic waste or contaminated water).
Switching to this alternative would have a positive impact both on human health and the environment, due to:

- **No harmful substances:**
  - ePD™ does not use any SVHCs.
  - ePD-coated parts are fully recyclable and fulfil the requirements of Directive 2000/53/EC - the “End of Life of Vehicles (ELV) Directive”, since they do not contain lead, mercury, cadmium or hexavalent chromium.
  - Chromium or other metals used in ePD™ are zero valent and harmless for human health.
  - ePD™ does not use any boric acid.

- **Better resource efficiency:**
  - ePD™ allows a significant reduction in the amount of raw materials use compared to conventional coating techniques and enables the recycling of non-used coating material during the process.
  - The ePD™ process uses far less energy than comparable conventional coating technologies.
  - ePD™ produces fewer emissions (GHG) in the production process compared to current coating systems and worldwide there is no requirement in view of the ePD™ process for extra CO₂ permissions.
  - The ePD™ process involves a significant reduction of toxic waste from emissions of solvents, i.e. volatile organic carbon (VOCs).
  - ePD™ reduces CO₂ emission due to logistical aspects. ePD™ coating equipment can be legally placed all over the world right into the supply chain without extra transportation efforts. Due to very strict legal regulations to install electroplating lines such as regulations for waste water, off-gas emissions etc., the electroplaters act as job-coater or in the tier 2 level in most cases. Especially in regions with water preserved areas it is not possible to operate electroplating lines. Due to the complex supply chain in electroplating, the raw materials need to be shipped to the electroplating plant for the coating and then shipped back to the assembler. This causes an enormous logistical effort with a lot of truck movements, which cause high CO₂ emissions. Also, in most cases the metallised part is only for decoration so that an assembling process will take place to combine the decorative part with basic bodies or electronic devices. To transport these sensitive parts extensive packaging has to be done, resulting in a lot of empty volume being shipped compared to the actual weight of the parts. Sometimes less than 10% of the load is the original part and 90% is packing and free space (i.e. front grill frames with a small outline and lot of empty space in the infield). With ePD™ and the reduced regulations however, the parts can be moulded, coated and assembled on site on demand.

- **Better control via a closed system:**
  - INUBIA I, the machine in which ePD™ is applied, is a closed system where the paint line and the PVD coating process are fully automated through robots and are processed in a grey room atmosphere with air cleaning ventilation technology. The closed system protects workers from exposure to the materials used in the process.
  - ePD™ effectively eliminates worker exposure to potential inhalation risks by materials and substances.
  - INUBIA I systems will not put workers at risk as the maintenance of the painting and PVD equipment has been standard for several decades.
The coatings applied on soft and flexible base materials using ePD™ technology ensure that the risk of sharp edges - from breaking upon impact - to human health are reduced or even eliminated in comparison to metallic coatings. Therefore ePD™ coated components qualify for safety-relevant parts in car interiors (e.g. airbag emblems that do not cut airbags upon impact). Also in sanitary applications, ePD™ eliminates coating damages, and consequently possible cuts for the user, which is a negative aspect of coatings achieved through electroplating.

The ePD™ technology has been approved through an extended field test and laboratory test with a big client to comply with “all regulations and to provide a safe product in contact with drinking water”. As a result the client is about to start its first mass production project.

In addition, the ePD™ technology has already been applied to other uses including medical devices such as hearing-aid housings which are in permanent skin contact. This shows that no dermatologic concerns occur with ePD™, even when the surface is damaged. This is not possible with electroplating due to the nickel content (nickel leaking) and the dermatological risk for allergies.

5. AVAILABILITY

ePD™ is a validated technology that has proven its application on an industrial scale in Oerlikon Balzers’ coating site in Suzhou, China. ePD™ on INUBIA I is today commercially available for industrial application in Europe and elsewhere. The first customers are already installing INUBIA equipment in Europe. German, British and French automotive OEMs such as Audi, VW, Daimler, BMW, Mini, JLR, PSA, and the telephone supplier Siemens Gigaset already use ePD™ just like Chrysler and Ford in the US. The ePD™ technology is developed to act as a flexible and environmentally friendly alternative to electroplating to cover all market segments in the medium and long term.

The ePD™ technology is currently mainly used in the niche markets for special products and features like safety or back-lighting. Due to further developments in processing, the cost per part has become more attractive. Additionally Oerlikon Balzers decided to expand to the sanitary and automotive-exterior market, which led to the development of the corresponding lacquer performance.

The basic approval in the automotive decorative market takes several years (1-2 for interior; 2-4 for exterior). As ePD™ was introduced about 4 years ago some part approvals were already given and the general approval (to replace electroplating) is expected by the end of the year 2015 for the first OEM. Several others are following. This general approval will have a great impact on the market making this a very sensitive topic, where a lot of technical discretion is needed.

Once a customer issues a purchase order (PO) to purchase ePD™ equipment, it takes about 1.5 – 2 years to install the manufacturing capacity, though this depends on the facility.

A regulatory push will help to open the very conservative sanitary and automotive markets.

OEMs also designed specifications for lacquer+PVD+lacquer and the ePD™ technology complies with all the specifications.

In 2005, ePD™ launched its first mass production. The evaluations from this long-term use of parts can give an adequate idea of its performance and long-term stability. A car manufacturer started the first ePD™ project for knobs on the air-conditioning unit, and three large car manufacturers changed the airbag emblem technology entirely to ePD™ because of safety issues.

Volumes

With the use of ePD, the coating market in the EU could be (fully) covered in 6-7 years. Oerlikon is a stock market company with sufficient financial power to build up the assembly and
engineering resources. Today, Oerlikon Balzers already operates in >32 countries with about 15 000 employees. It has been confirmed multiple times from the Oerlikon Balzers management to automotive board directors to build up sufficient resources when needed and a regulatory push in the form of a shorter authorisation would significantly speed up things as OEMs would require suppliers to switch to using ePD.

6. CONCLUSION ON SUITABILITY AND AVAILABILITY OF THE ALTERNATIVE

ePD™ is a European innovation and breakthrough technology. The use of ePD™ would give the EU automotive, sanitary, cosmetic and white goods industries as well as the electroplating companies a competitive advantage on the global market. ePD™ will help to increase European competitiveness in a fast developing global technology landscape with high potential.

Overall it is hard to compare ePD™ with electroplating as they are very different technologies. Chromium trioxide for the decorative market on plastics is an inorganic metallisation process with no comparable processing steps. The deposition occurs electrochemically from the liquid phase in the μm range. The deposition from the ePD-PVD layer occurs by plasma in the nano range and is sandwiched by two organic layers. The properties are very different, however they result in a visually similar effect. ePD™ is not able to replace an electroplated layer as it is an alternative technology with different durabilities and functionalities.

The ePD™ alternative however is completely corrosion and wear resistant, and complies with all the specific requirements of the different industries. It even has enhanced functionalities such as for 3-dimensional parts which encounter regular complications in the electroplating process. The technology can be applied to a wider range of parts and allows a bigger variety of applications.

Overall it is not only a viable and technically feasible alternative, but it also has a large positive impact on health and is better for the environment as it does not use any SVHCs, has less waste, does not require multiple treatments during the lifetime of the product and therefore saves emissions. In addition to being a feasible alternative to chromium trioxide, the ePD™ technology does not use boric acid, which is very close to being placed on REACH’s ANNEX XIV. Boric acid is currently used in the functional chrome plating process. If the current time schedule from ECHA is realised, the sunset date is May 2020. This will have huge implications on electroplating and many potential alternative technologies that have been developed so far, as they represent no real or long-term option after 2020. Therefore Oerlikon Balzers’ technologies are not only a viable alternative to chromium trioxide in functional chrome plating but also to boric acid in the future.