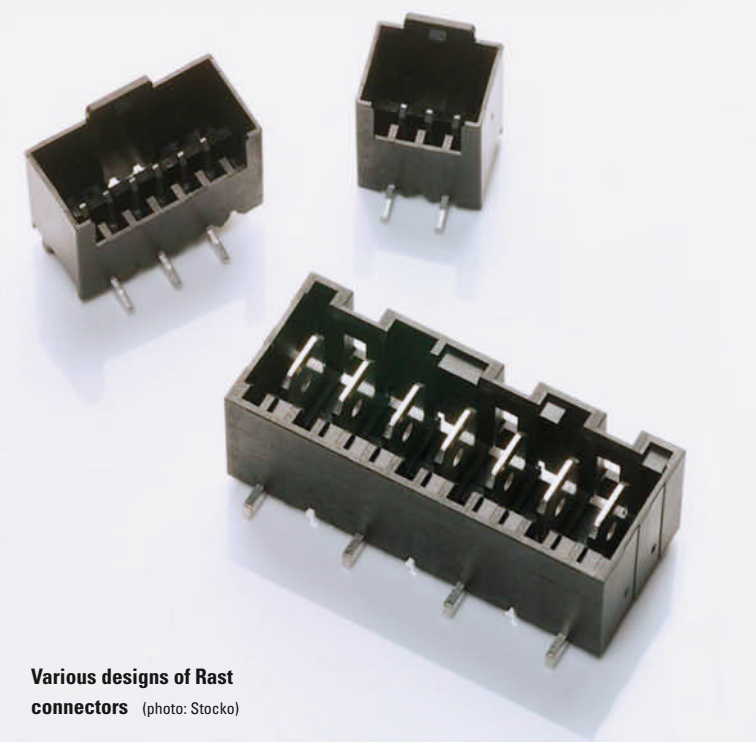
High-Temperature Polyamide.

Standardization and modularization are the keys to coping with the increasing use of electronics in household appliances. One way to effect standardization is to use so-called Rast connectors. The plastic housings of these plug-in connectors have to meet substantially higher specifications on account of different developments and trends, especially in production.



Various designs of Rast connectors (photo: Stocko)

Plug-In Connectors for Household Appliances

MICHAEL DEGENHARDT ET AL.

With an estimated size of USD 160 billion in 2010, the global household appliance industry, also referred to as "white goods", is a large market, which not only affects our functional home but it is also being impacted by the social structure of an average household. Global demand for appliances is set to rise by a low single digit percent annually through to 2015. This will be mainly driven by expansion in market penetration in developing countries, innovative electronics technologies and environmental and energy concerns, mainly throughout Europe. The electronics proliferation will continue, likely reaching down to even very basic offerings. Sensor technology, improving permanently, comprises an important part of this **(Fig. 1)**.

Connectors provide a detachable link of appliance products, internal circuit boards and the many sensors used to convert current appliance products into really intelligent systems which can be accessed or controlled on the go from literally anywhere at any time at our convenience. Connectors typically use metallic contacts, have a plastic insulator and are generally enclosed in a housing. Certain trends in the appliance industry influence the design of such connectors and will drive their size, form and choice of material.

Growing Requirements

A key feature of the growing use of electronics content in appliance products is standardization and modularization. Standardization is most prominently enabled by the Rast connector system – Rast is an acronym for the German words Raster Anschluss Steck Technik (translated as Pitch Connection Plug Technology) – featuring not only multiple technical advantages but also enabling a highly modular system approach. As more and more functionalities are added to appliance products, there is an increase in the number of connectors interlinking these modular functions to the main control unit. The Rast system is able to bundle many such connections of individual harnesses and connectors, reducing assembly time as well as the risk of human assembly errors. Moreover, a lower number of components also reduces the PCB footprint and manufacturing costs.

Renewed awareness on the part of society and industry with regard to environmental issues has led to a situation in which halogen-free plastics and lead-free soldering are rapidly becoming the norm. To satisfy these trends, architects and designers on the manufacturer side are increasingly deploying the corresponding new technologies. These affect plug connectors made from polymer materials, too.

Product and Technology Trends

Intelligent, remote accessed appliance products do not only deliver the standard small improvements in innovation such as a reduction of water and detergent consumption, they also facilitate a quantum leap in power and consumables reduction. In the future, it will be possible to →

Translated from Kunststoffe 4/2012, pp. 87–91
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE111001

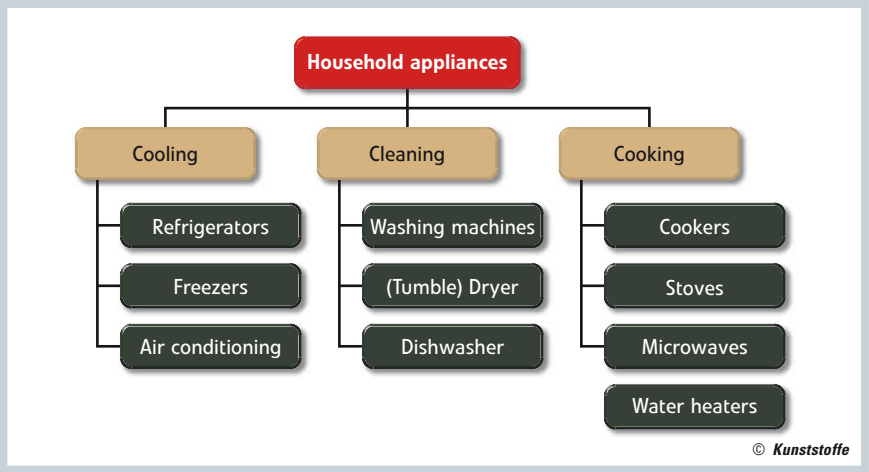


Fig. 1. Household appliances with a growing demand for electronic sensors (figure: DSM)

monitor home power consumption, quite conveniently via a smartphone, without having to be physically present on site **(Fig. 2)**.

In the near future, however, we can expect a strong growth of such intelligent products. Smart grid is the facilitating innovate power network which will soon enter various industry segments. Such networks will also carry information on time-dependent cost of electricity. Intelligent appliance products which are able to hook up to such a smart grid can deliver breakthrough cost-cutting while reducing impact on the environment. Leading companies in the field of appliance and electricity have formed alliances to implement new product lines of such intelligent systems. Appliance products hook up to a backbone which can be the standard power line or an IP based system.

Remote maintenance is another key driver for the industry to look into IP based solution. Such a system is already a standard in other industry segments such as the Semiconductor equipment industry. Equipment regularly performs self diagnosis and, in the event of slight irregularities, sends status reports to the manufacturer. Long before the user actually recognizes the need for service or repair, he can pro-actively be contacted by the equipment manufacturer to schedule maintenance.

Rast Connectors and their Development

Rast connectors are used for a variety of appliance components, such as pressure sensors, relays, pumps and rotary switches **(Table 1)**. In addition, Rast products are specified for connections to printed circuit boards in motor controls and switches. Because the connectors have a standard configuration, trader and component suppliers can use standardized designs and have less need for custom-manufactured components **(Title photo)**.

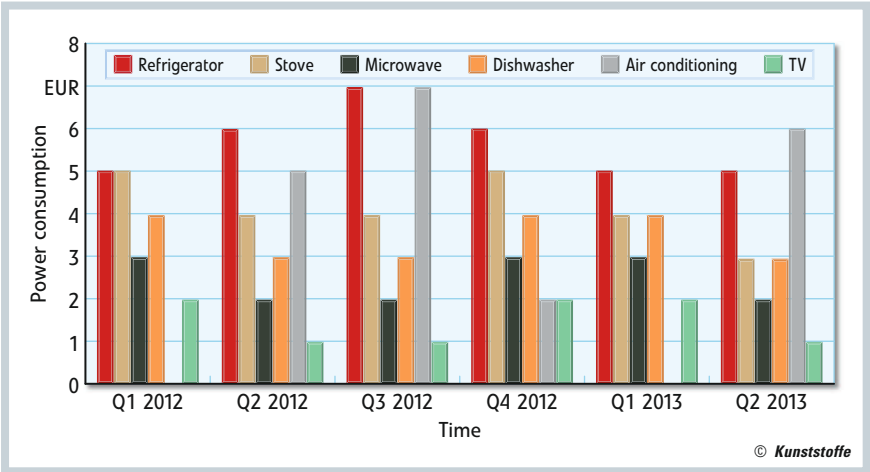


Fig. 2. Energy assistant tracking consumption of different appliance and comsumer products, enabled by an IP or power line backbone (figure: DSM)

The term Rast is usually followed by a numerical value which represents the contact centerline spacing, in millimeters, for the interconnection. For example, a Rast 5 interconnect consists of a connector housing with contacts spaced on 5 mm centerlines. These products are available in standard wire tab/receptacle and card edge mounted versions. Products are available with 6 to 16 A current ratings as common choices. Rast 2.5 products are much smaller and so take up less space than Rast 5 products; they are therefore designed for smaller current strengths **(Fig. 3)**. The Rast standard specifies a series of connecting properties, including the geometric dimensions of the housing (upper part [connector] and lower part [soldering pot]) and the definition of the upper part and lower part designation depending on the encoding/positioning.

Increasingly, Rast connectors are being used in the Appliance industry as they meet manufacturer requirements. They are safe, easy to assemble, and fool-proof (i.e. impossible to connect in the wrong position). Color coding for identification is not required, feature size is smaller, and the manufacturing process is faster since all connections at each particular device are done in one operation. The production process can be fully automated, which in turn requires drastically reduced manpower and less complexity in material administration.

Considering the entire supply chain, the total cost of a harness made from other connections without Rast is higher. In ad-

	Number of Rast connectors per appliance (parts)	Estimated segment plastic consumption for connectors (tons)
Dishwashers	40	480
Dryers	30	160
Refrigerators	15	390
Freezers	15	100
Washers	28	730
Total	On average 25.6	1,860

Table 1. Average number and Europe-wide market size for connectors and plastic housings in appliance applications (figure: DSM)

Advantages SMT	Disadvantages SMT
Smaller parts	More heat generated
Higher desity layout	Small clearance makes cleaning difficult
Cheaper PCBs (no holes to drill)	Visual inspection difficult
Improved shock and vibration characteristics	Good joint formation important for mechanical reliability of assembly
Improved frequency response	Assembly more difficult than in wave soldering
Easier soldering (difficult to heat holes in multilayer boards)	Lower mechanical strength versus wave soldering
Easier to shield from EMI/RFI	Greater number of different materials to match CTE's
Easier to automate manufacturing	
Only one soldering process	

Table 2. Advantages and disadvantages of Surface Mount Technology (figure: DSM)

dition, the manufacturer will gain significantly improved quality, because thanks to RAST there are no more loose connections.

In Europe, the Rast system evolved over many years, from a "crimp-snap" style contact in the 1970s to the present Insulation Displacement Connection (IDC) system. Originally, the standard crimp-snap contacts had an open wire barrel configuration crimped to the wire conductor; this assembly, in turn, would be snapped into a housing with Rast mating features. Europeans then developed an IDC version to gain additional applied cost savings using automation. The IDC version has the contacts preloaded in the housing, and the housing and wire are terminated automatically by high-speed harness-making equipment.

Standardization and globalization are important driving forces in the appliance industry, also driving connector development. Standardized Rast IDC connectors have been used in Europe for over 20 years and are gradually making their way into the American market.

Rast IDC is intrinsically a superior termination when compared to conventional crimping for smaller wire sizes. The connectors are ideally suited for high volume automation thus saving costs.

The transition to Rast is slowed down in Asia and America by the existing equipment base that still covers many crimp termination machines and by the high initial investments on the Rast IDC systems. While lagging behind Europe, the American Appliance industry has now started to catch up.

Sustainable, Eco-friendly Soldering

Reflow soldering is also becoming gradually more important in the appliance industry with its advantages motivating more and more manufactures to make the transition from the current dominant wave soldering. For certain designs, Pin In Paste technology may be applied, which makes it possible to use reflow soldering on what are basically Pin Through Hole (PTH) connector designs **(Table 2, Fig. 4)**.

Eco-design in electronics is not limited to avoiding banned materials as defined in governmental regulations. The total life cycle of the product should be assessed with a focus on hazardous materials (REACH, ROHS), carbon emissions, energy and water use, recycling, use of rare earth metals and minerals and more. For collaboration along the supply chain, it is necessary to understand the measures needed and to match them to each other. The manufacturers' responsibility for a product will evolve into cradle-to-grave. Design for recyclability means design-for-disassembly. This will require active control of the design and manufacturing process along the value chain.

New safety standards, too, have an influence on the design and production of electronic devices and parts. The new IEC 60335-1 European safety standard had a big impact on the plastics industry. The big challenge is the Glow Wire Temperature (GWT) on end products, the connectors, at 750 °C **(Fig. 5)**.

Material for the Connector Housing

Due to the abovementioned trends in the appliance connectors industry (lead-free soldering, the move in soldering technique from PTH to SMT technology, sustainability, new safety standards), greater demands are placed on the plastic connector material.

The change from wave to reflow types of soldering means that the connector material has to resist significantly increased temperatures. Consequently, the heat distortion temperature (HDT) of the material used needs to be well above 250 °C. As a result, commonly used materials such as PA6 or PBT no longer meet the requirements and high temperature resistant materials need to be used. →

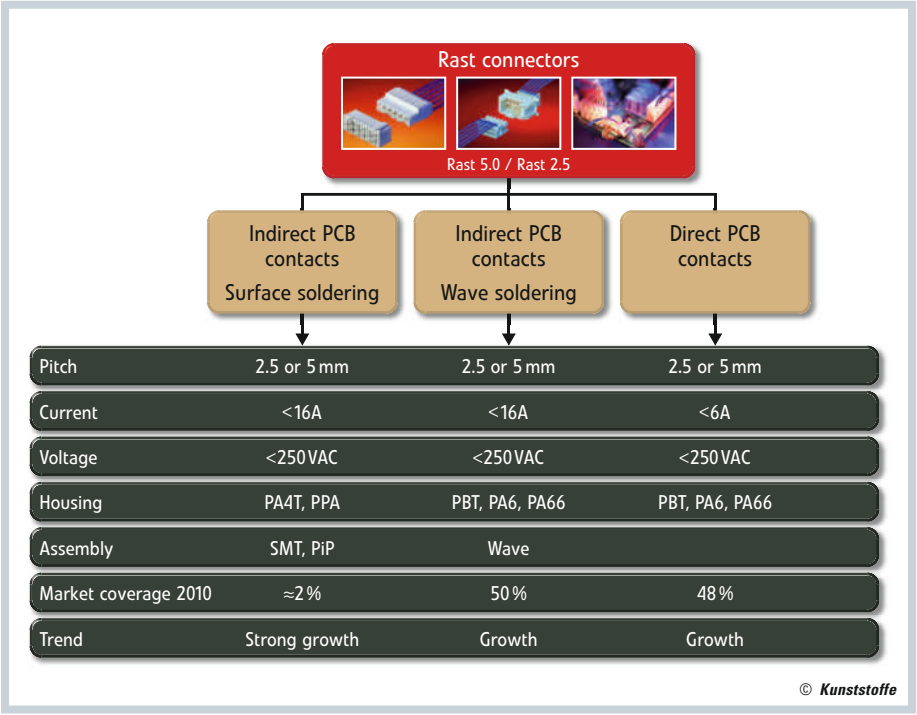


Fig. 3. Overview of materials used in Rast connectors (photo: Stocko)

Furthermore, with increased focus on sustainability, these high temperature resistant materials need to become free from halogen containing flame retardants. Replacement of halogen containing flame retardants in polymers is currently ongoing but especially for the high temperature resistant materials, finding halogen free solutions is not always easy due to the high processing temperatures and thus the required high thermal stability of the used halogen free flame retardant. Most of solutions the currently available possess major drawbacks such as low mechanical performance, low flowability and too high levels of outgassing and corrosion. On the other hand, intrinsically flame retardant, hence intrinsically halogen free, materials such as liquid crystalline polymers (LCP) suffer from low weldline strength and low CTI (Comparative Temperature Index).

Property	PPA (30 %GF V-0)	ForTii (30 %GF V-0)
	DAM	DAM
HDT A [1.8 MPa]	281 °C	305 °C
Melting point [°C]	310 °C	325 °C
E-modulus [MPa]	10,000	12,000
Elongation [%]	2	2
Strength [MPa]	150	155
Charpy [kJ/m²]	8	10.0
Flamibility [UL94]	V-0 @ 0.4 mm	V-0 @ 0.2 mm
VDE GWT approved (775 °C)	No	Yes (0.4 mm)
Jedec rating	MSL 2A-3	MSL 2
IPC/JEDEC J-STD-020	Floorlife 4 weeks	Floorlife 1 year

Table 3. Comparison of material properties (figure: DSM)

Finally, the new European safety standard as decribed in IEC 60335-1 requires a glow wire performance of the end product of at least 750 °C. While this was more or less straightforward for halogen containing systems, halogen free systems have proven to be much less effective in glow wire performance and hence, many materials find it difficult to achieve this GWT 750 °C requirement. For high temperature resistant materials this barrier is even higher, due to the limited choice in halogen free solutions.

One of the few connector material solutions able to meet these new demands is in the newly developed high temperature polyamide from DSM, Stanyl ForTii, a polyamide 4T **(Table 3)**. This material perfectly fits the market trends as described above, thanks to its unique combination of high melting point, high HDT value and excellent fit for the few available halogen free flame retardant systems without sacrificing tremendously on flow and mechanical properties. Stanyl ForTii (product designation F11), a halogen-free, heat-resistant plastic containing up to 30 % glassfiber reinforcement, is now being used in various Rast solutions by Stocko-Contact GmbH & Co. KG, Wuppertal, Germany. F11 is currently one of the few halogen-free, heat-resistant plastics to have gained VDE certification. ■

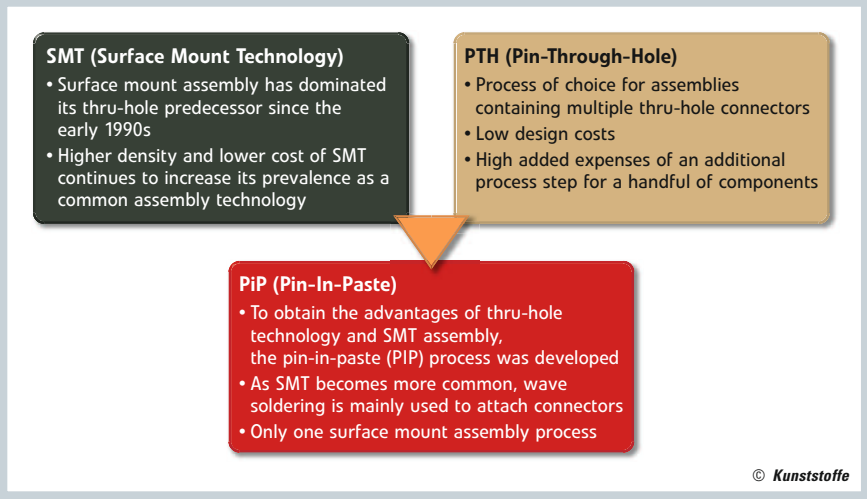


Fig. 4. Pin In Paste technology allows the use of reflow soldering while staying with PTH design (figure: DSM)

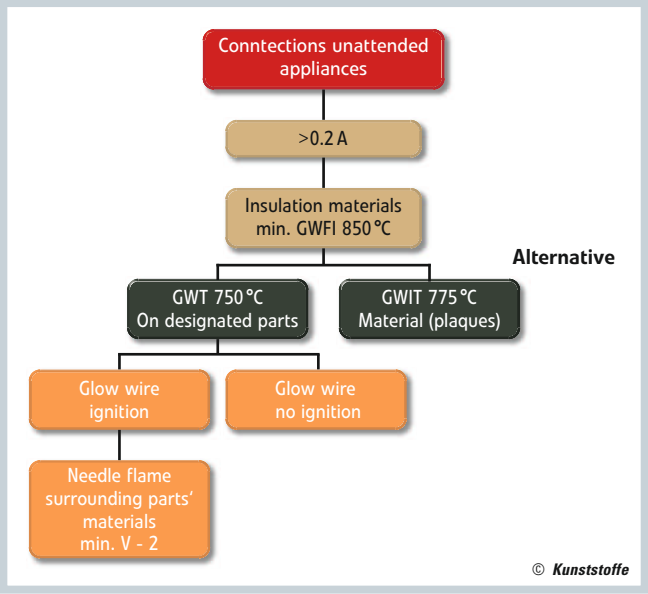


Fig. 5. IEC 60335-1 guidelines for unattended appliances (figure: DSM)

THE AUTHORS

MICHAEL DEGENHARDT, born in 1961, is a Development Engineer at Stocko-Contact GmbH & Co. KG, Wuppertal, Germany.

PATRICK DUIS, born in 1972, is a Project Engineer for Connectors at DSM Engineering Plastics, Sittard, the Netherlands.

DR. TAMIM SIDIKI, born in 1970, is Global Marketing Manager Stanyl ForTii at DSM Engineering Plastics.

DR. IR. WILFRED VAN PELT, born in 1973, is Global Technical Product Manager Stanyl and Stanyl ForTii at DSM Engineering Plastics.

