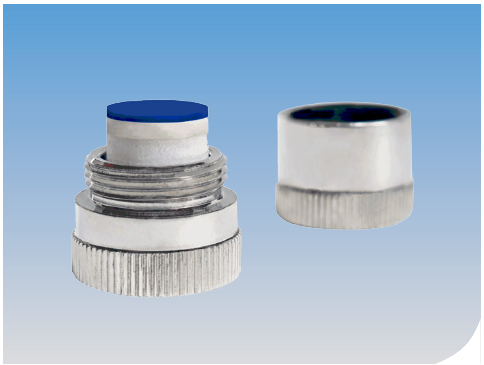

Fig. 1 PART-LIFT™, device for detecting the particle and fiber fragment coating on surfaces of low roughness (Patent Labuda).

Win Labuda

A Kind of Particle-Collector

Clear & Clean - Research Laboratory

Whilst the registration of the number of particles or microbes present in liquids and gases can be satisfactorily conducted through an available selection of adequate measuring processes, there is a considerable deficit in methods to identify and count particles, fibre fragments and microbes on surfaces. With the aid of the Particle and Microbe Collector, recently introduced by the author, it is possible under the microscope, by strong sideward Illumination, to achieve a quick visual comprehension of the presence of particles, microbes and fibre fragments on a plane and even surface. Making use of the electronic Image analysis it is also possible to conduct an automatic counting and classification of the particles from a relatively small size up to several millimeter - depending on the microscope chosen. Within a few minutes it is possible to obtain almost complete information about the spectrum of particles deposition on a plane surface. In this way a problem is eased, which up to now has led to many false assumptions in technical cleanroom work: Most particle counters for air or liquids make no further distinction between particles and fibres of 10 and 1000 or more µm in size. In this way a grain with a diameter of 850 µm is often registered under the same classification as a 12 µm-particle. Therefore the surface-contamination by meso-particles, macro-particles and particularly by fibre-fragments larger than 10 µm is generally not yet very well known.

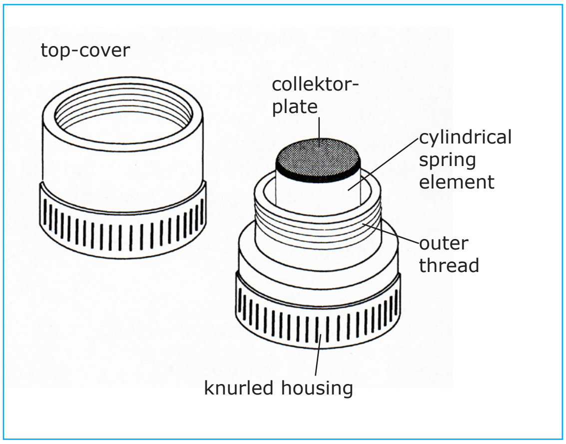

Fig. 2 Scheme PART-LIFT™-Collektor

Mechanics and Operation

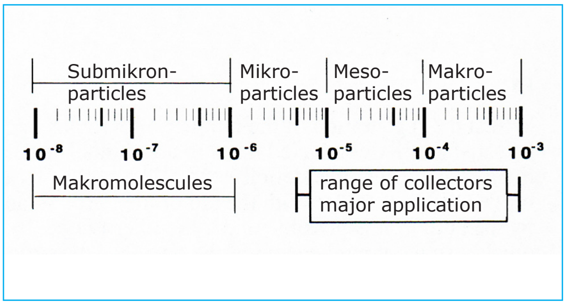

Fig. 3 Ranges of particles by size as used by the author

The two piece collector consists of a closable metal capsule with a screw thread. Attached in a central position to the base of the capsule is a cylindrical spring element, made of soft foam. A collector-plate with a slightly adhesive surface is fixed onto the upper side of the spring element. The adhesive substance on the surface of the collector plate is self-restoring, so that the collector can be used many times. When the base of the capsule with the collector-plate is pressed for a minimum of 5 seconds against a dry and roughly flat surface, the particles, fibres, fibre-fragments or microbes, which are loosely attached to it, are picked up by, and remain on the collector plate. The top level of the collector plate stands out from the thread or contact level of the base by several millimeter. Just enough to ensure the effective pressure against the surface to be analysed is always around 5 - 6 Newton. After completing the collecting, the top part of the capsule may be screwed onto the base and the so secured particle sample is then ready to be given on to a laboratory for microscopical analysis. After measurement or examination there are two possibilities for cleaning and using the collector again:

A - The collector-plate is pressed for about 5 seconds onto a coating carrier which has been applied with a special adhesive (PART-LIFT™ Cleaning Pad, available as an accessory). The collector-plate is then cleaned by slowly pulling off from the coating carrier. This process can be repeated if necessary.

B - With a special fluff-free cloth, which has been soaked in an about 50:50% mix of DI-water of the highest purity and Isopropyl Alcohol. Even the small particles can be removed through careful wiping, using the aforesaid clean cloth. Yet, most cloths are not really clean enough for this operation and a cleaning as described under A may have to follow B.

The Particle-Collector is then ready for further use. The maximum operational life of the device is - as with every adhesive coat - dependent on various environmental factors and of course on the number of analyses carried out. In principal one can reckon with a collectors maximum life-span of 2 years.

Efficiency of Removing Particles

After the lifting of the device from the surface to be analysed a large Portion of the particles resident on the surface should now be on the collector-plate for investigation. How large a percentage this may be depends on the various qualities of the surface. However, the Institute for Process- and Aerosol-Measuring Technologies of the Duisburg University has tested the efficiency of removal of the collector on a polished silicon disk (wafer). The results are as follows:

series of investigation	measurement number	size of particles. µm	position of square on the wafer	efficiency of removal in %
1	1	0.48	top	81.6
1	2	0.48	bottom	82.3
1	3	0.48	center	44.4
1	4	0.48	right	84.9
1	5	0.48	left	93.1
2	1	0.48	top	89.0
2	2	0.48	bottom	80.5
2	3	0.48	center	29.1
2	4	0.48	right	81.1
2	5	0.48	left	44.1
3	1	0.48	top	98.5
3	2	0.48	bottom	96.3
3	3	0.48	center	84.6
3	4	0.48	right	95.2
3	5	0.48	left	94.1
4	1	0.21	top	91.0
4	2	0.21	bottom	90.9
4	3	0.21	center	90.0
4	4	0.21	right	91.8
4	5	0.21	left	94.8
5	1	0.21	top	88.0
5	2	0.21	bottom	91.3
5	3	0.21	center	87.1
5	4	0.21	right	88.9
5	5	0.21	left	88.0

Tab. 1 Results of the various series of investigation

Method of measuring

A silicon disc (wafer) with a surface-roughness Ra of 5 - 10 nm had been homogeneously covered with fluorescent Latex-spheres of a diameter of 0.48 and alternatively of 0.21 µm. The so prepared wafer had been fixed onto an automated X-Y-stage of an optical Epifluorescence-microscope for Computer controlled positioning. The software controlled X-Y-stage would be positioned at random to 468 different places within the area to be investigated and at each of them the amount of particles traced would be recorded. After the particle-collector had been operated on the square of investigation on the wafer, the same 468 different places previously searched for the presence and counting of particles had been investigated again and the particles found had been recorded. The difference between the two particle-counts is expressed as a percentage removal-efficiency of the Particle-Collector. The 5 series of 5 measurements each, totalling in 25 measurements of a square of 4 mm^2 was obtained.

When measurement 3 of series 1 and measurement 3 of series 2 showed incomprehensible deviations from the rest of the data, it was discovered, that the angle of the initial contact between the collector and the surface to be analysed was of importance for the accuracy of the measurements. If the angle was around 90 degrees relative to the wafer, then air bubbles would form between the collector plate and the wafer and prevent the close contact between the two surfaces. Therefore the number of particles collected, was reduced. After the way of touching the surface of the wafer was changed to an angle of about 30 degrees and slowly moving the collector to an upright position the data of the subsequent 3 series of investigation showed no further inconsistency (tab. 1).

The above data had been so surprising to us because we had anticipated a severe reduction of the collecting-efficiency for particles with diameters of 0.21 µm. But in fact after averaging the results we only found a decrease by 4.4% from 93% for 0.48 µm particles down to 89% efficiency for 0.21 µm particles. It will be one of the future tasks in connection with this device to investigate into the collecting efficiencies for meso- and macro-particles because this is the intended field of the collectors main application.

Applications

The Particle-Collector was in fact designed by the author primarily in order to have at hand a fast and reliably working tool for measuring the cleanness of cleanroom-wipers, paper and gloves during their production and final quality checks as well as for the comparison of various manufacturers products. The field of usage of the Particle-Collector described is however, not confined only to this. It could be the statistical registration of fine deposits on critical surfaces. It is also possible with the same collector to conduct quality-inspections of incoming goods, which formerly could not be properly performed. It is for all products, which in delivery-condition are only allowed to carry or release limited amounts of fibres, particles or bacteria on their surface and/or interior. For example the collector may be used in the following areas of application:

- Hospitals
  checking the cleanness of Operation-theatres and the presence of microbes on walls and other surfaces.
- General cleanroom-industry
  garments, paper, gloves, Containers, foils, bags and wipers, interior of equipment before and after cleaning-operations.
- Pharmaceutical industry
  bottles and containers, spreading of powder-particles.
- PC board industry
  cleanness of PCB in the condition of supply.
- Asbestos & Textile industry
  coverage of surfaces in working- areas with fibres dangerous to the human health.
- Atomic Industry
  tracing of radioactive dusts.

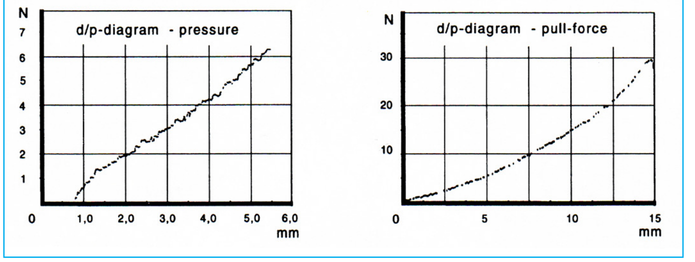

Fig. 4 The left diagram shows the operational pressure in Newton relative to the distance between the collector-plate and the level of max. compression (end of the thread). The diagramm on the right shows the pull-force neccessary for vertical removal of a smooth and even surface adhering to the collector-plate.

At this early time is not possible to know all possible applications for this device but the author is very thankful for any advice leading to applications yet unknown.

Limitations

This Particle-Collector - like any other particle tracing device - has its limitations and these are to be found in the following areas:

Uneven surfaces: Because the collector plate of the device is of even construction, it is not easy to collect particles from a number of uneven shaped surfaces if their radius of curvature is small relative to the diameter of the collector plate. Practical tests will show here what is outside the bounds of possibility.

Rough Surfaces: The data taken by the Institute for Aerosol Technology (tab. 1) was obtained from a silicon disc (wafer) with a surface roughness Rz below 0.1 µm. It is obvious that from a certain surface roughness level onwards the number of particles to be collected by this method will tend to decrease. If the „valleys“ of the surface are larger than the particles to fill them, then the „peaks of the mountains“ prevent the adhesive collector plate from coming in contact with those particles. This is true if the „valleys“ are not unusually long.

Reduced adhesion: This device binds particles by adhesive forces between the collector plate and the particles to be collected. In order to increase the strength of adhesion, the collector plate of this device inherently carries a kind of adhesive, of which a very thin layer continuously covers the surface of it, so that the particles become embedded in the adhesive which results in a substantial increase of the binding forces. If the particles, however, are e.g. only available in a wet state, then water is introduced into the system as a further layer around the particle, which has almost zero binding force to the adhesive and therefore the system will not work.

Ultra Clean Surfaces: Because small amounts of the adhesive, inherent in the collector plate may be transferred to the surface to be analysed during the contact between these surfaces, the device may not be used for analysing such critical surfaces as e.g. silicon wafers and all objects, which may be damaged by the remains of the adhesive.

In summary it should be noted that this kind of particle collector is suited for analysis of even, dry, and relatively smooth surfaces, which can not be damaged by the remains of ultrathin layers of adhesive. There may be unimportant limitations, like extreme densities of particle coverage by more than one layer of dust, very hot or cold surfaces or others yet unknown to the author.

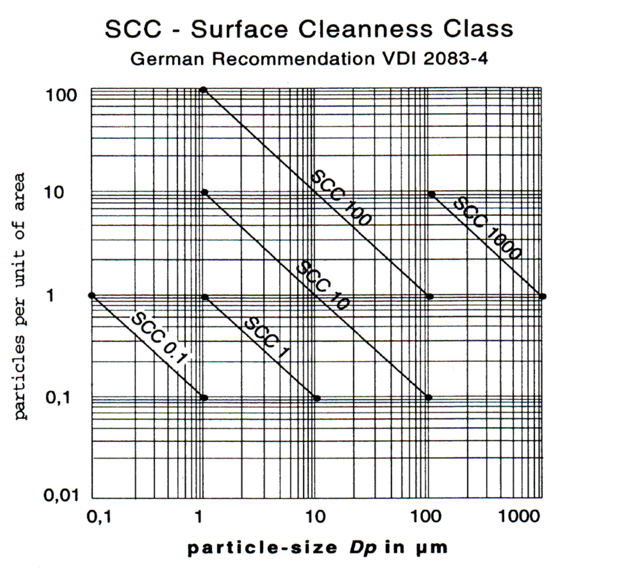

Fig. 5 The German VDI-recommendation for surface-cleanness 2083-4 contains a classification for various grades of surface-cleanness. The collector-device is one of the means to classify surfaces according to the diagram.

Image Transfer and Analysis

In fact, Bernhard Klumpp [1] in his thesis in 1993 has given us a great wealth of valuable information, summary and literature-reference about the physical and technical aspects of measuring particles on surfaces, using the optical microscope and scattered light. For the time being there is not much to add to his explanation and findings. A large part of Klumpps thesis however, deals with particle diameter around 1 µm whereas the author is mainly concerned with Meso- and Macro-Particles as well as Fibre-Fragments. In this area of concern tight tolerances of the accuracy of the obtained data do not play a very important role. The average particle size on the exterior of cleanroom garments after some days use for instance is often in excess of 10 µm. The same is true for material abrasion in the equipment used in cleanrooms. Also cleanroom wipers leave particles much in excess of 10 - 50 µm in size after being used for cleaning slightly rough surfaces. This to a smaller extent is also true for Latex and Vinyl Gloves. Also the edges of some cleanroom-papers carry particles and fibres way above 100 µm. The major demands here are:

- a simple method for the collection of the particles, microbes etc.
- a secure way of transportation of the sample to the place of analysis
- comparative analysis and fast access to the quantitative particle data

The Particle-Collector described here seems well suited to fulfill the demands specified above.

The particles or microbes present on the collector-plate are expediently illuminated with intensive sidewards light or laser beam. In this way their scattered light stands out very well against the dark background of the collector plate. It is, however, possible to make the sample visible through the Dark-Field-Illumination, which is sufficiently described in the microscopical literature. For microbes there are many ways of making them visible by using fluorescent microscopical methods, which are well known amongst microbiologists.

The Electronic Image Analysis is available for the automatic counting and /or form-factor-analysis of particles or fibre-fragments. For the first investigations the author used the Optimas-Software developed in the US. The following interesting data on the particles to be analysed may be obtained from the microscopical image.

- total number
- 3D-luminance-surface
- major axis lenght
- longest axis

- equiv. perimetric diameter
- Feret-diameter
- surface-area in µm²
- max width

and many more

The time to obtain the full data for each of 200 particles from the opening of the collector to the data printed is around 1 - 2 minutes.

The Undiscovered World of Mesoparticles

There is only one clean-feature being permanently data taken of in most cleanrooms and this is the cleanness of the air. Cleanroom-engineers are proud, if in a cleanroom they can maintain a level of air-cleanness below one particle >0.5 µm per cubic-foot. On the other hand, large numbers of particles are being transferred to the cleanroom or generated in there, decidedly larger than that. Major sources of generating such particles are operators working there, chemicals used for production, equipment in operation, use of convertibles like wipers and gloves etc., but also garments and shoes. A large part of these particles generated or transferred are well above 0.5 µm in size.

The reason for the whole group of such mesoparticles as well as macroparticles having largely escaped our attention is obviously the lack of methods for their effortless trace and measurement. This is because the principal particle-counting-device in the cleanroom-industry is the laser-particle-counter and most of those instruments count all particles above 10 µm in diameter without further differentiation. However, the adverse impact of e.g.120 µm-particles for the production might be completely different from 10 µm ones. Luckily, at least in the semiconductor -industry meso- and macroparticles do not play a major role in the composition of particle originated defects. It is, however, important that we put more effort into this area of investigation and the Particle-Collector might be a valuable tool for this.

Examples

The following examples shall illustrate one of the possible applications of the Collector.

Fig. 6 *Collector-Plate after cleaning* - as seen by the electronic image-analysis-program. There are 4 particles remaining an the active collector-section after the cleaning operation. They are clearly shown an the screen of the monitor and also in the diagram tab I0. The number of particles remaining an the collector-plate is the „grey-value", later being deducted from the particle-count after the proper use of the collector. The investigated section of the collector-plate for fig. 6, 7 and 8 was 9 x 5.8 mm.

Fig. 7 *Cleanroom-Wipe* - In this case the particle-collector was pressed for 5 seconds onto the surface of a cleanroomwipe and then analysed by the electronic image-analysis. Significantly more particles (37 pcs) are an the collector-plate than to be seen an the picture beside. Because of the reduction in space for this picture, not all particles to be seen in the diagram fig. 10 are visible here.

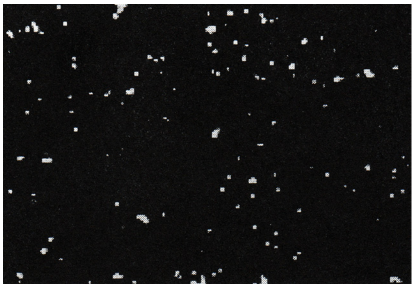

Fig. 8 *Cotton-Wipe* - The same collecting procedure was used as for the cleanroom-wipe. From the large number of particles and fibres traced by the electronic image-analysis-system, the difference to the cleanroom-wipe of fig. 7 is clearly visible. However, research has to be done about the possibility of the collector-plate tearing out fibres and particles, weakly bound to the textile body, which in the normal course of operation would not become loose.

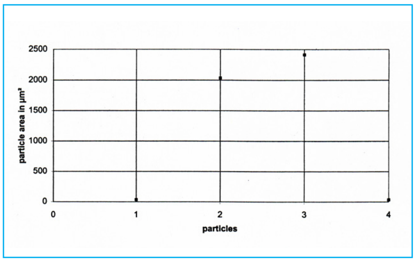

Fig. 9 The diagram shows the number and area-size of particles, which in this case remained an the cleaned collector-plate. The number of particles to remain an the plate is called the „grey-value" and varies with the surface cleanness obtained from cleaning.

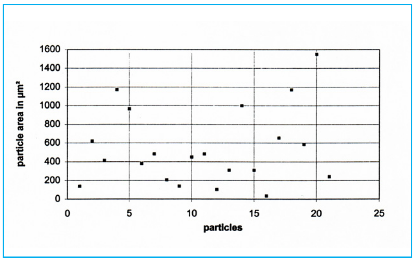

Fig. 10 The diagram shows the number and area-size of the particles/fibres collected from the surface of the cleanroom-wipe in fig. 7 According to the VDI 2083-4 Specification for Surface-Cleanness, fibres are particles with a length exceeding 5 times their diameter.

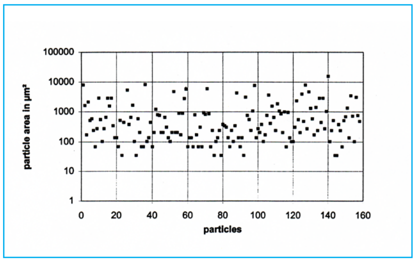

Fig. 11 The diagram shows the number and area-size of the particles/fibres collected from the cotton-wipe in fig. 8. Cotton-wipes have practically disappeared from cleanroom-applications. The diagram is just to show the difference to a cleanroom-wipe.

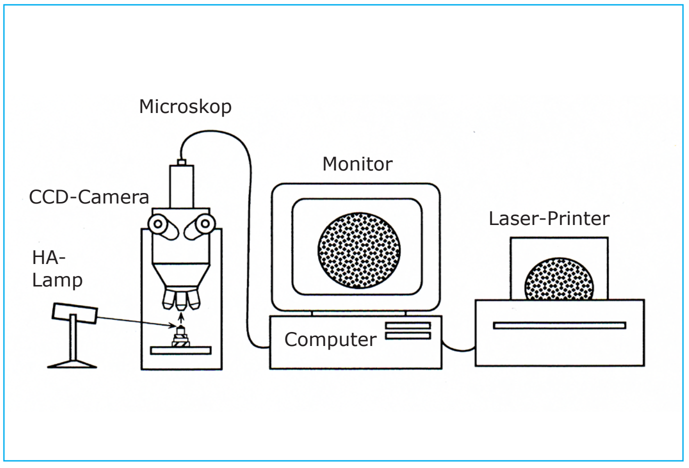

Fig. 12 Analysis of the surface-cleaness - using the Particle-Collector with electronic Image-Analysis

Remarks

The „*Particle-Collector after Labuda*" described in this paper is commercially available under the trade-mark PART-LIFT™. Patents for the device have been applied in Europe and many industrialised countries out of Europe.

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