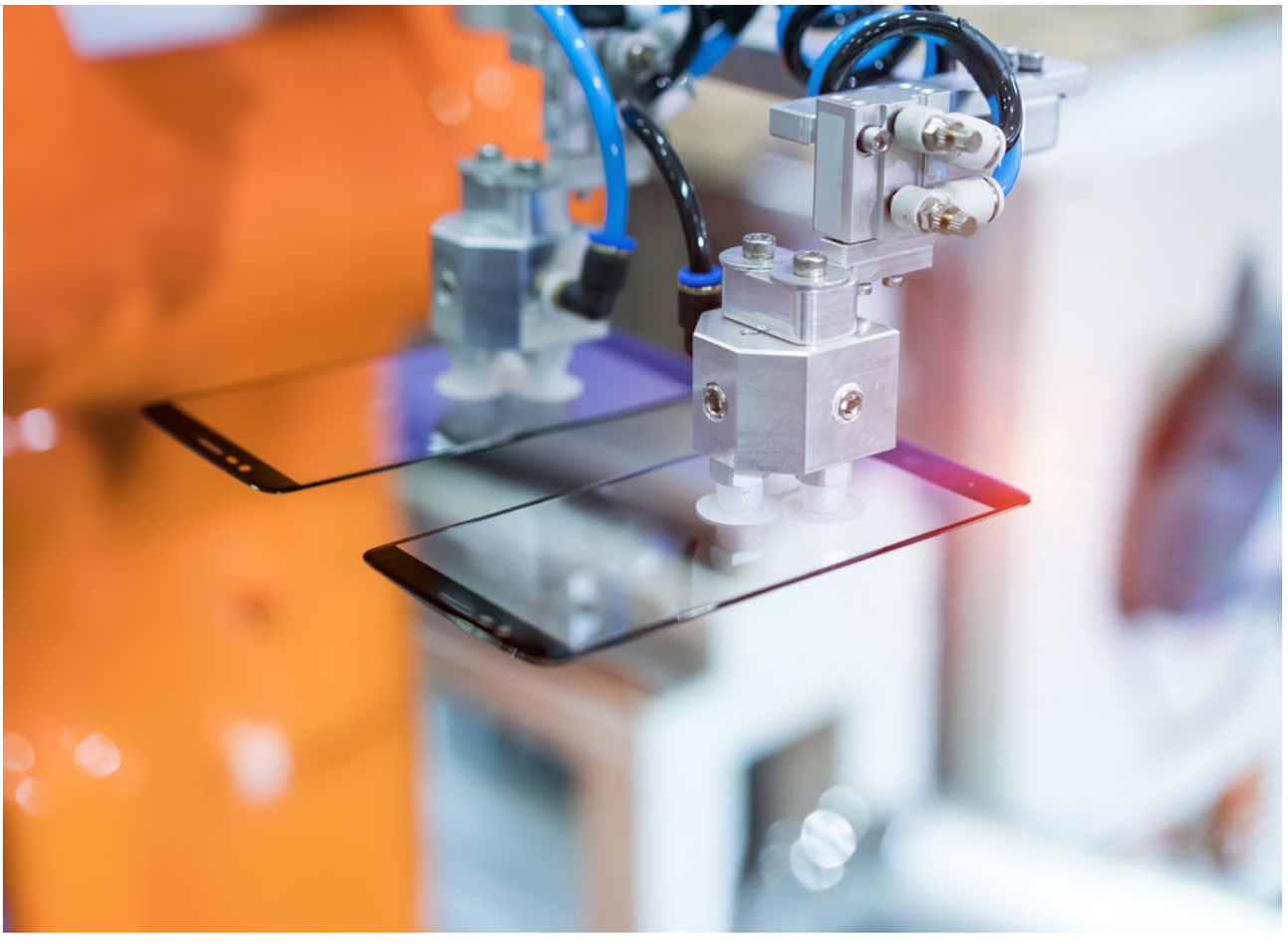

WHITE PAPER:

Energy supply systems for cleanrooms - Revolutionise overall technical effectiveness of production equipment and generate higher yields

December 2020

igus®

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Contents

Cover picture: Manufacture of displays in a cleanroom
Source: iStock

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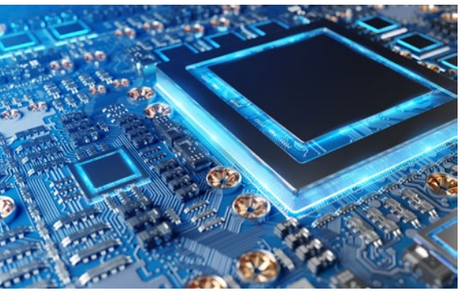
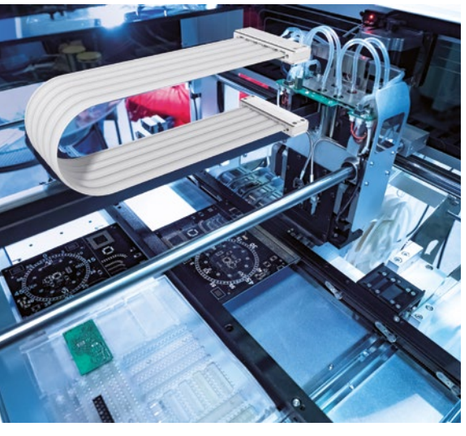
Introduction

On a chip the size of a fingernail, there is room for several billion transistors and the connecting structures are as thin as one thousandth of the diameter of a human hair. These proportions make it clear: Every foreign particle, no matter how small, is a problem in production. This is why semiconductor production takes place in cleanrooms. Here, extreme requirements are placed on the energy supply systems. These requirements can be met with products developed by igus®. The design engineers working in this area have explored completely new avenues. Instead of conventional cables, cores combined with a flexibly configurable protection profile are used. The advantages of this system are evident, even in the highest cleanroom class.





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

The semiconductor as a core product of digitisation

International semiconductor manufacturing is a large and growing market with more and more high-quality electronic components being produced, whereby digitisation is progressing inexorably, and not only in industry. Semiconductors are the "brains" in smartphones, computers, cars and machines.

According to the Statista data platform, the industry had a turnover of around 412 billion US dollars in 2019 - and this is increasing. In 2020 alone, investments amount to around 73 billion US dollars.

A large part of this sum is being invested in new production equipment. The producers are concerned with more than just increasing the operating speed of machines and equipment. Production reliability is also high on their agenda. And this requires cleanliness - as one of the most important factors. This is because most manufacturing takes place in cleanrooms where the cleanliness requirements are very strict.

Why cleanroom?

Why this is so can be easily explained. In the production of wafers (the "basic material" of semiconductor chips), feature sizes of less than 10nm are now normal. As a comparison a human hair is between 40 and 60µm thick. This is 40,000 to 60,000nm. The size comparison shows that the size of a particle with a diameter of only 1µm is considerable at this level and can render the very cost-intensive intermediate product (wafer, chip) useless.

For this reason, the machines used to manufacture semiconductors - for example lithography equipment for printing conductor paths - are also 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.

The requirements

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 contains no more than a single-digit number of particles with a size of less than 3µm. This can only be achieved with difficulty in the long run given the challenging measuring point selected.

By way of comparison, one cubic metre of city air contains between 15 and 100 million particles and, in supposedly clean mountain air, a cubic metre still contains around 10 million particles. Cleanroom employees are not allowed to smoke even before they start work as this would contaminate production. This is because 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) m^3	Max. particles (0.5 micron) f^3	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

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

Links: Products by cleanroom class
Source: igus® GmbH

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Example: OLED production: Every particle counts

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 manufacturer of flat panel displays 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

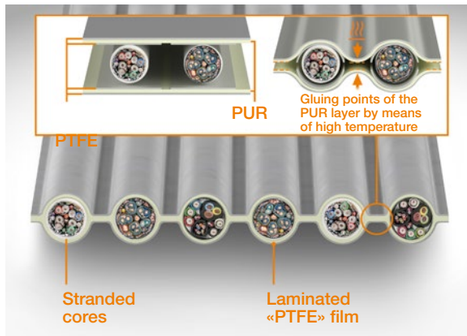
For these reasons, types of cable approved or certified for cleanroom applications are employed in this sensitive area of use. Where cables have to move, PTFE flat ribbon cables have been proving their worth for over 25 years. They consist of a multi-layer jacket that holds individual stranded cores 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 give off any particles into the ambient air.

Such a cable system, however, also has disadvantages - especially the extensive maintenance work needed. Since the stranded cores are fused together in a continuous flat strip and cannot be separated, users must replace the entire system if a single core breaks, as a result of which downtimes occur. Moreover, the user cannot add extra cores if machines or flat ribbon cables have already been installed. The system is therefore not flexible either.

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® 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

Stranding 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 supply of energy and the transmission of motor control, bus and Ethernet signals are fused together with a PTFE film. Electrical protection is therefore guaranteed, but not mechanical protection.

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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: Modular profile system

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 cores against mechanical influences and prevent particles from contaminating the ambient air. A further advantage is that the e-skin® single pods have a modular design. If users want to start using new cables, they can easily connect single profiles to each other.

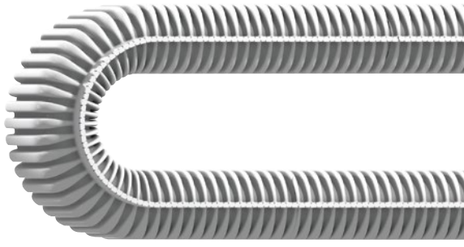
For the closed version of the e-skin® flat single pod, support chains made of highly wear-resistant plastic are available and ensure reliable operation and adherence to the defined bend radius of 40 to 100mm. As additional options, strain relief elements can be integrated into the energy supply system for cleanrooms.

Apart from the previously described advantages, the movable, cleanroom-compliant cables developed by igus® are also characterised by their lower noise during use compared to the PTFE flat ribbon systems commonly available on the market. And they are around 20% more cost-effective - in accordance with the igus® motto "Tech up - Cost down".

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

Corrugated tube supersedes corrugated hose

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. They cannot therefore be used without support. 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 40mm, 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.



Modular corrugated tube consisting of two half shells and openable.
Source: igus® GmbH

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40 million test cycles before market launch

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-axis tests with various travels and rates of acceleration, the laboratory also performs special tests. In a climate chamber, for example, temperature variations between -40 °C and +60 °C are possible.

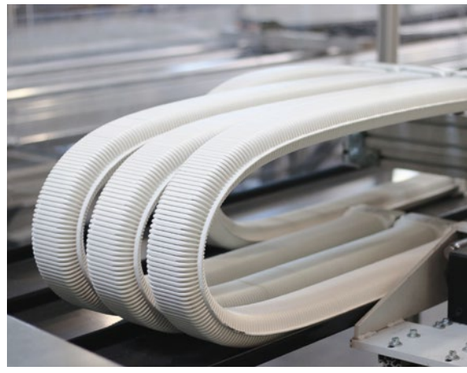
CFCLEAN and e-skin® flat have already been thoroughly tested in the igus® energy-chain and cable laboratory for more than one and a half years, with currently over 40 million cycles completed and no end in sight. The CFCLEAN cores, combined with the e-skin® single pods, are now ready to be launched on the market.

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.

The new igus® cleanroom laboratory was built the 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

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 0.1µm 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.



Modular, openable corrugated tube for cleanroom applications
Source: igus® GmbH

Production and packaging under cleanroom conditions

In order to ensure this, 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. The plans - being drawn up jointly with the Fraunhofer IPA 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® single pods described above.

Target markets: semiconductor manufacturing, medical technology and pharmaceutical production

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.

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