Apple launched the first iPhone in 2007, and, along with it, a whole new market. Smartphones have seen huge growth since then, but the market is now reaching maturity and shifting into commoditization. Meanwhile, the Original Equipment Manufacturer (OEM) landscape has seen drastic changes. Well-known brands like Nokia, Motorola and RIM have disappeared, while brands like Vivo and OPPO reach the world’s top five smartphone manufacturers due to their strong market position in China. Even though these brands are still unknown in many countries, they are competing with Huawei to secure the third biggest market share after Samsung and Apple. Yet the performance, features and design are all similar between the manufacturers.

As smartphones near commoditization, OEMs are increasing focus to capture the new Wearables and Connected Home markets. Major changes are expected soon in smartphone technology, enabling OEMs to differentiate in a fiercely competitive environment. Throughout 2017 and 2018, the mobile industry will see incremental improvements in performance, as well as new hardware technologies such as flexible displays, and breakthroughs in software such as artificial intelligence to enable your smartphone to become an even closer companion.

The good and the bad of metal casing
For many years, Apple has favoured aluminum body smartphone designs—an concept for high-end devices largely acquired from Sony Corporation (Japan) and its late ’80s Walkman. With the popularity of the iPhone came the trend of metallic cases in aluminum, stainless steel, titanium or magnesium. These materials combine superior mechanical performance with a valued aesthetic and feel. In most mid- to high-end models, metallic cases have replaced plastic housings.

While the intrinsic thermal conductivity of metal helps to spread increasing heat from ever-more powerful processors, their electrical conductivity causes Radio Frequency (RF) attenuation, and therefore weaker transmission and reception of radio signals. One way to overcome the electromagnetic interference (EMI) shielding issues of metallic casing is to ground the case, and make it an extension of the antenna.

Modern smartphones have multiple antennas: Cellular (GSM, EDGE, 3G, 4G, LTE), GPS, WiFi and Bluetooth. Smartphones have two cellular antennas, to ensure good reception regardless of the absorption of the hand holding the device. The primary antenna lies at the top of the phone, and the secondary cellular antenna is located at the bottom. The phone can switch between these two cellular antennas, depending on which is getting better reception.

Smartphone Trends:
The next generation of smartphone casing
To ensure good reception efficiency in combination with the design, the metal casing is typically separated into three parts (Figure 1). The metal-body upper back of the phone is connected to the top antennas, and doubles as an antenna amplifier. The main body is grounded, and the bottom of the back enclosure is connected to the secondary antenna, again doubling as an amplifier for the antenna. In order to function correctly, the top and bottom antennas must be electrically isolated from each other. This is the main role of the insulating plastic antenna separator, which can be distinguished by the colour, which varies from that of the metallic enclosure.

![Antenna Separators](image)

**Figure 1:** The evolution of antenna separators across the different iPhone generations.

The latest generations of iPhones (6/7) have increased the width of these insulating separators. This increases reception efficiency further by using the separators as RF transparent windows where RF signals can be transmitted to and from the antenna(s) inside the enclosure. The increased thickness also helps to reduce capacitive leakage through the separator. The insulation provides both electrical resistance and capacitance, and can conduct current through both paths. These separators therefore need a high electrical resistance, so very little current actually leaks. Capacitive power is frequency dependent. With smartphones’ increase in data rates, the increased separation width directly contributes to less leakage through the insulator.

Despite all of this sophisticated engineering, the metallic casing is not ideal for RF design, particularly if frequencies continue to increase. Since metal casings have become a common design choice, the material no longer serves as a differentiator among OEMs. The industry will see a stronger shift to glass front and back covers in 2017. Huawei launched its beautiful glass-case Honor Magic in December 2016, and showcased it at CES 2017. The silky feel of this phone’s bright white, entirely halogen-free beautiful glass-case is remarkable. Longer serves as a differentiator among OEMs. The industry will see a multi-scale roughness that contains micro and nano features to allow for optimum polymer infiltration and interlock. An overview of the NMT process is shown below, as well as examples of suitably textured substrate surfaces. It is important to achieve strong bonding that avoids trapped air gaps, and that prevents delaminating under stress or poor conditions.

![Substrates](image)

**Figure 2:** ThInnovation in smartphone thickness since the launch of the iPhone 10 years ago.

Going glass: the next generation of smartphone casing

An all-glass smartphone housing may be an Industrial Designer’s ambition – at least aesthetically. Yet it may not have the required mechanical integrity needed to pass product tests, such as drop and tumble, necessary to ensure reliability during the course of its day-to-day use. As a result of this and the ongoing ThInnovation trend, we can expect to see high-end models with all-glass designs continue to use metallic frames, so long as fully flexible displays are not implemented. These metal frames will continue to support the smartphone design, acting as an antenna amplifier that counteracts the RF attenuation linked to parts in the smartphone housings, such as printed circuit boards (PCBs), EMI shields, and metallic coatings.

The selection of metal used for the frame has implications for mechanical integrity, weight, durability, and the achievable finishing processes and effects. Aluminum is an attractive choice due to its low density, recyclability, and low raw material and fabrications costs, however aluminum alloys exhibit corrosion over long-term usage in metal frames. Stainless steel alloys are capable of a wider selection of finishes than aluminum alloys, including finishes from matte to high gloss, from polished to brushed metal, and even fine hairline finishes. Its surface can be treated with Vacuum Metallization (VM), Physical Vapor Deposition (PVD) or Electrodeposition (ED).

PVD can also be considered as an alternative to nickel plating, as some consumers are sensitive to nickel, and the waste treatment has environmental restrictions. Increased weight, due to its higher density, may be a concern, however its higher mechanical properties also allowed for reduced wall thickness, possibly making the increase in device weight negligible. If weight is a concern, titanium can also be considered.

<table>
<thead>
<tr>
<th>Property</th>
<th>Aluminum</th>
<th>Stainless Steel 304</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>2700 kg/m³</td>
<td>8030 kg/m³</td>
<td>4540 kg/m³</td>
</tr>
<tr>
<td>Melt temperature</td>
<td>660 ºC</td>
<td>1399 ºC</td>
<td>1604 ºC</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>72 MPa</td>
<td>290 MPa</td>
<td>400 MPa</td>
</tr>
<tr>
<td>Elongation</td>
<td>60 %</td>
<td>55 %</td>
<td>27 %</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>70 GPa</td>
<td>286 GPa</td>
<td>116 GPa</td>
</tr>
<tr>
<td>Corrosion resistance</td>
<td>Very good</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

The stainless steel alloy SUS 304 is the most widely used.

New demands for metal-to-polymer bonding

Nano Mold Technology (NMT) provides direct metal-to-polymer bonding, and is an important secondary process that happens prior to decoration processes such as anodization or PVD. NMT overmolds a specially textured metal surface with a polymer to generate a strong bond. The bond’s strength may be influenced by the metal surface, the processing conditions, or the properties of the compound.

Different substrates require different treatments to achieve a suitable surface texture, but the key characteristic of the surface texture is a multi-scale roughness that contains micro and nano features to allow for optimum polymer infiltration and interlock. An overview of the NMT process is shown below, as well as examples of suitably textured substrate surfaces. It is important to achieve strong bonding that avoids trapped air gaps, and that prevents delaminating under stress or poor conditions.

The selection of stainless steel over aluminum poses additional challenges in selecting polymers for NMT. Aluminum is commonly anodized to protect the soft aluminum surface from scratches and corrosion and to add...
colour, depending on the design. Since anodization occurs after NMT, polymers that can survive the anodization process must be used, such as polybutylene terephthalate (PBT), PBT/polyethylene terephthalate (PET) blends, or polysulfone (PSU).

While anodization is ideal for aluminum, it is not suitable for other metals used for their higher mechanical strength, such as stainless steel and titanium. These alternative alloys are prime candidates to provide structural integrity to next-generation smartphones, yet they require polymers for NMT that can withstand the higher temperature of processing techniques such as PVD. PVD processing requires three hours at temperatures of 150°C to 180°C, making the polymers commonly used for NMT unsuitable. PPS is not an ideal material for external parts that need to meet high aesthetic requirements, due to its poor UV resistance and colourability.

OEMs must therefore select from higher temperature plastics, such as polyether ether ketone (PEEK), and the new and specialized high glass transition temperature (Tg) and heat deflection temperature (HDT) PPAs, which demonstrate performance competitive with PEEK.

The NMT process can be described using the following steps:

1) After cleaning the substrate, micro and nano-scale porosity are generated on the metal surface. For aluminum, a wet, multi-step chemical etching process is used.
2) Once the metal is suitably etched and cleaned, it is overloaded with a plastic compound. This results in a strong, metal-to-polymer bond due to the polymer filling of the surface texture.
3) After overmolding, the metallic layers of the part may undergo decoration processes such as PVD.

New high-temperature materials for NMT
DSM has developed a new material, based on its high-performance ForTii Ace polymer, that is suitable for NMT. ForTii Ace has the highest Tg of all polyphthalamides (PPAs). Its uniqueness lies in the chemistry of the C4 molecules, which enable superior crystallization behavior to other PPAs. Additionally, its high Tg, driven by aromatic content, brings the temperature and chemical resistance in line to that of PEEK, while outperforming PEEK in stiffness at high processing temperatures. ForTii Ace’s high polymer/molecular strength gives it the highest mechanical strength of all PPAs.

The material is able to achieve exceptionally high NMT bonding forces with titanium and stainless steel alloys. This is due to its high polymer strength and excellent processability. Control over flow and crystallization is essential to good bonding via NMT, to allow sufficient filling of the micro/nano pores. Once the metal surface structure is sufficiently filled, crystallization ensures excellent bond strength, and high stiffness and strength of the compound.

For bonding to titanium and stainless steel alloys, DSM has developed two dedicated NMT grades, ForTii NMX33 and ForTii Ace NMX5. For applications where dimensional stability, resistance to heat and UV for light colors, or dielectrics play an essential role, the ForTii Ace polymer is an ideal material. Both grades are commercially available, enabling designers to realize next-generation all-glass casings or other creative metal-to-plastic bonds that require the highest aesthetics and material performance.

NMT is an elegant technology for bonding metal to plastic, and is used in various applications and industries, including the industrial, aerospace and automotive sectors. Our complete NMT portfolio includes PBT and PPS compounds. This broad portfolio enables manufacturers to obtain material and application support for a variety of designs and industries via one focused point of contact.
ForTii NMX33 and ForTii Ace NMX5 show the highest performance in bonding strength to both stainless steel and titanium. With a melt temperature of 320°C and 340°C, respectively, these compounds show the highest temperature resistance, making them fully compatible with the extreme temperatures reached during PVD processing.

**Realizing the next jump in smartphone innovation**

As the smartphone matures as an application, the push to innovate its design and features increases rapidly. Both small startups and global multinationals are putting huge effort into new design concepts that allow differentiation in a lucrative multibillion dollar market. The clear trend in smartphones for 2017 is moving away from aluminum enclosures to glass or ceramic bodies with metal frames made from materials with higher mechanical strength, such as stainless steel or titanium. These designs will rely on proven plastic-to-metal bonding techniques based on high-performance engineering plastics, such as those in DSM’s portfolio, which can be seen in the next-generation concepts launching in 2017.

While standard NMT technology is widely used with PBT, PBT/PET, and PPS polymers, DSM’s new ForTii Ace compounds raise performance to the levels only seen with PEEK so far. These new materials are comparable with PEEK in terms of chemical, mechanical and thermal resistance, while offering very good dimensional stability and excellent bonding strength to metals with more mechanical strength. ForTii Ace enables designers to move beyond the current materials’ capabilities to realize the next big jump in smartphone innovation.