

USB-C means “one cable for all”

Make magic with plastic

Summary

USB is the industry bus standard used for transferring data and power to and from digital devices. Device charging over USB has become a major consumer feature in recent years. USB is by far the most popular and successful means of connecting peripherals, with some 5 billion ports being produced every year.

The introduction of the USB-C connector is the result of the need to reduce electronic waste. Legislation in Europe, for example, is enforcing the use of a standardized charging interface, so that one charger and its associated cable can be used for multiple devices. As a result, the USB-C connector will be obligatory from 2017.

So the industry is looking how to overcome the design challenges for this new connector and searching for high performance plastics materials solutions for internal components in plugs and receptacles for the new generation of USB connectors, USB-C. USB-C connectors will need to carry more power than previous generations in a much smaller form factor. So the performance properties of the materials used for holding all the conductive elements together are especially critical. Reliability is a key requirement, so the industry is looking for plastics that are tough, reliable, rigid and with high flow.

In this paper we will highlight the design and material challenges for USB-C. We compare several high temperature thermal plastics, looking at the best balance of mechanical and electrical properties and precision molding in production of USB-C connectors. Polyamides 46 and 4T have both already been approved by several global producers of these connectors. They answer the need for improved levels of safety, performance, and reliability. DSM supplies these materials under the brand names Stanyl and ForTii® respectively.

High performance polyamides provide improved reliability and safety in next-generation USB-C connectors

Introduction

“Thinnovation” is the design challenge in mobile. Companies around the world involved in production of USB connectors are looking for high performance plastics materials solutions for internal components in plugs and receptacles for the new generation of USB connectors, USB-C. Plastics processors are gearing up for production, with many now going through approval stages with their customers with prototypes and early samples. Total production levels are probably no more than around one million pieces per month, but when production hits full swing, volumes will be ten times that.

It is estimated that production of USB ports will rise to over five billion units by 2018, an increase of over 19% from 2012. Some electronics OEMs, including Apple, Google, Lenovo and Microsoft, have already launched equipment that incorporates Type-C ports. As far as operating systems are concerned, Windows 10 will support USB 3.1 and USB-C. Apple's OS X has supported USB 3.1 and USB-C since the introduction of the 2015 version of the Macbook laptop computers. Android M will support USB-C.

Why USB-C?

USB (which stands for Universal Serial Bus) is the industry bus standard used for transferring data and power to and from digital devices. Device charging over USB has become a major consumer feature in recent years. But even though it is a standard, there are numerous types of USB plugs and sockets. In a joint attempt to reduce e-waste and in alignment with the legislation, the electronics industry decided to develop a standardized charging interface, so that one charger and its associated cable can be used for multiple devices. As a result, the European legislation will make USB-C obligatory from 2017. Several electronics OEMs have already launched equipment that incorporates Type-C ports.

What is USB-C?

The Universal Serial Bus, or USB, is the industry bus standard used for transferring data and power to and from digital devices. It is one of the most successful interface technologies ever invented. Few interfaces have lasted as long or enjoyed such widespread use. Device charging over USB has become a major consumer feature in recent years, and USB is by far the most popular and successful means of connecting peripherals, with some five billion ports being produced every year. Even so, USB still has its limitations. The plug has to be inserted the right way, the data rate can still be frustratingly slow, and the charging function is often below par when used to power larger batteries. It has also been clear for some time that USB technology had to advance to serve newer computing platforms and devices as they trend toward smaller, thinner and lighter form-factors. Many of these newer platforms and devices have already reached a point where existing USB receptacles and plugs are inhibiting innovation, especially given the relatively large size and internal volume constraints of the Standard-A and Standard-B versions of USB connectors.

About USB-C

The industry standard as of 2017

First USB connector with a reversible design

Backwards compatible with billions of USB devices

Delivers up to 100W (20 volts & 5 amps) at twice the speed of current USB ports

Each successive generation of smart phones is thinner than the previous one. Over the past 10 years, on average the thickness of a smartphone has been reduced by an astonishing 12% per year. This puts almost incredible pressure on component producers to downsize products. USB-C is enabling the next step in so-called “thinnoating” and allows a much faster charging of devices. The Type-C connector overcomes an important draw-back that has traditionally been associated with USB connectors. Until now, numerous different types of plugs and receptacles have been available, so, for example, charging two different mobile phones often requires two different sets of chargers and cables. In addition, “in” and “out” connectors have different shapes. The new USB-C standard is the first USB connector with reversible design allowing it to function perfectly whether you plug it in right-side up or upside down.

The Type-C connector supports the new SuperSpeed USB 3.1 format, which offers data-transfer rates as high as 10 Gbps, or roughly double the speed of current USB 3.0 versions. It's still backward compatible with all the USB 2.0 formats (LS, FS, and HS), so even legacy systems will be able to take advantage of the new connector when it's designed into dongles.

The introduction of the USB-C connector is also an answer to the call to reduce electronic waste. Legislators in Europe, for example, have for several years been pushing for the use of a standardized charging interface, so that one charger and its associated cable can be used for multiple devices; similar moves have been taking place in China and Korea.

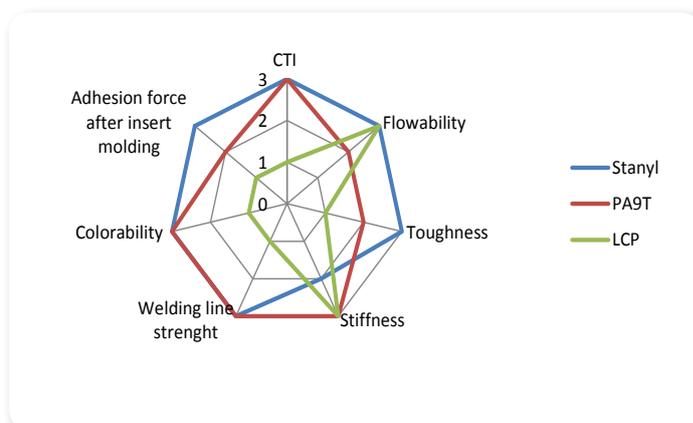
As a result, the USB-C connector will become the standard design from 2017, as decreed by USB Implementers Forum (USB IF), the non-profit corporation founded by the group of companies that developed the original Universal Serial Bus specification.

The USB Power Delivery specification is also being updated to enable USB PD to support the USB-C Cable and Connector specification, supporting charging up to 100 W. USB-C specifications are contained within the overall USB 3.1 standard that also covers data transmission rates.

USB-C will support USB 3.1 with the top speed of 10Gbps and power output of up to 20V (100W) and 5A. This is 10 times more than the previous 10W of USB3.0. This means that manufacturers of electronic devices can ditch chunky power bricks. For cables this means that a lot of currently used AC cables can be replaced by DC cables with thinner diameters. Considering most 15-inch notebook computers require just around 60W of power, this means in the future laptop computers can be charged the way tablets and smartphones are now, via their USB port. There are more reasons why USB-C will be even more popular than the current generation. For example, a new “Alternate Mode” specification allows USB-C connectors and cables to send non-USB data. Alternate Mode is supported by the DisplayPort digital display interface and by MHL (Mobile High-Definition Link, an industry standard for the interface between portable consumer electronics devices and high-definition TVs and audio receivers). On top of all this, Thunderbolt 3 technology recently announced by Intel will also use USB-C connectors.

A new design, a new materials challenge

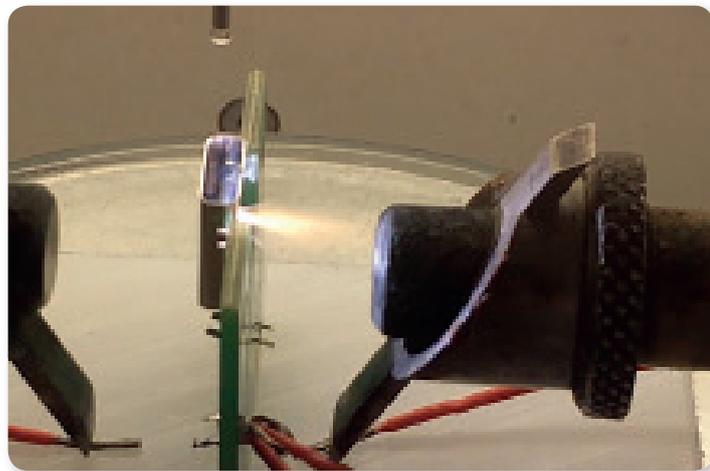
The USB-C connector represents a major challenge in terms of design and production. That is because the USB-C connector is much smaller than its predecessors, and yet it has to handle much more power. As shown in the sidebar (USB Evolution), the various pins on the USB-C connector are spaced with a pitch of just 0.5 mm, compared with 0.65 mm on a USB 3.0 Micro B connector, and 2.0 mm on a USB Type A connector. The thinnest insulating wall has come down from 1.84 mm on the USB Type A to a miniscule 0.12 mm on a USB-C connector. It is difficult to successfully design and consistently mold parts with such thin walls and create a part that has the necessary mechanical and—critically—electrical properties.



Very tough material performance requirements

As already noted, USB-C connectors will need to carry more power than previous generations in a much smaller form factor. So the performance properties of the materials used for holding all the conductive elements together are especially critical. Reliability is a key requirement, so the industry is looking for plastics that are tough, reliable, rigid and with high flow.

Many component producers have begun developments in new USB-C connector designs using liquid crystal polymers, LCPs. Traditionally, LCPs are often favored in thin-wall electronics because of their excellent flow properties, and because prices of some commodity grades are relatively low, sometimes under \$10/kg; LCPs are well-known by USB connector makers, since they have been the favored polymer in previous generations of USB. But in many cases, USB-C connectors are likely to fail stringent tests regarding their electrical properties, especially resistance to surface tracking, expressed as Comparative Tracking Index, CTI, and also mechanical properties.



The importance of CTI

The CTI of the plastic that acts as an insulator as well as a mechanical anchor around the conductors is more than ever a key for product reliability with the USB-C connector. If the insulator does not have sufficiently high CTI, there is a risk that at some point a short circuit will result, damaging the device and possibly even starting a fire. This is not scaremongering: there are various reports of mobile devices catching fire during charging.

There are essentially three routes to reducing the risk of fire hazard caused by tracking:

- Increasing the creeping distance (defined by conductor pitch and insulator wall thickness);
- Lowering the level of environmental pollution (dust, sweat, etc.);
- Using an insulation material with a higher CTI.

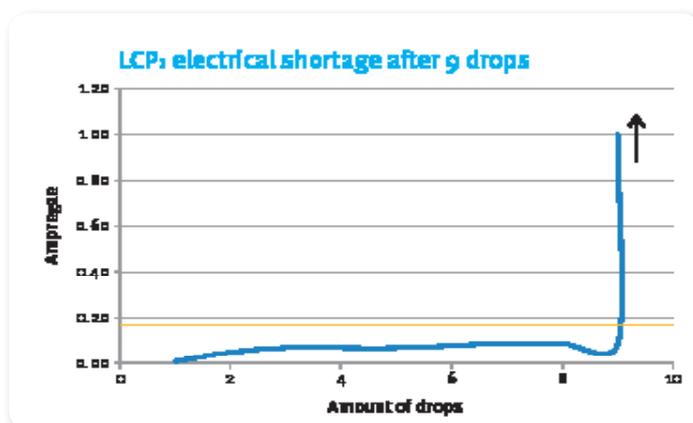
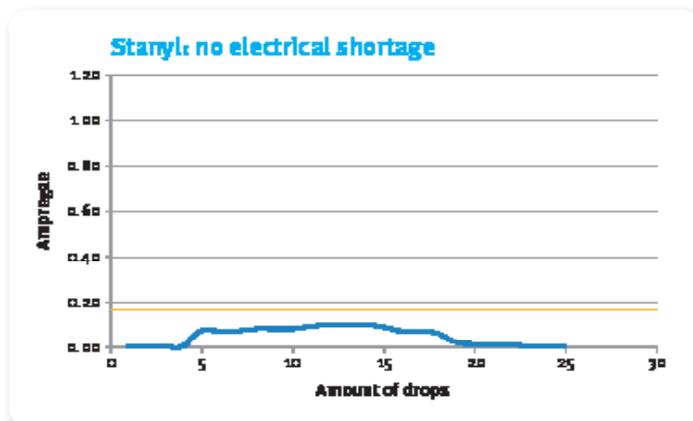
The creeping distance in the connectors is pre-defined and cannot be modified. Reducing the level of environmental pollution at connector level can only be done by additional sealing, adding to the cost of the device. So using a material for the insulator with as high a CTI as possible is the most viable solution to increase end product safety.

Potential real-life failure mode

- Conductive contamination builds up on the surface of the connector; (e.g. dust, cotton particles, sweat, moisture)
- Electric field generates small current on the contaminated surface, which carbonizes the insulator material surface;
- Carbonized surface leads to a higher current, further degrading the surface, which leads to final failure (arcing/very high current resulting in fire hazard).

Solutions more appropriate than those possible with LCPs or halogen containing PA's (PA9T or PA6T) can be found with high performance halogen-free polyamides, such as PA46 and PA4T. High performance polyamides 46 and 4T offer the best balance of mechanical and electrical properties and precision molding.

Polyamides 46 and 4T have both already been approved by several global producers for use in the next generation of USB-C connectors. They answer the need for improved levels of safety and reliability. PA 46 and PA 4T both have high CTIs of PLC class 0, well above recommended 400V. They maintain this high performance for twice as long as alternative materials such as LCPs, most of which have CTIs under 400 V. In tests on connectors produced in LCP, the connector pins fail after nine drops, causing a short circuit; neither PA 46 nor PA 4T fails at all (see graph). It is therefore not surprising that halogen-free polyamides are explicitly recommended by the USB-IF in the USB 3.1 specification.



Mechanical requirements placed on thermoplastics used in USB-C connector plugs and receptacles are considerable. Fine details in the physical structures of USB-C connector plug housings vary among producers, but in all cases, from a mechanical point of view, the biggest challenge is the balance between toughness and stiffness. High performance polyamides from DSM offer an ideal balance in this regard. Furthermore, the flame retardant additive systems that they incorporate to provide a UL 94 V-0 rating contain no halogens.

One of the most critical parts of the connector plug housing is the ribs that separate the metal contacts for power and data transfer. As indicated earlier, these ribs are normally little more than 0.12 mm in thickness, putting extraordinary demands on the processing properties of plastics materials. PA 46 and PA 4T both offer high flow in combination with high weld-line strength. This ensures excellent processability needed to meet demands for very high levels of productivity and also provides connector designers with flexibility in component structure and tooling design. On the other hand, the required high pin pull-out strength (the force needed to pull metal contacts out of the housing) is ensured.

USB-C connectors may be very small, but they are complicated assemblies of plastics and metal. Different producers are considering slightly different routes in the design, but one favored route, at least for the receptacle, is to use a process that involves sequential insert molding. A sort of “preform” is first made, which has a set of contacts embedded in it, and then this is used in a second insert molding process in which additional metal components are incorporated into the assembly.

With two-stage insert molding, it is advisable to use a thermoplastic in the first stage that has a melting point higher than that used in the second stage, to ensure that no remelting occurs that could cause the first set of inserts to shift position. But this second material still needs to have a melting point high enough to resist the temperatures involved in any possible subsequent high temperature soldering process. An ideal solution, therefore, is to use PA 4T for the first insert molding stage; this has a melting point of 325°C. The second insert molding stage can then be done with PA 46, which has a melting point of 295°C.

Conclusion

The most difficult part of a USB-C connector to produce is the plug front housing. Very thin ribs require high flow and high toughness material, and there is a weld line on the front side, which mandates a material with high welding line strength.

Material requirements listed below can all be fulfilled by high performance polyamides PA 46 and PA 4T:

- High flow, capable for 0.12 mm wall thickness design
- High stiffness, toughness and welding line strength
- High wear friction strength and high retention force (10,000 times mating/unmating durability test)
- Good process window
- UL94-Vo & high CTI (400V) to support USB PD 1.0 and 2.0 standard. (up to 5A and 20V)
- Good colorability to support Consumer Electronics market needs
- Lead free reflow soldering
- Compatible with high speed signal transfer up to 10Gbps

Further important advantages for high performance polyamides such as 46 and 4T in this application include their ability to withstand the very high temperatures used in lead-free reflow soldering processes used to assemble components on printed circuit boards, as well as their compatibility with ultrasonic welding (used for joining separate connector components together in some designs). They also have very good wear resistance which is essential for meeting OEM requirements on mating/unmating cycles. Parts successfully pass durability tests that involve mating and unmating plugs and sockets more than 10,000 times.

Bright color is becoming more and more popular in electronics devices enabling fancy designs and product differentiation for OEMs, so connector materials also need to be easy to color to the exact shade required by the customer. DSM polyamides are available in a broad color portfolio, and specifiers can make use of the company’s color matching service to obtain exactly the color they want.

USB Evolution	
USB Type A connector 12mm*4.5mm (plug) 2.0mm pitch	USB Type A thinnest wall Receptacle: 1.84mm Plug: 1.9 mm
USB 3.0 Micro B connector 12.2mm*1.8mm (plug) 0.65mm pitch	USB 3.0 Micro thinnest wall Receptacle: 0.48mm Plug: 0.8mm
USB-C connector 8.25mm*2.4mm (plug) 0.5mm pitch	USB-C thinnest wall Receptacle: 0.12mm Plug: 0.10mm

Design planet friendly devices

The introduction of the USB Type-C connector is the result of the need to reduce electronic waste. We can help you deliver a low or neutral carbon footprint. DSM’s portfolio of plastics includes halogen-free and bio-based materials. Make your next mobile device more planet friendly with components that are smaller, more durable, and environmentally responsible.

Expertise in USB Type-C for your team

We are supporting the design and engineering teams at the world’s leading OEMs - bring our expertise into your team. Contact your local DSM office today with your challenge. www.dsm.com

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