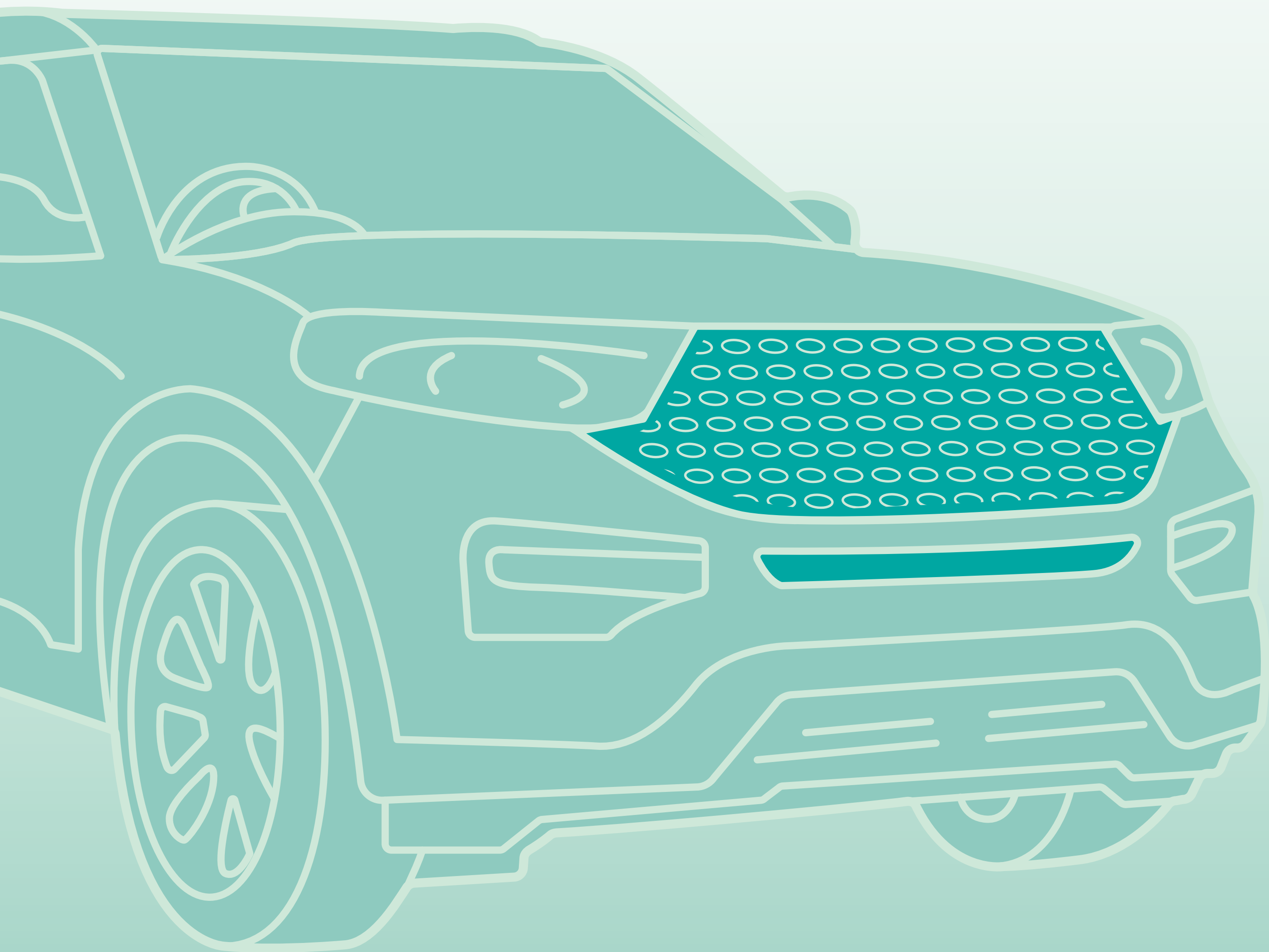
ELIX POLYMERS

A member of Sinochem International

Electroplating
ELIX ABS guideline



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1. Chrome plating process of ABS plastic parts

Chrome plating technology has been used for several years to combine functionality and aesthetics of decorative parts in several sectors such as automotive, consumer goods, appliances, cosmetics and sanitary. In addition to good aesthetics, the chrome plating process provides plastic parts with exclusive technical properties such as surface protection against wear/abrasion, resistance to UV light and chemical resistance.

ABS is the most used polymer for chrome plating applications, followed by ABS/PC blends. The presence of polybutadiene particles embedded in the SAN matrix makes ABS polymer the ideal candidate for chrome plating. These particles provide a microporous surface after the etching process, which is needed to stablish the required physical bonds and achieve the right adhesion between the plastic and the metal layers (see Figure 1.1). Other advantages of ABS are its easy processability, good surface quality, high mechanical and high impact properties.

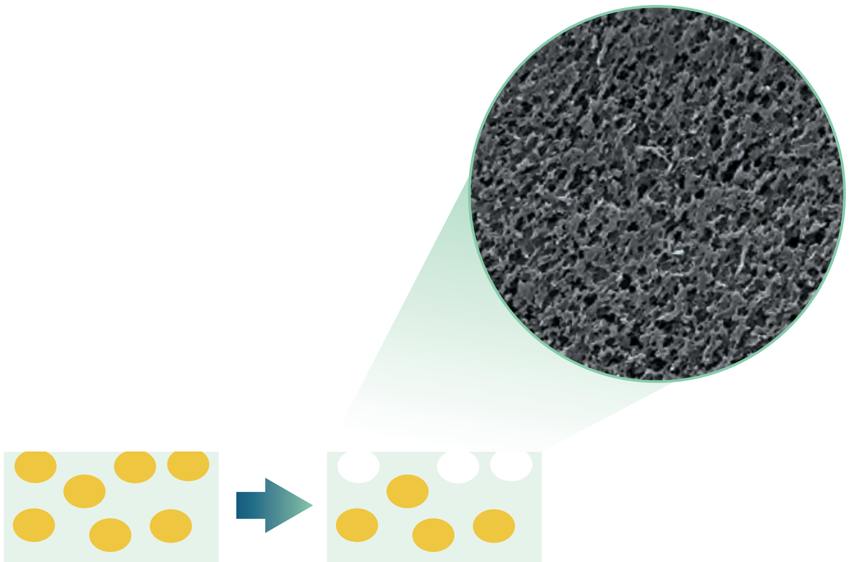


Figure 1.1: Microporous surface created after the etching process (the polybutadiene particles are represented by yellow spheres)

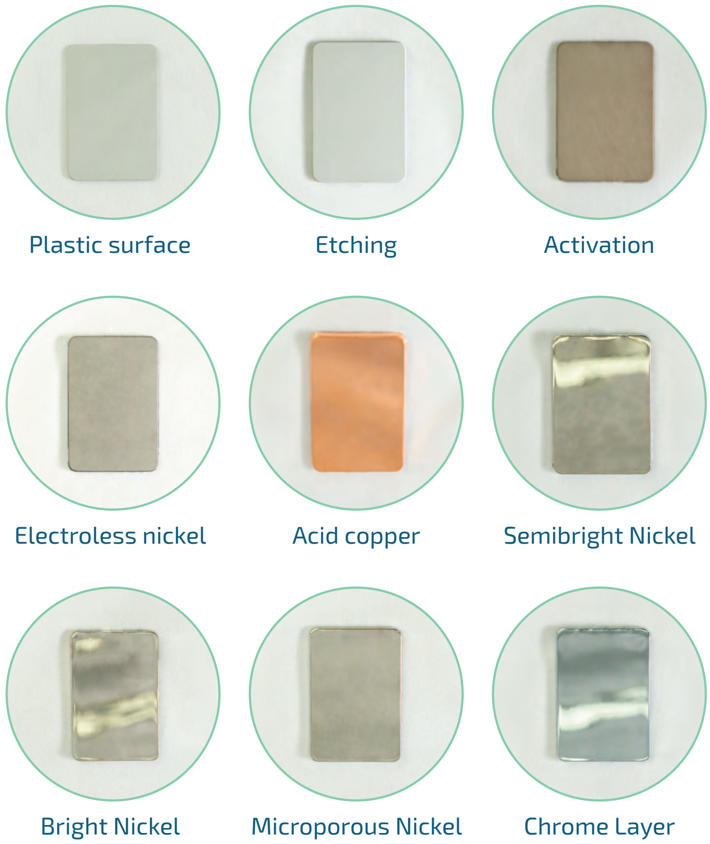
Chrome plating is a very complex process that requires several steps. Figure 2.1 shows the stages involved in a conventional chrome plating process. Of all these stages, the etching process is critical to achieve good adhesion strength between the metal and the plastic.

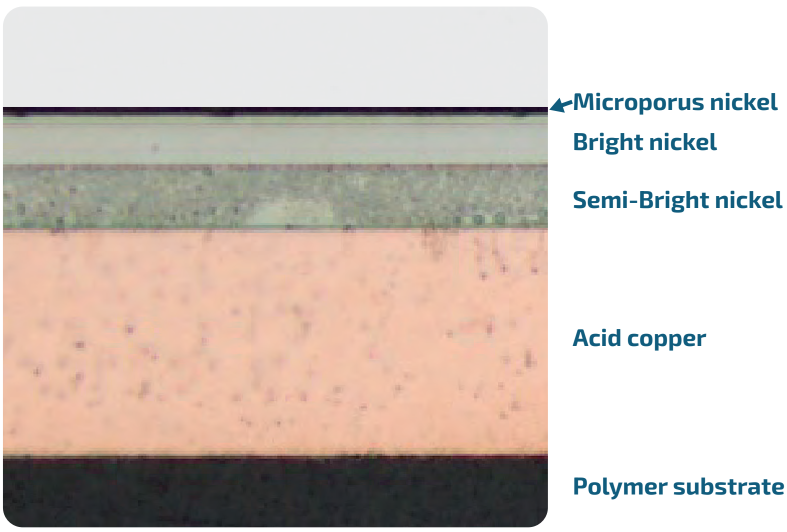
Pretreatment

- Plastic surface
- Etching process
- Neutralization
- Activation
- Acceleration
- Electroless nickel
- Initial copper or nickel

Main process

- Acid copper
- Semibright nickel (optional)
- Bright or satin nickel
- Microporous nickel (optional)
- Chrome layer





2. ELIX plating portfolio and benefits

In ABS and ABS/PC products, the polybutadiene rubber is removed during the etching phase to prepare the sites for mechanical bonding. The optimisation of the shape, amount and distribution of these polybutadiene (PB) particles are essential for obtaining good adhesion and good plating performance. For the best adhesion, the polybutadiene rubber at the surface should be round and well distributed. When the polybutadiene rubber is removed, "lock and key" sites are created for the mechanical bond with the electroless copper or nickel layer.

In this sense, ELIX technology is based on an emulsion process, which leads to a perfect control of the polybutadiene particle size distribution. Also, the grafting process of the polybutadiene particles improves the compatibility of these particles with the SAN matrix, avoiding the formation of agglomerates (see Figure 2.1).

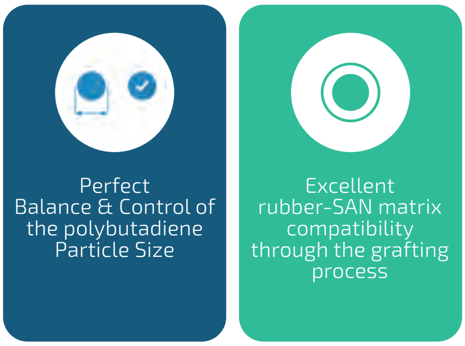


Figure 2.1: Advantages of ELIX technology in chrome plating processes

Additionally, special post-treatment processes, selection of the highest quality intermediate products and routine quality control tests adapted to the special requirements of the plating process are performed on the entire ELIX plating portfolio (see Figure 2.2), leading to the lowest scrap rate possible during the electroplating process. By implementing these optimisation processes to the rubber emulsion step and to the SAN mass polymerisation at the core of the manufacturing process, ELIX is able to obtain the highest purity of ABS, leading to a better surface quality of finished parts.

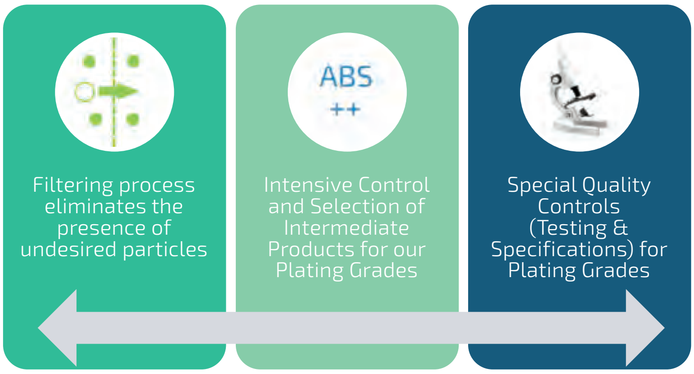


Figure 2.2: Special tests in ELIX chrome plating grades

ELIX polymers offers five electroplatable ABS-based materials: P2MC, 3095 PG, HH P2MC, ABS/PC ULTRA HH 4115 PG and ABS/PC ULTRA HF 4200 PG (see Table 2.1 and Figure 2.3). All these five plating grades have special material formulations designed exclusively for meeting electroplating process requirements.

The most known plating material in the ELIX portfolio is ELIX ABS P2MC, which is characterised for its very good flowability and mechanical property profile matching most applications in the market. In applications requiring a higher vicat, ELIX HH P2MC offers the same property profile but higher heat resistance.

Additionally, for those specific cases where a higher level of adhesion is requested, ELIX has developed ELIX 3095 PG, which provides improved adhesion values as a result of the special formulation that is used for this grade.

For traditional PC/ABS applications where more thermal resistance is needed, our ABS/PC grades are compliant with most automotive standards. ELIX ULTRA ABS/PC offers superior impact resistance levels and vicat values above 110°C. It also provides the benefit of reduced density and better platability compared to PC/ABS, as a higher ratio of ABS is included in its formulation.

Table 2.1. Summary of the main properties of ELIX plating grades

		ELIX ABS plating grades			ELIX ABS/PC grades	
PROPERTY	**STANDARD (UNIT)**	**ELIX ABS P2MC**	**ELIX ABS 3095 PG**	**ELIX ABS HH P2MC**	**ELIX ULTRA HH 4115 PG**	**ELIX ULTRA HF 4200 PG**
MVR	ISO 1133 (220 ºC / 10 kg)	25	14	22	14* *) 260 º C/5kg	26* *) 260 º C/5kg
IZOD ak	ISO 180-1A (23°C) (kJ/m²)	23	25	21	58	58
IZOD ak	ISO 180-1A (-30°C) (kJ/m²)	12	20	12	41	26
Tensile Modulus	ISO 527-1,-2 (MPa)	2200	1900	2200	2000	2100
Vicat	ISO 306 B50 (°C)	95	95	103	113	113
Hardness, Hk	ISO 2039-1 (N/mm²)	90	81	95	105	103
Density	ISO 1183 (g/cm³)	1,03	1,02	1,04	1,07	1,07
Molding Shrinkage, normal & parallel	ISO 294-4 (%)	0,4-0,7	0,6-0,7	0,6-0,7	0,65-0,75	0,55-0,65
		Plating ABS benchmark	High peel-off strength	High heat plating ABS	Plating ABS/PC blend	High flow ABS/PC blend

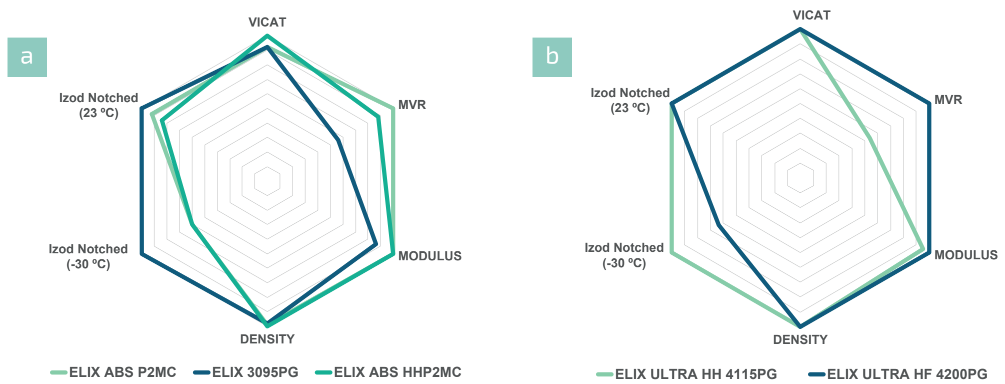


Figure 2.3. Comparative radar chart of a) ELIX ABS plating grades, b) ELIX ABS/PC plating grades.

ELIX ABS and ABS/PC plating grades have been tested applying the strict requirements of the different OEMs. The choice of the grade depends on the technical requirements detailed in the final part performance specification. For more details about the automotive OEM approvals of ELIX plating grades, please contact the ELIX technical team.

3. Injection guidelines for plating grades

ELIX Polymers has developed the ELIX injection moulding guideline, a document applicable to all the grades of the ELIX portfolio, including the ELIX plating grades. This guideline includes the following sections:

- Machine selection and auxiliary equipment
- Advice in processing parameters:
  - Drying conditions
  - Setting temperatures
  - Screw speed and back pressure
  - Injection and holding phase
  - Cooling time
  - Cleaning the plastification unit
- Troubleshooting guideline for defects obtained after injection moulding

In addition to the general recommendations provided in the ELIX injection moulding guideline, specific recommendations are provided for the injection moulding of plating materials that may affect the chrome plating performance.

Drying conditions:

It is very important to remove the humidity in the plastic granules before injection to avoid possible defects such as bubbles, streaks, delamination, etc. To accomplish this, drying recommendations are provided to ensure humidity levels after drying are lower than 0.02%.

Table 3.1. Recommended drying conditions for ELIX ABS and ABS/PC plating grades

ELIX Grade	Drying Temperature (ºC)	Permitted Residual Moisture Content (% weight)	Drying Time (h)		
			Circulation Dryer (50% Fresh air)	Fresh Air Dryer (High speed)	Dried Air System
ELIX P2MC ELIX HH P2MC ELIX 3095 PG	80	< 0,02	4 - 6	3 - 4	2 - 3
ELIX ULTRA HH 4115 PG ELIX ULTRA HF 4200 PG	90	< 0,02	4 - 8	3 - 4	2 - 4

Melt and mould temperatures:

Plating performance is highly affected by the surface stress and mould-in stress within the part. Minimising the mould-in stress of the polymer will improve its dimensional stability and reduce the stress between the metal and the polymer during thermal cycles, while minimising the surface stress will improve the plastic-metal adhesion.

To minimise surface and mould-in stress, high melt and mould temperatures are recommended, but at the same time, melt temperature should be optimised to avoid thermal degradation.

The recommended melting and mould temperatures for the plating grades are listed in Table 3.2.

Table 3.2. Recommended mould and melt temperatures for ELIX ABS and ABS/PC plating grades

ELIX Grade	Melt Temperature (ºC)	Mould Temperature (ºC)	Barrel temperature (ºC)			
			Feeding Section	Compression section	Metering System	Nozzle
ELIX P2MC ELIX 3095 PG	240 - 260	70- 80	180 - 210	210 - 240	230 - 260	240 - 260
ELIX HH P2MC ELIX ULTRA HH 4115 PG ELIX ULTRA HF 4200 PG	240 -260	70 - 80	200 - 220	220 - 240	240- 260	250 - 260

Injection and packaging stages:

Fast fill rates tend to increase the polymer chain orientation on the surface and decrease the mould-in orientation. Therefore, very high injection speeds should be avoided to minimise polybutadiene particles orientation and mechanical resistance reduction of the material surface which may lead to possible delamination issues (see Figure 3.1).

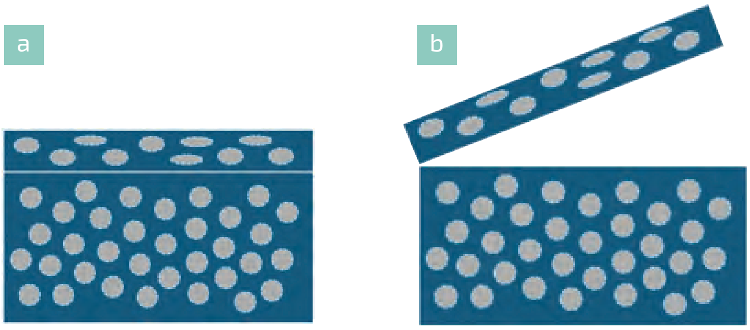


Figure 3.1. a) Change in the shape of PB particles from spheres to ovals due to high shear, b) delamination issues

Also, over-packing, which tends to increase internal stress, should be avoided to minimise possible problems during the etching process.

Tests carried out at different injection conditions:

To analyse the effect of the injection parameters on the surface stress and the mould-in stress mentioned above, a set of 8 tests were carried out using different melt and mould temperatures and injection speeds. Dog bone tensile test samples were used for these tests.

To detect surface stress, acetic acid test was carried out (Table 3.3).

To detect mould-in stress, the samples were heated to 120°C (above the Tg of the SAN matrix) for 4 h, and the deformation due to polymer change relaxation and stress release was measured (Table 3.4).

Effect of the melt and mould temperature:

Table 3.3 shows the surface stress obtained at different injection conditions, observing a reduction of the whitish areas when higher melt temperatures were used. Surface stress was reduced even further when the mould temperature was increased from 60°C to 80°C.

Regarding mould-in stress, higher mould temperatures showed significant less deformation in all cases. Looking at the melt temperature, at low injection speeds the mould-in stress was reduced when the melt temperature was increased from 240 to 260°C. The trend was not clear when very high injection speeds were used.

Effect of the injection speed:

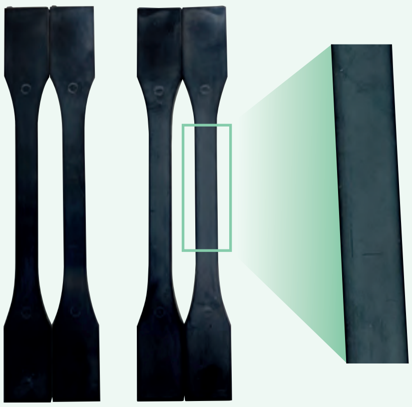
As expected, at very high injection speeds the degree of surface tension increased compared to low injection speeds due to a higher polymer orientation. This trend was observed with the different melt and mould temperatures that were used.

However, the trend experienced by the mould-in stress was not the same. When higher injection speeds were used, similar or even less deformation was observed in some cases, indicating lower mould-in stress.

Table 3.3. Detection of surface stress (whitish areas) after the acetic acid test using different injection moulding parameters

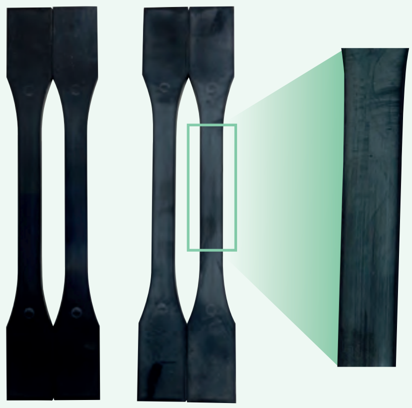
MOULD TEMPERATURE = 60°C

Melt temperature = 240°C



Speed 6 ccm/s | Speed 30 ccm/s

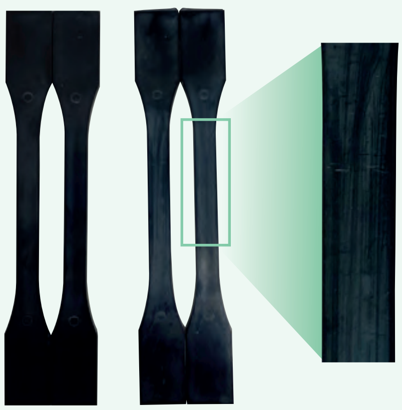
Melt temperature = 260°C



Speed 6 ccm/s | Speed 30 ccm/s

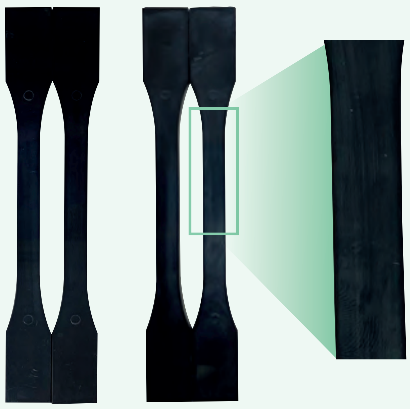
MOULD TEMPERATURE = 80°C

Melt temperature = 240°C



Speed 6 ccm/s | Speed 30 ccm/s

Melt temperature = 260°C



Speed 6 ccm/s | Speed 30 ccm/s

Table 3.4. Deformation after heating the specimens to 120°C for 4 h to detect mould-in stress using different injection moulding parameters

MOULD TEMPERATURE = 60°C

Melt temperature = 240°C

Speed 6 ccm/s   Speed 30 ccm/s

Melt temperature = 260°C

Speed 6 ccm/s   Speed 30 ccm/s

MOULD TEMPERATURE = 80°C

Melt temperature = 240°C

Speed 6 ccm/s   Speed 30 ccm/s

Melt temperature = 260°C

Speed 6 ccm/s   Speed 30 ccm/s

Summary:

As a summary, Table 3.5 shows the key moulding conditions to be considered for the injection of chrome plated parts:

Table 3.5. Recommended injection conditions for plated parts.

PARAMETERS	RECOMMENDATION
Drying temperature and time	General recommendation: 4 hours at 80°C (ABS) or 90°C (ABS/PC). Check humidity (<0.02%)
Melt temperature	Slightly higher than for non-plated ABS parts (240-260°C)
Injection speed	Slower injection speeds
Mould temperature	Higher side of the range (70-80°C)
Back pressure	Lower back pressure if possible

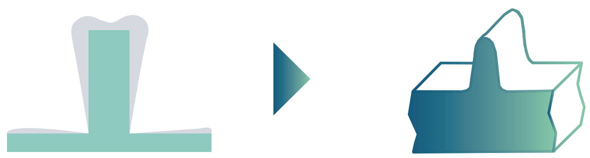
4. General recommendations on part design

Mould design is a key factor that affects the aesthetics and the residual stress of the moulded part as well as the overall plating performance.

The general recommendations in terms of mould design to avoid these issues are:

Ribs and Bosses:

To avoid sink marks on the surface opposite the ribs, that will be more visible after plating, the rib thickness should not be greater than 0.5 times the wall thickness. Also, bosses should have round angles rather than sharp edges in order to avoid stress concentrations.



Recommended geometry

Planes:

Larger parts and long flow lengths are more likely to have higher residual stress and higher mismatch between the mechanical and thermal properties of the plastic substrate and the metal layers.
To reduce the distance that the polymer needs to run inside the tool cavity and avoid problems linked to long flow distances, designers often use multiple injection points. Sequential injection is another option used to avoid flow fronts and weld lines.

Edges and Corners:

Sharp edges and corners should be avoided, since they concentrate stresses, reducing mechanical performance and causing high, localised shear rates, which can lead to issues after plating in terms of metal adhesion and thermal cycles performance.

Recommended geometry

Wall thickness:

The presence of non-uniform thicknesses along the part will be an added challenge to the residual stress generation, as the material will not be cooling down uniformly. Gradual transitions between different wall sections, as well as adding round angles are recommended to reduce the localised thickness variation and stress concentration.

Recommended geometry

Although these recommendations are provided with the aim of reducing residual stress and improving adhesion and performance after thermal cycles, they will also help obtain an equal distribution of the current density on the part, and therefore a uniform electroplate thickness.

5. Troubleshooting

While surface defects after chrome plating are a very heterogeneous group of defects with many different root causes, in this guideline only those defects where plastic substrate can play a role are analysed.

In some cases, defects created during the injection are attributed to the chrome plating process or vice versa. For this reason, it is very important to make a good analysis of the cause of the defects. Equipment such as microscopes have been used as efficient analysis methods. In this way it is easy to see the origin of the defect and therefore, limit the possible causes.

The first part of this section is focused on the recommended techniques that can be used to detect the cause of each defect. The second part explains the corrective procedure that should be followed when the root cause has been identified, and the third part summarises the ELIX technical service that is offered to address all these analyses.

5.1. Defects after plating – characterisation and detection:

5.1.1. Gas/moisture blisters, streaks

Cause

Bubbles in the melt, coming from moisture, trapped air or degradation gases

Signs

Tests to detect the root cause

- Humidity content measurement
- Thermal degradation analysis (GC tests, performed at ELIX)
- Acetic acid test

Detection procedure

Humidity content: Is the moisture level in the material higher than recommended, or is moisture observed on the mould surface?
- YES → Check **5.2.1. Corrective procedure – moisture**
- NO ↓

Thermal degradation analysis: Is the monomer content in the moulded part too high?
- YES → Check **5.2.3. Corrective procedure – thermal degradation**
- NO ↓

Does the acetic acid test show stress areas near the weld line? Is the defect localised on the weld line?
- YES → Improve venting near the weld line
- NO ↓

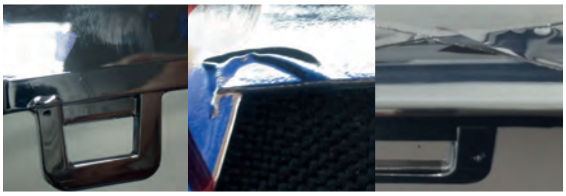
Check the venting system and mould maintenance

5.1.2. Low adhesion/thermal-cycle blisters

Cause

Low adhesion of the plastic-metal, which could lead to blisters after thermal cycles, can be caused by improper etching (under or over etching), or surface orientation due to improper moulding conditions or mould design.

Signs



Tests to detect the root cause

- Humidity content measurement
- FTIR analysis (performed at ELIX)
- Surface tension test
- Thermal degradation analysis (GC tests, performed at ELIX)
- Acetic acid test
- TEM (Transmission electron microscopy) analysis
- SEM (Scanning electron microscopy) analysis

Detection procedure

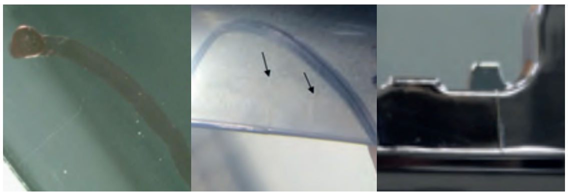
Humidity content: Is the moisture level in the material higher than the recommended values?	YES →	Check **5.2.1. Corrective procedure – moisture**
NO ↓		
FTIR: Is FTIR analysis showing lower PB content than expected for this material?	YES →	Check **PB distribution along the SAN matrix**
NO ↓		
Surface tension: Are values lower than the normal range?	YES →	Check **surface contamination** by surfactants, mould releasing agents, among others
NO ↓		
Thermal degradation analysis: Is the monomer content in the moulded part too high?	YES →	Check **5.2.3. Corrective procedure – thermal degradation**
NO ↓		
Acetic acid test: Is the part showing signs of surface stress?	YES →	Check **5.2.4. Corrective procedure – residual stress**
NO ↓		
TEM in the moulded part: Are PB particles oval instead of spherical due to surface stress?	YES →	Check **5.2.4. Corrective procedure – residual stress**
NO ↓		
TEM in the moulded part: Are PB particles non-homogeneously distributed?	YES →	Poor PB distribution in the ABS or ABS/PC matrix
NO ↓		
SEM in the etched part: Is the surface showing signs of under-etching or over-etching? Peeling test: Is there plastic attached in the metal layer after peeling?	YES →	Optimise the etching temperature and time
NO ↓		
- Check chrome plating process - Check part design		

5.1.3. Cracking after thermal cycles

Cause

Thermal-cycle cracking could be caused by moulded-in stress in the plastic part, complex geometry, or improper metal layer thickness (acid copper). These factors magnify the mismatch between the thermal expansion properties of the plastic and metal, leading to cracks after thermal cycles

Signs



Tests to detect the root cause

- Thermal degradation analysis (performed at ELIX)
- Acetic acid test
- Thermal test – heat the moulded part to 110°C for 2 h
- Cross-section microscopy

Detection procedure

Are the cracks near the ribs, notches or bosses? — **YES** → Check **part design recommendations**

NO ↓

<u>Thermal degradation analysis:</u> Is the monomer content in the moulded part too high? — **YES** → Check **5.2.3. Corrective procedure – thermal degradation**

NO ↓

<u>Acetic acid test:</u> Is the part showing signs of stress? — **YES** → Check **5.2.4. Corrective procedure – residual stress**

NO ↓

<u>Thermal test:</u> Is the part deforming after stress release? — **YES** → Check **5.2.4. Corrective procedure – residual stress**

NO ↓

<u>Cross-section microscopy:</u> Is the copper layer too thin in the defective area? — **YES** → Optimise the chrome plating process to increase the copper thickness to standard values

NO ↓

Use a material with higher flowability and/or higher HDT

5.1.4. Pitting

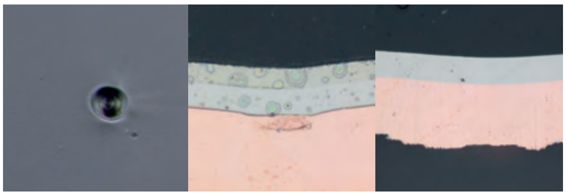
Cause

Pitting can be caused by different reasons: mechanical damage, contamination, plastic voids, discontinuity of a metal layer, etc.

Tests to detect the root cause

- Cross-section microscopy
- FTIR analysis (performed at ELIX)
- Stippen test (performed at ELIX)
- Thermal degradation analysis (performed at ELIX)

Signs



Detection procedure

Is the pitting defect raised (elevation) and easily detectable by touching?

YES → Check the plating process:
- Impurities in the copper or nickel bath
- Embedded nickel in the copper layer
- Uneven copper thickness

NO ↓

Cross-section microscopy: Is the defect located in the metal layers?

YES → Check plating process

NO ↓

FTIR analysis/stippen test: Are the analyses showing material contamination/gels?

YES → Check for possible source of contamination

NO ↓

Thermal degradation analysis: Is the monomer content in the moulded part too high?

YES → Check **5.2.3. Corrective procedure – thermal degradation**

NO ↓

SEM in the etched part: Is the surface showing signs of over-etching?

YES → Reduce etching time

NO ↓

- Avoid mechanical damage before racking
- Check moisture content of the material before injection
- Ensure that packing pressure is enough to compensate for material shrinkage

5.2. Defects after plating – corrective procedures

5.2.1. Corrective procedure – moisture

Is moisture found on the mould surface?

YES →

1. Check drying system
2. Check mould cooling for leaks
3. Use dried air system

NO ↓

1. Check drying system
2. Check drying conditions
3. Check transport and storage conditions
4. Reduce residence time in hopper

5.2.2. Corrective procedure – trapped air

Are there air hooks?

YES →

1. Reduce injection rate
2. Avoid sharped edges or transitions

NO ↓

Are defects present near the gate?

YES →

1. Reduce decompression speed and decompression length

NO ↓

1. Reduce injection rate
2. Reduce screw rpm
3. Increase back pressure
4. Check venting system

5.2.3. Corrective procedure – degradation of the material

Is the melt temperature higher than recommended?

YES:
1. Decrease cylinder temperature
2. Reduce screw speed
3. Reduce back pressure

NO ↓

Is melt residence time excessively high?

YES:
1. Reduce cycle time
2. Increase plasticising time delay

NO ↓

Defect near the gate?

YES:
1. Use injection speed profiles
2. Check hot-runner system

NO ↓

1. Avoid small runners
2. Check venting system

5.2.4. Corrective procedure – residual stress

Are there signs of stress whitening due to strong shear rate?

YES:
1. Increase melt temperature and mould temperature
2. Optimise the speed profile (use higher filling times)
3. Reduce screw speed
4. Check mould design

NO ↓

Is demoulding occurring under excessive residual pressure?

YES:
1. Optimise the switch over point to holding pressure
2. Reduce the holding pressure
3. Increase mould temperature and cooling time if necessary
4. Check that mould temperature is uniform along the whole cavities

NO ↓

1. Check mould design
2. Choose a material with higher flowability

5.3. ELIX technical service

ELIX Polymers has a team of experienced professionals as well as the resources required to support our customers during the injection process of chrome plated parts. ELIX technical service provides assistance during the trials at the customer´s facilities, helping them to identify the root cause when facing problems or optimise the process. Additionally, special testing is carried out by the ELIX laboratory to detect possible problems that may occur during the injection process and which may affect the results after chrome plating, i.e., residual stress on the part or polymer degradation.

Some examples of the tests offered by ELIX Polymers to analyse moulded parts are:

- Surface stress: Acetic acid test to detect surface stress on the moulded part. For this test, parts are immersed in acetic acid. Then the parts are inspected looking for the appearance of whitish areas, indicating the part has been subjected to surface tensions.

- Residual stress: To detect mould-in stress, the moulded part is placed in the oven at high temperature and the part is checked for deformation after it has cooled. The deformation is indicative of the residual stress level.

- Polymer degradation: An analysis of the moulded part using gas chromatography is carried out to detect thermal degradation of the material during the injection process.

- Surface contamination: Surface tension measurements are taken to detect possible contamination of the material.

- Microscopy analyses: An evaluation of the metal layer thickness using optical microscopy, an observation of the etching performance through SEM, or a study of the polybutadiene shape and distribution through TEM analysis can be carried out in collaboration with external laboratories.

The aim of this comprehensive service is to work together with our customers to find the best solution. Please, contact the ELIX technical team to find out more about ELIX's services in support of chrome plating projects.