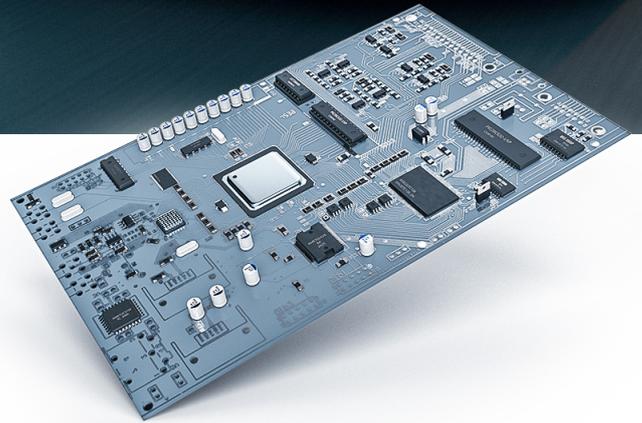


Technical Paper

Identify the root cause of particle contamination
for automotive electronic components



ZEISS Technical Cleanliness Solutions



Seeing beyond

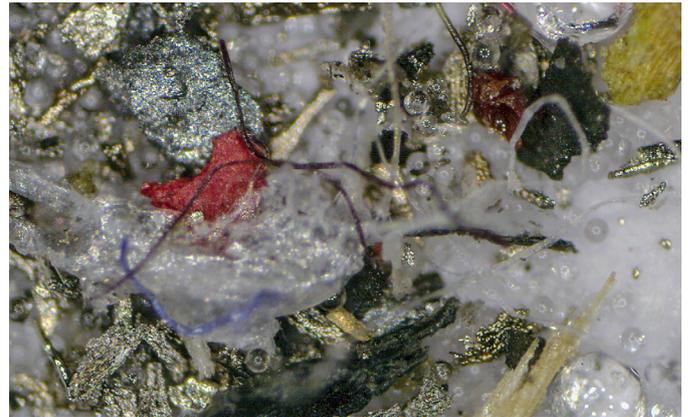
Mastering failures caused by particle contamination

Particle contamination is the enemy of product efficiency, functionality, and longevity.

Production processes, the production environment, and the final packaging all have an influence on component cleanliness. As a result, compliance agreements with limiting values often need to be implemented between the customer and supplier or between product development and production. This means that the cleanliness requirements are not fixed and can be specifically chosen by the customer in accordance with the product geometry function, manufacturability, and verifiability of the component.

Technical cleanliness is attracting increased attention in industry because it promotes the efficiency and effectiveness of individual industrial products. Not only does it begin with the suppliers at the very start of the production chain, it is applicable to all industries – covering everything from implants in the field of medical technology, engine components and assemblies in automotive to fuels and lubricants aerospace. Particulate contamination may

impair performance in the automotive industry by migrating from previously non-critical areas to sensitive locations such as semiconductors, with metallic and non-metallic particles that gather on these parts causing the car to malfunction or even stopping the engine. This paper specifically addresses particle contamination on an electrical component within an automotive application.



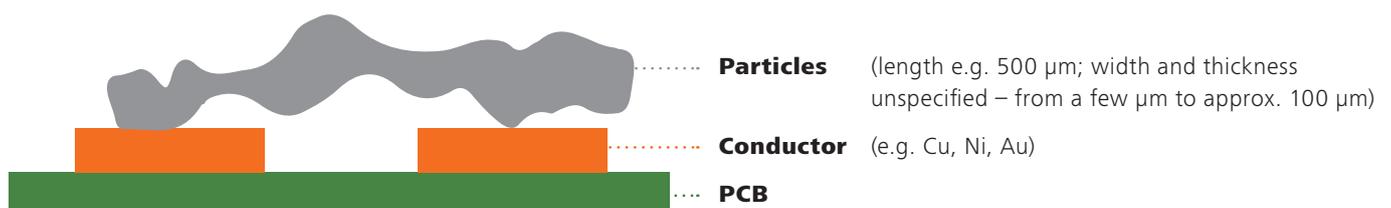
Short circuits caused by conductive particle contamination:

One of the potential causes of a short circuit is a contaminated component. The following scenario sees a short circuit occur when the electronic circuit is interrupted by various materials.

In this experiment, ZVEI (German Electrical and Electronic Manufacturers Association) investigated whether particles on

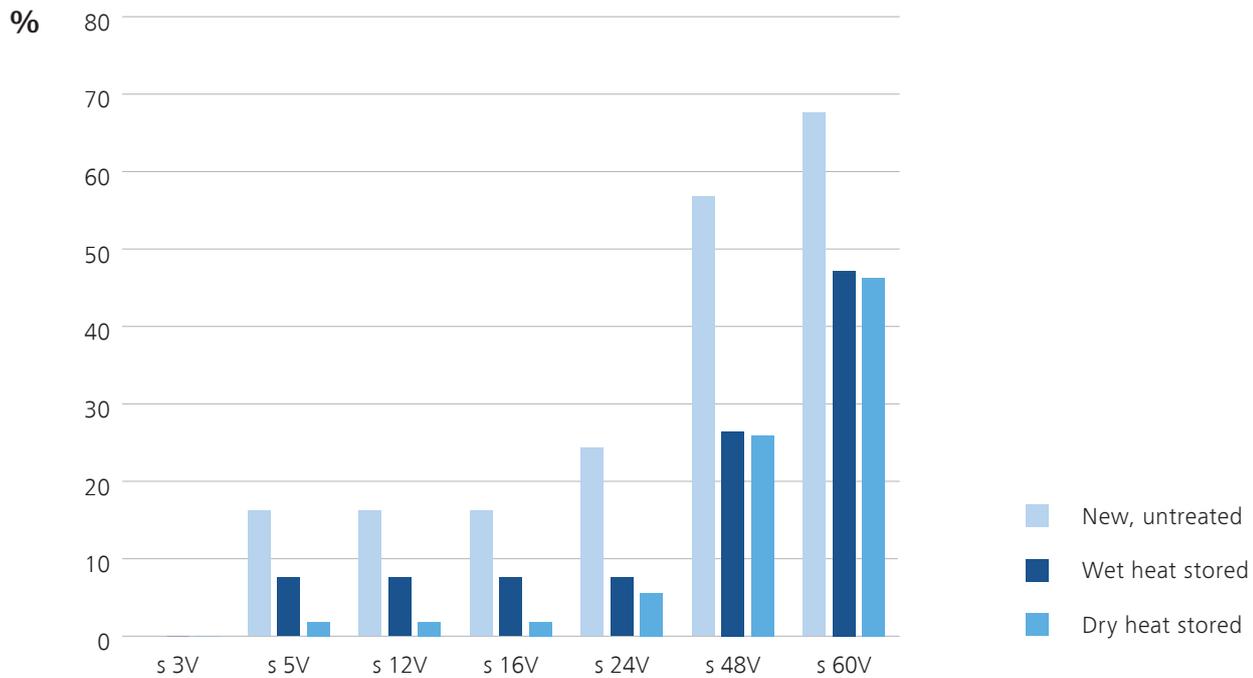
the traces influence the current flow of the traces. A particle is placed over two adjacent traces, and the DC voltage between the traces is increased from the starting point V1 up to 60 V in increments of 1 V. Each voltage point is applied for 5 seconds. The current of the voltage source is limited to 2 mA. If the current flow is insufficient, the currently applied voltage is noted as breakdown voltage or step voltage.

This process was repeated until 25 breakdowns were reached.



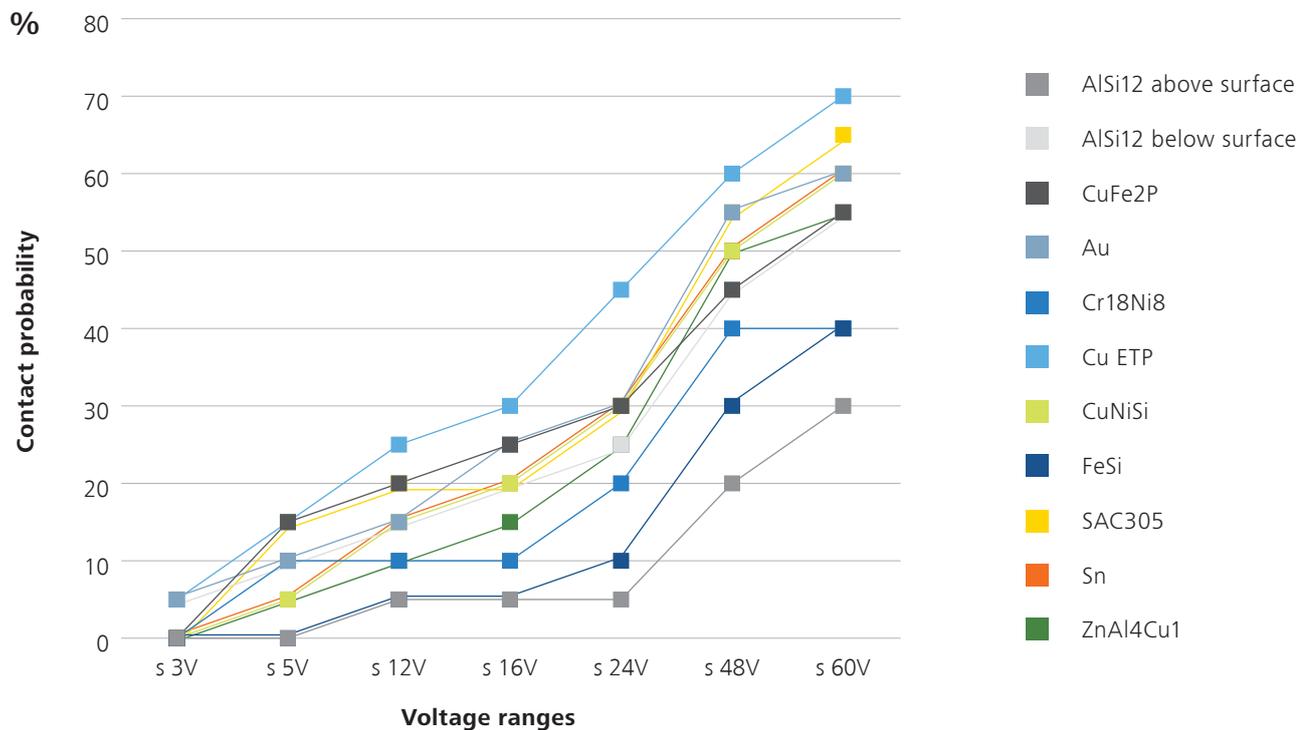
(source: https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/Februar/ZVEI_Technische-Sauberkeit-in-der-Elektrotechnik_dt_engl/ZVEI_Guideline_Technical-Cleanliness-in-Electrical-Engineering_second-edition_Version-2020.pdf)

Comparison of Cu particles in three conditions on SAC305 PCBs



(source: https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/Februar/ZVEI_Technische-Sauberkeit-in-der-Elektrotechnik_dt_engl/ZVEI_Guideline_Technical-Cleanliness-in-Electrical-Engineering_second-edition_Version-2020.pdf)

Overview of all metals in the voltage classes, rounded



(source: https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/Februar/ZVEI_Technische-Sauberkeit-in-der-Elektrotechnik_dt_engl/ZVEI_Guideline_Technical-Cleanliness-in-Electrical-Engineering_second-edition_Version-2020.pdf)

Adhesion of the particles to the PCB was observed during the experiment. This is an electrothermal breakdown process in which, as the voltage increases, a layer of impurities jerkily reduces the resistance from the megohm range to the ohm range.

Comparing the results, it is apparent that the applied voltage, particle state, and particle material have an influence on the contacting properties. The probability of interference varies between different particle types, but it nevertheless increases as the voltage level increases.

List of materials used in the test

1	Cu	Copper	e.g. cables, power rails
2	CuNiSi	Copper alloy	e.g. contact material, press-in pins
3	Au	Gold	e.g. bonding wire, connector coating
4	Sn	Pure tin	e.g. coatings
5	SnAg3Cu0.5 (SAC305)	Solder material	e.g. solder paste, solder bars
6	ZnAl4Cu1	Zinc alloy for die-casting	e.g. housings
7	AlSi12	Aluminum alloy for die-casting	e.g. housings, covers, holders
8	CuFe2P	Copper-iron	e.g. bus bars, lead frames
9	FeSi3	Electrical steel	e.g. stators, rotors, transformers
10	X10CrNi18-8	Spring steel	e.g. springs
11	MnZn-oxide	Ferrite	e.g. magnetic core, chokes, transformers

(Table 28 List of materials used: fig. 93/94; source: https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/Februar/ZVEI_Technische-Sauberkeit-in-der-Elektrotechnik_dt_engl/ZVEI_Guideline_Technical-Cleanliness-in-Electrical-Engineering_second-edition_Version-2020.pdf)

The quality solution: technical cleanliness.

But what is technical cleanliness?

Technical cleanliness is a two-stage procedure that uses a light microscope to examine the number and size of particles present, followed by an electron microscope to confirm the chemical composition and origin of the particles. It therefore seeks to eliminate system failures that could potentially be caused by these particles. The necessary level of technical cleanliness is determined on the basis of the particle-sensitive points on the system in question. The relevant particles may also differ in character – while combustion engines typically encounter hard and abrasive metallic particles, electronic engines can be susceptible to low- and high-conductivity particles.

Most particles are generated during the processing of components and assemblies (approx. 80%) and only a fraction (approx. 20%) are due to environmental influences. Since manufacturers cannot address every possible malfunction and manufacturing process, the aim here is to focus on metallic particles.

When it comes to PCBs, any metallic particles that measure

> 200 µm or more present a potential risk of electrical short circuit. If the metallic particles are of a certain length, angle and position, and they land on the PCB in a particular way, they can cause a short circuit. This is what makes it important to find these critical particles and detach them from the PCBs. Since there is no such thing as total cleanliness or purity, then the focus should be on the most practically feasible and economically viable solution for the designated location and purpose. Particle contamination has been a growing problem for the automotive industry since the early 1990s, when systems started becoming increasingly complex and installation spaces ever smaller. VDA 19/ISO 16232 was therefore established as a standard for enabling customers and suppliers to address the risk of potential damage of products across the production chain.

In the electronics industry, VDA 19 does not specify any limiting values for component cleanliness. These must be defined according to component function, producibility, and verifiability.

When residual contamination is sufficiently low, the system is considered adequately clean.

ZEISS Technical Cleanliness Solutions

Example workflow for semiconductors in cars

Extraction of particles from the component: Not a trivial process

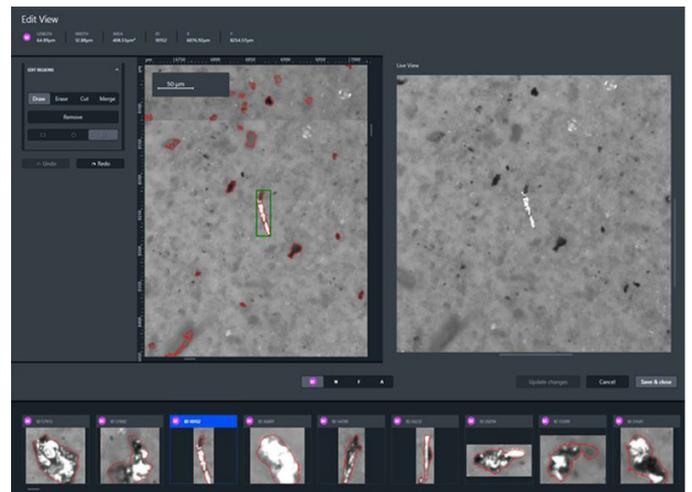
Particles are removed from electronic circuit boards via a blowing process. Since the electronic circuit boards can be damaged by water, this cleaning process is performed with air – with a jet of clean and oil-free compressed air from a spraying tool and bonded to the wetted chamber wall. This process takes place in a box equipped with a pressure vent to prevent overpressure.

After being rinsed off the wetted chamber with a fluid that subsequently flows through a filter, the particles are duly captured in this filter and ready for analysis under the microscope.



Determination of particles with light microscopes

The filter is placed under the light microscope (e.g. Axio Imager 2, Axio Zoom.V16) in order to detect all the non-metallic and metallic shiny particles on the filter.



In the ZEISS ZEN Technical Cleanliness Analysis software, all such particles are listed in a table and categorized accordingly. Thanks to the intuitive user interface, as well as the guidance provided to the user throughout the application and in the workflow, you do not need to be an expert in microscopes or software operation. The support by defined microscope hardware and software settings makes complex analysis processes both much easier to perform and more reliable. Data is stored by the system and exported if necessary, with the software also able to generate a report according to the relevant standards. ZEISS ZEN core Shuttle and Find also connects this data to electron microscopy solutions, generating a seamless workflow for switching between these technologies.

As the software enables the direct retrieval of highlighted particles from a light microscope to an electron microscope, this further boosts productivity and efficiency by providing immediate access to the dedicated analysis view in the high-resolution electron microscope.

Light microscopes



ZEISS SteREO Discovery.V8

Particle size $\geq 15 \mu\text{m}$
Standard analyses



ZEISS Axioscope 7

Particle size $\geq 50 \mu\text{m}$
Standard analyses



ZEISS Axio Zoom.V16

Particle size $\geq 5 \mu\text{m}$
Advanced analyses



ZEISS Axio Imager 2

Particle size $\geq 1 \mu\text{m}$
Advanced analyses

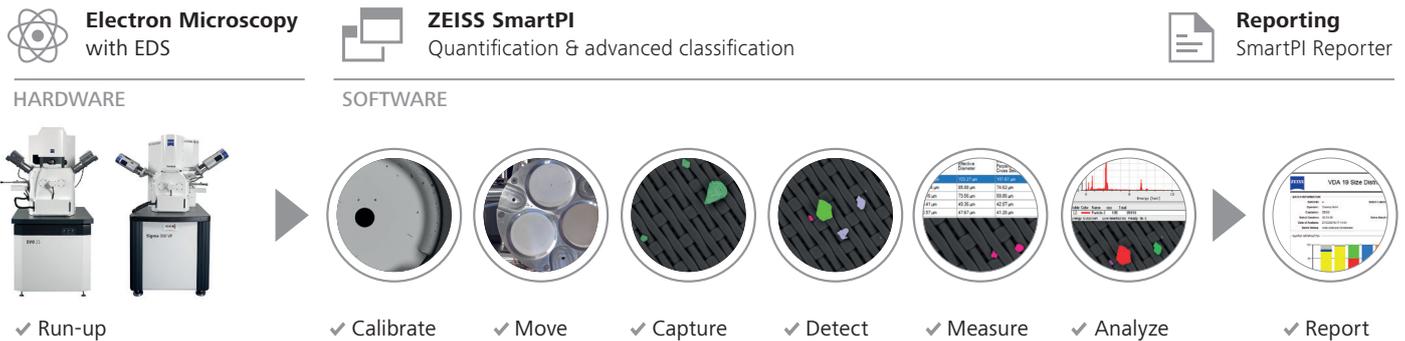
Understand the root cause of particle contamination with electron microscopes

In order to find out more about the particles, filter is placed in an electron microscope such as ZEISS EVO or ZEISS Sigma. Our connected system makes it easy to find the individual particles with the support of ZEISS SmartPI SEM software. The use of a uniform portfolio uniquely enables us to save the coordinates of a critical particle and therefore identify the particle type with the ZEISS SmartPI software. The system then analyses the

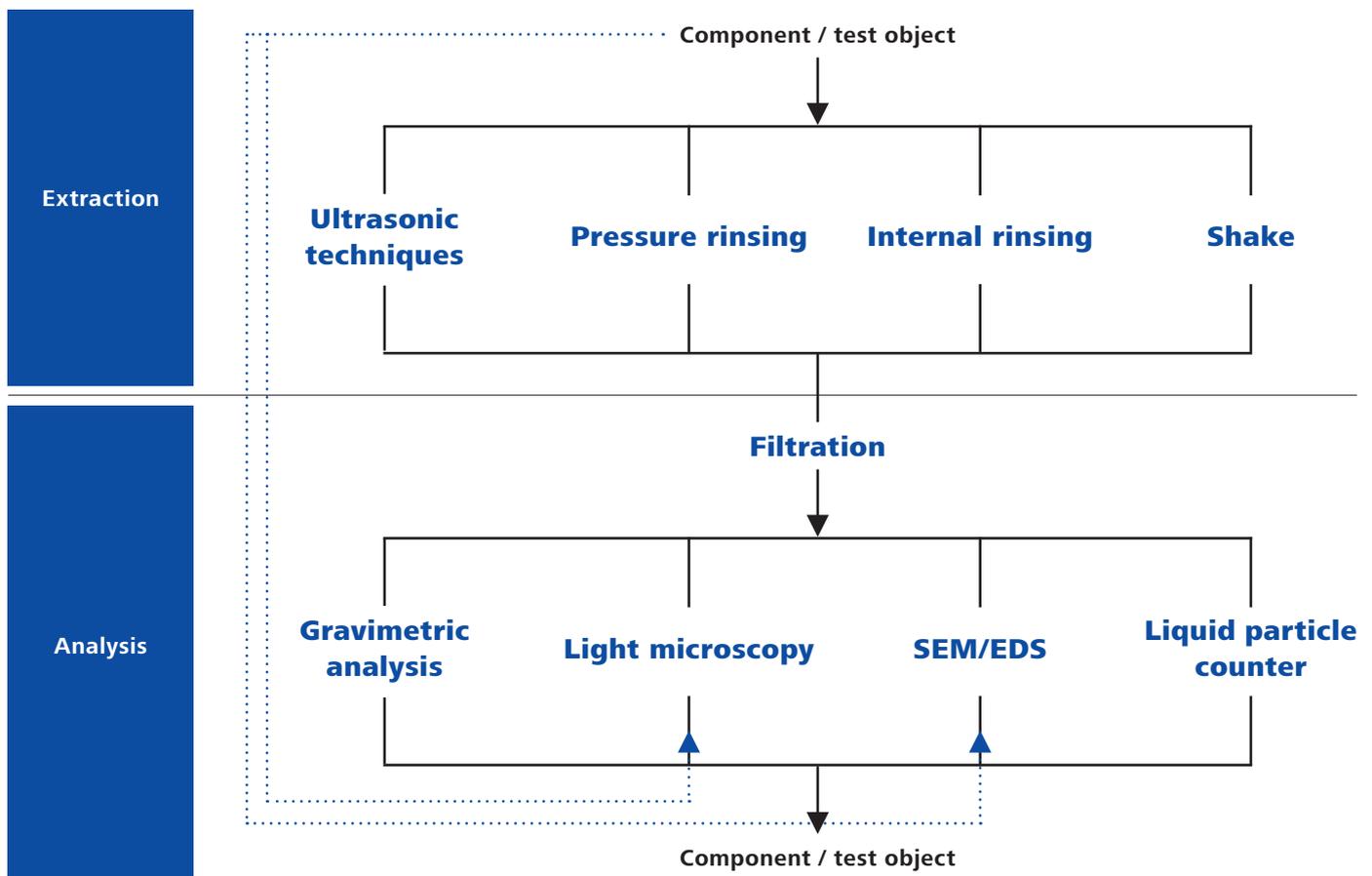
material, how it is built up, and where it is coming from (e.g. forging process or supplier) – after all, the chemical composition of the particles is determined by EDS measurement in order to determine their origin.

ZEISS SmartPI provides much more than size, shape, distribution and corresponding particle morphology, it also provides chemical composition and material characterization, thereby enabling the user to locate the root cause of contamination.

ZEISS SmartPI can also design and create individual reports specific to customer needs.



Workflow overview



Services from ZEISS AG

Technical cleanliness is rapidly growing in importance within the automotive industry. At ZEISS, we help professionals understand our systems and bring them closer to the handling of our machines.

We provide assistance for everything from construction, service, and repair to employee training on correct use of the equipment. We are always available and at your side every step of the way. Our Demo Center is fully equipped to prepare you for every aspect of our machines.

Source:

https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/Februar/ZVEI_Technische-Sauberkeit-in-der-Elektrotechnik_dt_engl/ZVEI_Guideline_Technical-Cleanliness-in-Electrical-Engineering_second-edition_Version-2020.pdf

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