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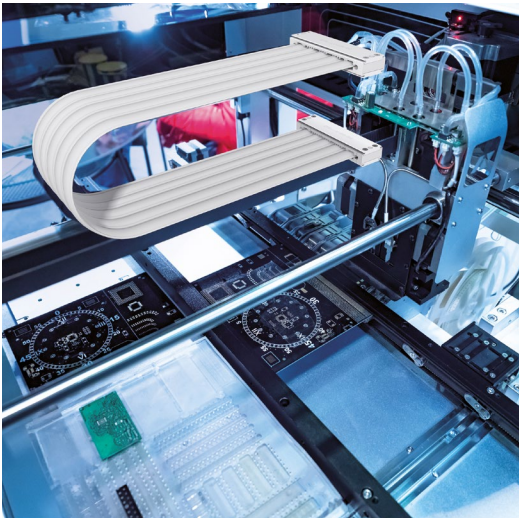
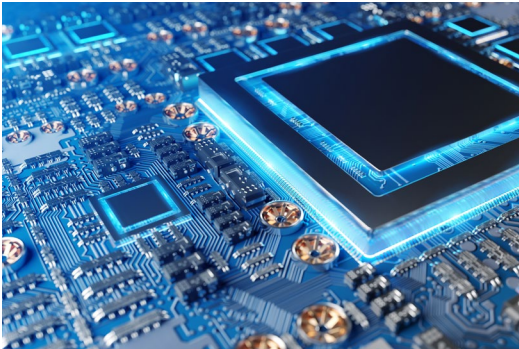
Increase equipment effectiveness and generate higher production yields

On a chip the size of a fingernail, there is room for several billion transistors; the connecting structures are as thin as one thousandth of the diameter of a human hair. These dimensions mean that: every foreign particle, no matter how small, is a problem in production. Therefore, semiconductor production takes place in cleanrooms, where extreme requirements are placed on the energy supply systems. To meet these requirements, the design engineers at igus® have ventured beyond well-trodden paths: for example, instead of conventional cables, stranded elements are combined with a protective profile that you can configure yourself. This durable and easy-to-install system is perfect for the highest cleanroom class.

The semiconductor as a core product of digitalisation

International semiconductor manufacturing is a large and growing market because the demand for high-quality electronic products is increasing around the world and digitalisation is constantly progressing. Home electronics of any kind such as smart phones, household appliances and even simple LED lights need semiconductors as their "brains", as do of course computers and cars, albeit in vast quantities.

According to Gartner, the IT market research institute, the industry will be worth around \$624 billion in 2024. This corresponds to an increase of 17% compared to the previous year. This increasing trend will continue: in 2025, it is expected to amount to \$721 billion. Accordingly, a lot of money is invested: the construction of 84 new microprocessor factories began between 2021 and 2023, with an investment volume of around \$500 billion.



A look at cleanroom manufacturing
Source: iStock; igus® GmbH



With the help of a laminar flow box, it is possible to create cleanroom conditions exactly where they are needed.
Source: igus® GmbH

A large part of this goes into new production facilities. One reason for this is that a race is on again in the planning and construction of new production facilities and plants, driven by the "Chip Acts" support programs in the US, the EU and Japan.

When planning new or modernising and expanding existing facilities, producers are not just concerned with increasing production speed. Production reliability is also high on their agenda. And this requires cleanliness - as one of the most important factors. The reason is that the greatest part of manufacturing takes place in cleanrooms where the purity requirements are very strict.

Why such high demands for cleanliness?

It is now possible to produce transistors with a feature size of 3-5nm (nanometres). For comparison a human hair is between 40 and 60µm thick. That is 40,000 to 60,000nm. The size comparison shows that the size of a particle with a diameter of only 1µm (= 1,000nm) is considerable at this level and can render the very expensive intermediate product (wafer, chip) useless.

For this reason, the machines used to manufacture semiconductors - for example lithography equipment for imprinting conductor paths - are already manufactured under cleanroom conditions.

The very strict cleanliness requirements do not only apply to the semiconductors themselves but also to other frequently used products from the area of electronics, such as displays, touch screens, monitors, LEDs, OLEDs and so on. Apart from this, there are other areas of production where cleanroom conditions are partially prescribed, including medical technology manufacture and the production of pharmaceuticals.

Specific: requirements for cleanrooms

The cleanliness requirements in semiconductor production are specified in ISO standard 14644-1, which defines different cleanroom classes. In addition, the manufacturers that produce components under cleanroom conditions often have very extensive "cleanliness specifications" of their own, which every supplier has to comply with.

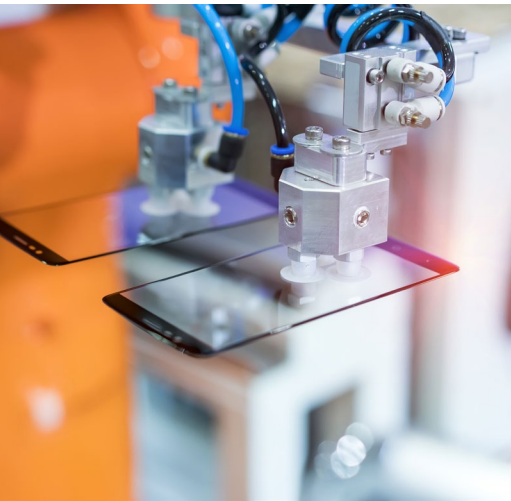
In the case of some manufacturers of semiconductors and related products such as display, strict requirements apply regarding abrasion, i.e. the particles given off by energy chains. They carry out measurements in the direct surroundings of the energy chain and require that each cubic metre air contains no more than a single-digit number of particles with a size of less than 0.1µm. This can only be achieved with difficulty in the long run given the challenging measuring point selected.

A simple comparison makes it clear why such a level of cleanliness is a challenge: one cubic metre of city air contains between 15 and 100 million particles, and in supposedly clean mountain air, you can find around 10 million particles per cubic metre. Cleanroom employees are not allowed to smoke even before they start work as this would contaminate production. The reason is that the area around a smoker contains approximately 100 million particles, all of which are bigger than 0.5µm. These examples show why every single machine component in the cleanroom has to be tested and its features specified with regard to abrasion, degassing etc.

ISO 14644-1	FED STD 209E	GMP (non-operational)	Max. particles (0.5 micron) m³	Max. particles (0.5 micron) m³	igus® products that comply with the standard
1	N/A		N/A		Energy chains, cables, corrugated tubes, pneumatic hoses
2	N/A		N/A		see above
3	1		35		see above + linear guides
4	10		352		see above
5	100	A & B	3,520	100	see above
6	1,000		35,200	997	see above
7	10,000	C	352,000	9,967	see above
8	100,000	D	3,520,000	99,675	see above
9	N/A		35,200,000	996,747	see above

Products by cleanroom class
Source: igus® GmbH

Example: OLED production: Every particle counts



Manufacture of displays in a cleanroom
Source: iStock

Why does cleanliness play such a big role in production facilities in this branch of industry? Here is a real example of this as well. A OLED displays manufacturer commissions a new manufacturing machine, in which a lot of money has been invested. Initially, the machine works with an "OK ratio" of only 5%. This means: The reject rate is 95% and the machine will therefore be unable to produce economically.

The persons responsible then intensively consider the issue of cleanliness. Only by diligently improving cleanliness in the production environment (with minimal investment and without any significant change in the machine's technical make-up) are they able to increase the OK ratio by a factor of 16 to 80%. The result is that the machine is started up and operates for years with a high degree of efficiency.

This shows that every particle - or rather, every particle that is absent - counts and affects the productivity and economic efficiency of production in a cleanroom. This is all the more important given that investment in semiconductor production can amount to billions of euros or dollars.

Critical: Cables and energy supply systems

The electrical cables of automated cleanroom machinery need to be regarded critically in many respects. This is because the typical materials for cable jackets are often undesirable for cleanrooms in view of the requirements for such an environment. Over time, they can de-gas, give off particles to the surroundings or contain components such as silicon which are forbidden in cleanrooms.

In addition the cables frequently supply moving (linear) axes with electrical energy and signals. Every movement is a risk as far as cleanliness is concerned because abrasion can occur - especially in semiconductor processing, where the energy supply systems often move at one-second intervals.

Current state of the art: PTFE flat ribbon cable

For these reasons, types of cable approved or certified for cleanroom applications are employed in this sensitive area of use. Where cables have to move, PTFE flat ribbon cables have been proving their worth for over 25 years. They consist of a multi-layer jacket that holds individual stranded cores together. The jacket consists of a PTFE film which is just a few μm thick as an inner layer, a somewhat thicker PUR middle layer which is a few μm thick, and a further PTFE outer layer which is just a few μm thick. This creates an enclosed system that is self-supporting and does not release any particles into the ambient air.

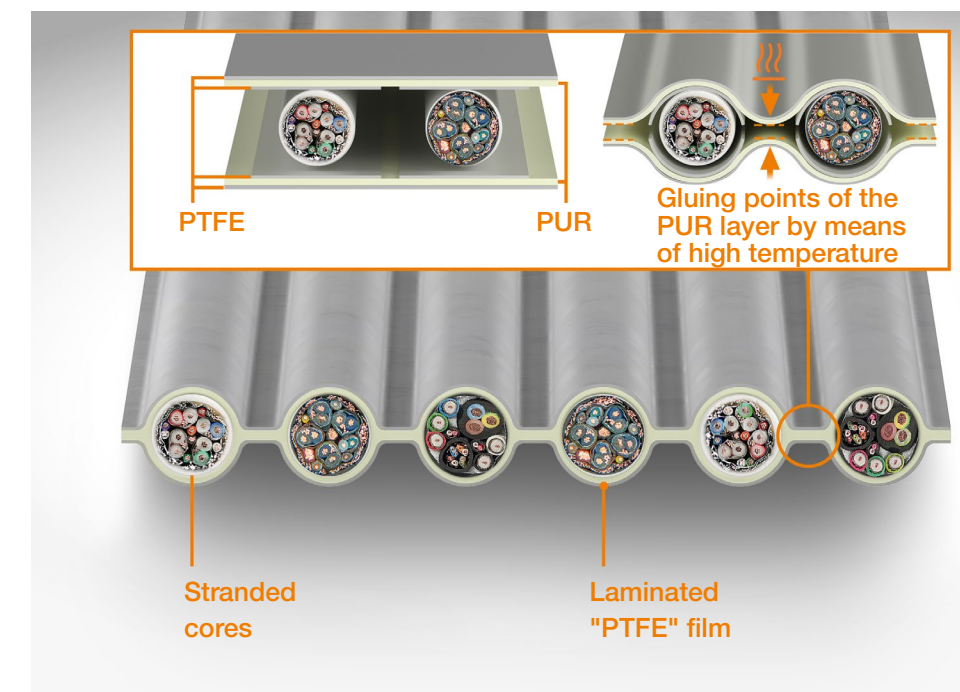
Such a cable system, however, also has disadvantages - especially its need for extensive maintenance work. The stranded cores are fused together in a continuous flat strip and cannot be separated. This means that users have to replace the entire system if a single core breaks, which results in downtime. Moreover, the user cannot add extra cores if machines or flat ribbon cables have already been installed. The system is therefore not flexible either. In addition, it often happens that individual cables or pods rub up against each other to relative movement, which results in unwanted abrasion.

Cables that can be pushed through and have a sleeve-like structure were or are being used as an alternative as well. However, their use is only unproblematic if the cables are without connectors or if the connectors are only fitted at a later time, a procedure that is not practical. This solution is also not fully ideal in practice.

igus® took these disadvantages as a reason to develop a user-friendly alternative that meets cleanroom requirements; it consists of two components: the CFCLEAN cores, which are suitable for cleanrooms, and the e-skin® flat single pod, a plug-in system that is also suitable for cleanrooms.



PTFE flat ribbon cables commonly used in this market
Source: igus® GmbH



Schematic diagram of how a PTFE flat ribbon cable is produced
Source: igus® GmbH

CFCLEAN: A cable system without outer jacket, suitable for cleanrooms

CFCLEAN is an addition to the igus® chainflex® cable range. Strictly speaking, however, they are not actually cables as the latter, by definition, consist of core elements with individual insulation for electrical protection and an outer jacket for mechanical protection. In the case of CFCLEAN, however, the igus® developers dispensed with the outer jacket. The cores for the transmission of energy and motor control, bus and Ethernet signals are welded with a PTFE film. The electrical protection is therefore guaranteed, but not the mechanical protection.

By definition, the CFCLEAN elements are therefore "only" cores but they do have diverse advantages; thanks to the absence of an outer jacket, their diameter is reduced by 18% and their weight by 21%. What's more, the restoring forces are very small due to the particularly soft strand structure. This is important because the semiconductor industry often uses linear drives whereby the restoring force of flat ribbon cables lifts the linear carriages upwards and can overload the system. CFCLEAN takes the strain off the linear system and, thanks to the weight saving, also reduces the amount of drive energy needed. Last but not least, friction is reduced in this way.



CFCLEAN

Source: igus® GmbH

For mechanical protection: the e-skin® flat single pod

What the CFCLEAN system lacks, however, is mechanical protection. This is provided by means of newly developed profiles called "e-skin® flat single pods", which are made of high-performance plastic.

In contrast to the established flat ribbon cable system, these profiles are not fused with the cores. A zip fastener makes it possible to open them so that the user can insert the CFCLEAN cores in a few easy steps or, in the case of the closed version, which is also available, the user can push them through the chamber openings.



This "division of labour" means that the profiles protect the cable elements against mechanical influences and prevent particles from contaminating the ambient air. A further advantage is that the e-skin® flat single pods have a modular design. If users want to start using new cables, they can easily connect single profiles to each other.

For the closed version of the e-skin® flat single pod, support chains made of highly wear-resistant plastic are available and ensure reliable operation and adherence to the defined bend radius of 40mm to 135mm. As additional options, strain relief elements can be integrated into the energy supply system for cleanrooms.

Apart from the previously described advantages, the "single pods" from igus® are also characterised by quieter operation compared to PTFE flat ribbon systems commonly available on the market. They are also around 20% more cost-effective - in accordance with the igus® motto "tech up - cost down". This series contains three sizes: SKF10, 12 and 15, all of which are available in an ESD-compatible version.

Modular principle for ISO Class 1 applications - flat cable guidance system with stranded structure
Source: igus® GmbH

Application example: 31 million cycles and more per year

An application example illustrates the performance and service life of e-skin® flat single pods. A German manufacturer of precision equipment for semiconductor manufacturing ("volume pattern generators"/VPG for the production of photo masks as templates for microchips) also develops and manufactures the XY tables with air bearings for the precise positioning of UV laser sources in-house. They were looking for a solution for the energy supply system. It was important to take into account that even the smallest dust particles impair the quality of the exposure - and that even the slightest turbulence in the energy supply would reduce the precision of the exposure process.



The e-skin® flat is used in "volume pattern generator" (VPG) systems from Heidelberg Instruments.
Source: igus® GmbH

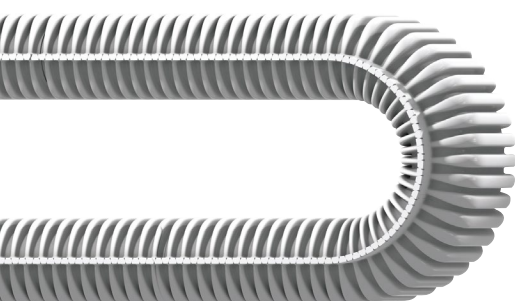


The e-skin® flat has very small bend radii and high resistance to wear and abrasion.
Source: igus® GmbH

During this development project, igus® introduced the e-skin® flat single pod - exactly at the right time. The designers of the plant manufacturer set up a long-term test and were completely satisfied with the results. igus® made some final adjustments to the fastening elements, and the new energy supply system for the new VPG plants was finished.

This solution has now proven itself in highly dynamic applications with cycle times of around one second, amounting to more than 31 million cycles a year. High-quality igus® chainflex® cables with low-abrasion TPE jackets are used. And that's not even the highest number. In internal tests, the e-skin® flat single pod has already completed more than 60 million cycles, and the cables still achieve ISO Class 1 according to DIN EN ISO 14644-1. In addition, 40 cable sets (e-skin® flat single pod with chainflex® cables) with more than 100 million cycles are currently being tested in the igus® cable test laboratory (see page 10).

Corrugated tube supersedes corrugated hose



The modular, openable corrugated tube consists of two half-shells.
Source: igus® GmbH

The e-skin® portfolio, which is suitable for cleanrooms, also includes a corrugated tube variant that isn't burdened with the disadvantages of classical corrugated hoses, which display very little inherent rigidity and stability if lateral force is applied. In addition, cable replacement involves a lot of maintenance effort as the hoses cannot be opened.

The corrugated tube variant from igus®, on the other hand, consists of an upper and a lower shell with an inner height between 20 and 40 mm, and is self-supporting thanks to its oval geometry so that the hose is self-supporting over short distances. It is also very easy to open and fill thanks to its zip fastener mechanism. The interior separation consists of individual separators and shelves that can be attached to the grooves in various ways.

100 million cable test cycles in the laboratory

Before the market launch, igus® tested the CFCLEAN stranding system and the modular e-skin protection systems intensively. In the company's in-house 3,800m² test laboratory, engineers generate around one million electrical measurement data records per year - at times, over 800 tests are performed simultaneously. In addition to linear test axes with various travels and accelerations, the laboratory can also make use of special tests. In a climate chamber, for example, temperature variations between -40°C and +60°C are possible.

CFCLEAN and e-skin® flat have already been thoroughly tested in the igus® energy-chain and cable laboratory for more than one and a half years, with currently over 100 million cycles completed and no end in sight. The CFCLEAN stranding elements, combined with the e-skin® flat single pods, are now part of igus® product range.

In the igus® test centre, there is also a cleanroom laboratory, which igus® built in collaboration with the Fraunhofer IPA institute. With the help of the laboratory, igus® tests whether moving plastic components comply with the highest cleanroom standards. In this laboratory, there are two laminar flow boxes, which are equipped with high-performance filters and enable tests in uncontaminated air. For larger test set-ups, the boxes can be connected to each other. Long-term tests can be carried out under realistic conditions here and products can be improved in a very short time, whereby customer-specific test set-ups can also be directly implemented.

Suitable for cleanroom Class 1

One of the results of these and also external tests is that the modular plug-in system has been certified as suitable for cleanrooms in accordance with Class 1 requirements as specified in ISO 14644-1 - this is the highest air purity class. The requirements in this context are: a maximum of ten particles with a size of 0.1 µm are permitted in one cubic metre of ambient air. The user therefore has the certainty in black and white: the moving cable system developed for cleanrooms does not give off any particles to the ambient air.

Alternatives: cleanroom-compatible energy chains with a smooth operation

However, manufacturers of machines and systems for semiconductor production can find alternatives in the broad igus® energy supply product range.

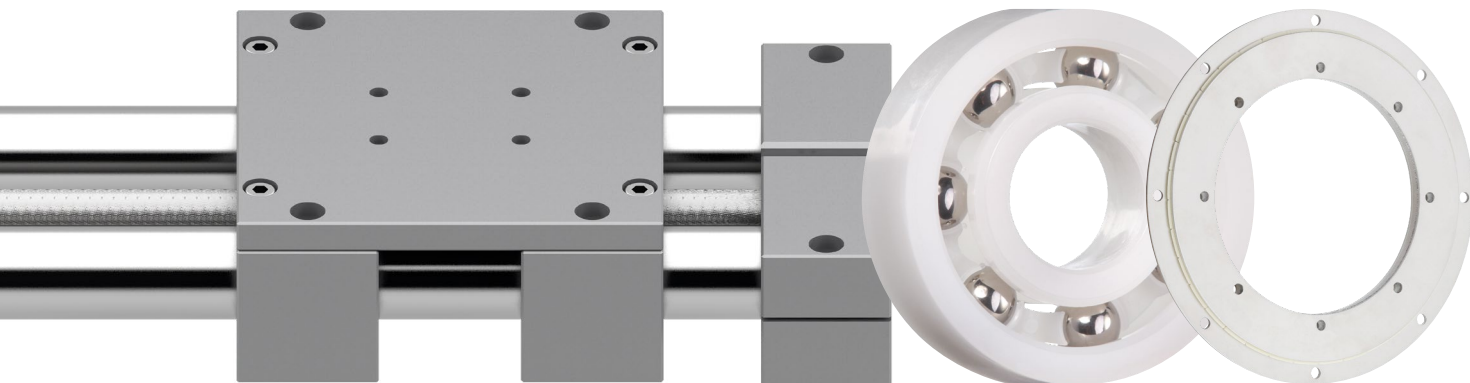
The C6 series energy chain was also developed as a "cleanroom chain" (ISO cleanroom Class 1). It sets standards in terms of abrasion resistance: even in the laboratory, the abrasion is barely measurable, not even under high loads. Further advantages are extremely quiet operation and easy installation. A robust stop-dog system ensures high stability and side parts made of ESD material prevent static build-up.



The igus® cleanroom laboratory was built by Fraunhofer IPA institute for the rapid development of particle-free motion plastics® suitable for cleanrooms up to air purity Class 1 according to ISO 14644-1.
Source: igus® GmbH



Cleanroom-compatible e-chain® C6
Source: igus® GmbH



A complete range of products - including bearing technology

The igus® product range for semiconductor manufacturing and other application areas involving cleanroom technology includes not only the energy supply systems described here, but also drive technology components and systems. Among other things, the focus is on drylin® linear bearings, which offer great advantages here: they operate without lubrication, run smoothly and have very good abrasion resistance.

The design of the PRT slewing ring bearings of the PRT series are also suitable for cleanrooms. They are frequently used in feeders and conveyor belts in semiconductor, display and electronic component manufacturing. Other product lines that can demonstrate their advantages here are the linear guides of the drylin® series and the corrosion- and chemical-resistant xiros® ball bearings. They are characterised by smooth operation, a long service life and minimum abrasion thanks to a combination of high-performance plastics (with incorporated lubricant) and ceramic balls.

Production and packaging for cleanroom applications

To ensure that the desired specifications described here for the cleanroom-compatible energy supply system can be realised, production takes place under strict cleanliness conditions. In Korea - a centre of semiconductor production - igus® put a cleanroom into operation for the automated production and packaging of the e-skin® corrugated tubes in compliance with cleanroom requirements in October 2020.

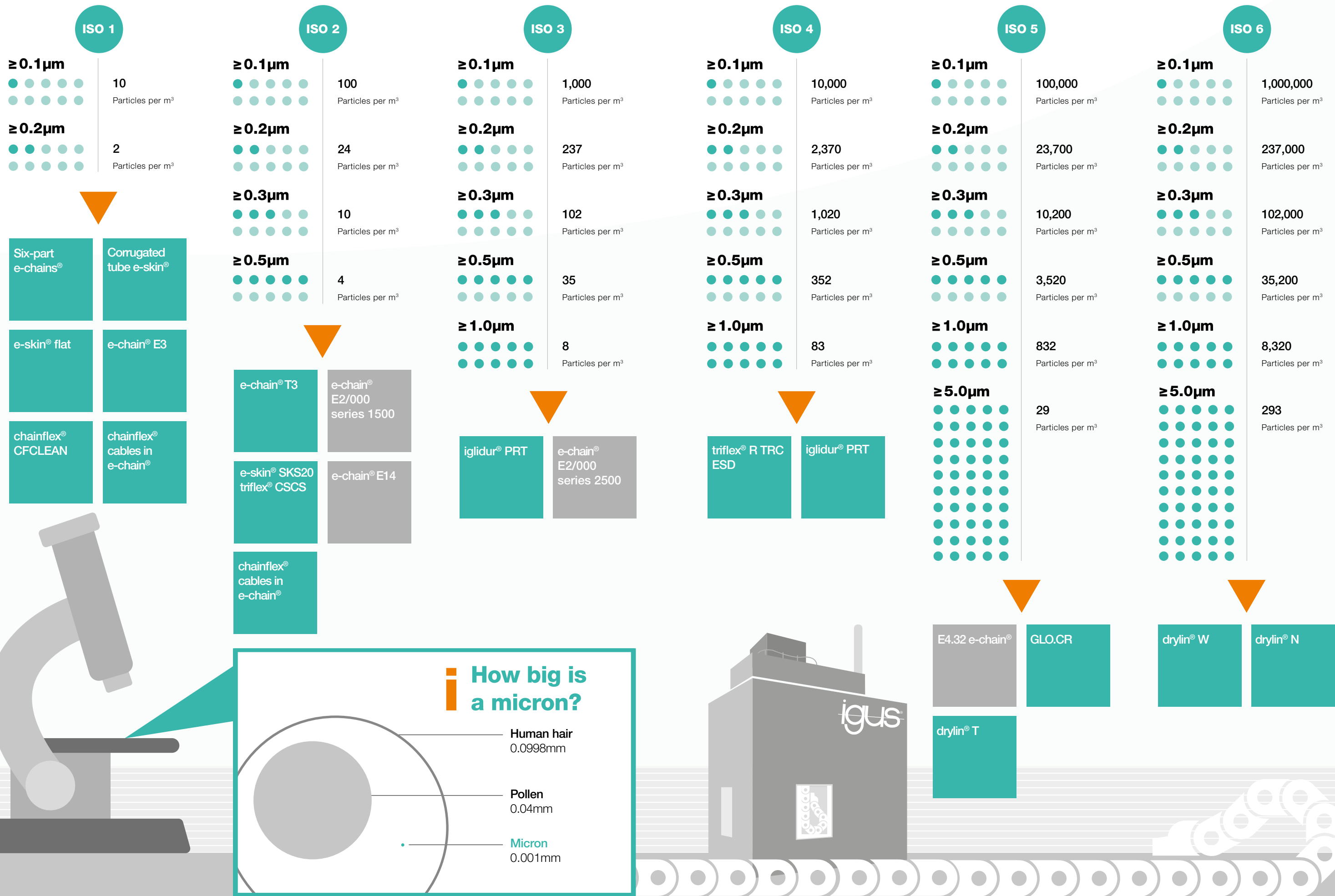
In a subsequent step, a similar production cleanroom will also be created in Cologne (Germany). The plans - being drawn up jointly with the IPA Fraunhofer Institute - are already very advanced. The products that will be manufactured there include not only the e-skin® corrugated tubes but also the e-skin® flat single pods described above.

Target markets: microelectronics, e-mobility, medical and pharmaceutical technology

The target markets for this broad range of products that are suitable for cleanrooms include not only the semiconductor and electronic component sectors - including display manufacturers - but also the medical technology industry (e.g. the manufacture of implants) and the facilities engaged in the production and filling of pharmaceuticals and medicines. Here, another feature of energy supply systems that are suitable for cleanrooms is very advantageous: ease of cleaning thanks to the smooth surfaces.

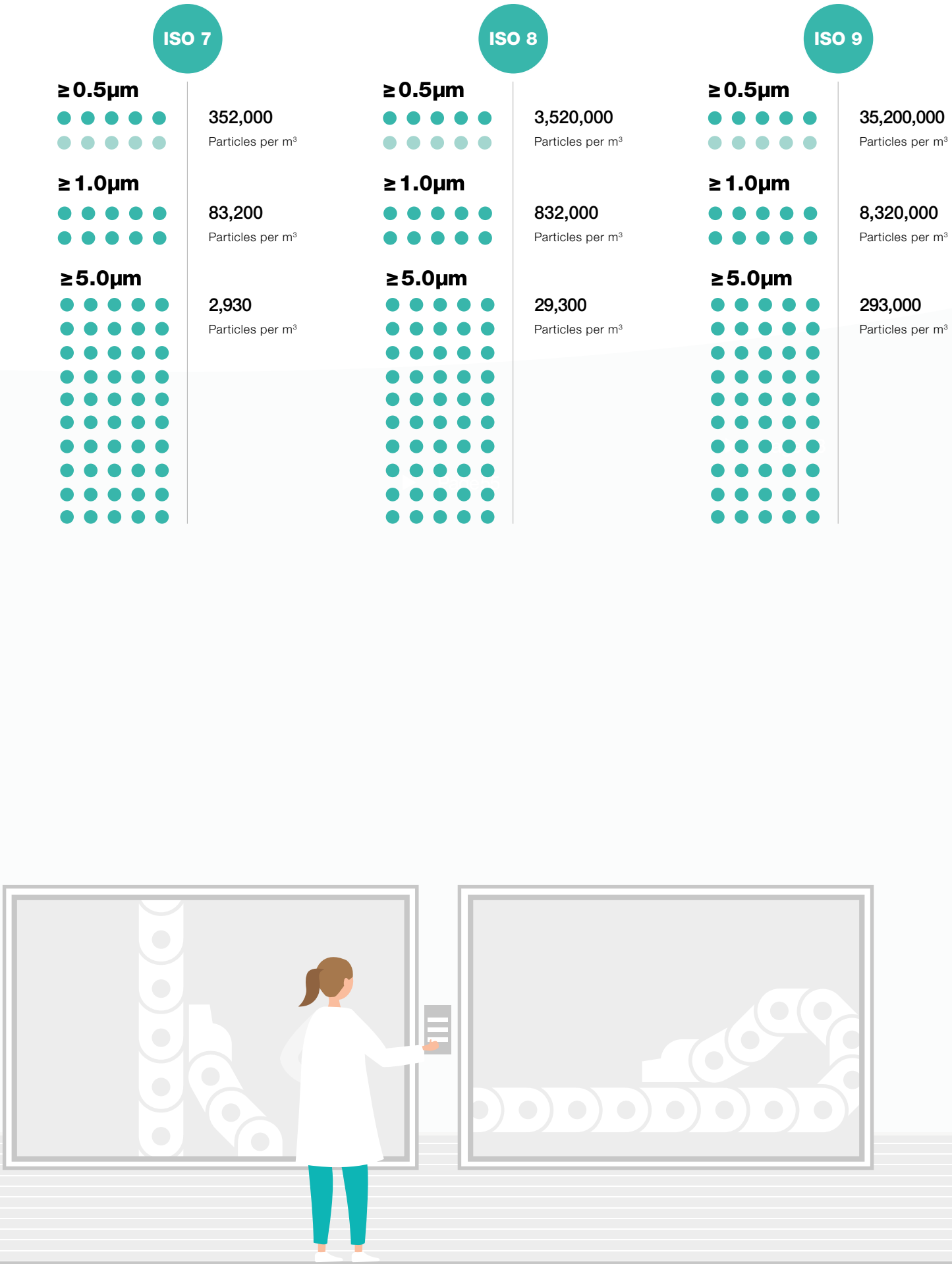
An overview of all igus® products that are suitable for cleanrooms

Cleanroom classes according to DIN EN ISO 14644-1



An overview of all igus® products that are suitable for cleanrooms

Cleanroom classes according to DIN EN ISO 14644-1



Corresponds to approx.		Limits (particle per m³) for particles equalling or greater than ...					
Class	FED STD 209E	≥ 0.1µm	≥ 0.2µm	≥ 0.3µm	≥ 0.5µm	≥ 1µm	≥ 5µm
ISO 1		10	2				
ISO 2		100	24	10	4		
ISO 3	1	1,000	237	102	35	8	
ISO 4	10	10,000	2,370	1,020	352	83	
ISO 5	100	100,000	23,700	10,200	3,520	832	29
ISO 6	1,000	1,000,000	237,000	102,000	35,200	8,320	293
ISO 7	10,000				352,000	83,200	2,930
ISO 8	100,000				3,520,000	832,000	29,300
ISO 9						8,320,000	293,000

Product*	Page	Cleanroom class								
		ISO 1	ISO 2	ISO 3	ISO 4	ISO 5	ISO 6	ISO 7	ISO 8	ISO 9
Six-part e-chains®	12	●								
chainflex® CFCLEAN	28	●								
chainflex® cables in e-chain®	54	●	●							
drylin® N low-profile guides	66						●			
drylin® T rail guides	66					●				
drylin® W profile guides	66						●			
e-chain® E14	64		●							
e-chain® E4.1	64					●				
C6 e-chain system®	22	●								
E3 e-chain system®	50	●								
E6.1 e-chain system®	24	●								
e-chain system® T3	52		●							
e-skin® flat	30	●								
e-skin® flat ESD	38	●								
e-skin® SK SKS SKY	42	●								
e-skin® SKS20 / triflex® CSCS	46		●							
GLO.CR	20					●				
iglidur® PRT-04-100-CR	66			●	●					
e-chain® series 1500	64		●							
e-chain® series 2500	64			●						
triflex® R TRC ESD	48				●					

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