Cleanroom-Paper

morphological qualities of surface and edges of 5 different cleanroom-papers, release of particles and other parameters

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Summary

● There are no applicable test-methods in existence, revealing the particle-release during the use of cleanroom-papers. Therefore this parameter has to be determined by microscopic observation of the surface and edge-qua-ities.

● Because of the very small market for these special papers there are only five known manufacturers worldwide. Their products have been analysed by secondary electron-microscopy. The results are shown in the different pictures of this paper.

● Many users would like to know the difference between a cleanroom paper and a Standard copying paper - would like to learn about the particular performance-profile and which parameters are important for cleanroom use. These items are presented below.

Introduction

Cleanroom-papers serve the communication in cleanrooms, the logging of production-data and as a second kind of use, the physical separation of such products which should not be stapled an top of each other without an interleaved sheet. Cleanroom-papers belong to the group of materials, which in many cleanroom-based manufacturing sites permanently pass through the cleanroom - just like overalls or wipes. Therefore a well balanced clean-concept will give this product its due attention.

The expectations of some cleanroom experts, who anticipated already in 1989 the paperless cleanroom to be standard in the industry by 1994 were not realistic. The quality of modern cleanroom papers has remarkeably improved ever since and the installation of SMIF-Systems have lessened the danger of convertible-based contamination so that the paperless cleanroom is not a valid topic any longer. There are two kinds of cleanroom-paper on the market. One is based on cellulose- and the other one is virtually plastic foils. The latter group Gould so far not really succeed for two reasons:

It would need very strong technical points to specify a plastic foil in exchange for biodegradeable paper. This is in view of the great efforts, everybody is making, to reduce the ecological burden of non-bio-degradeable waste and the threat of adverse legislation in the near future. The very minor technical advantages of plastic foils do not justify the negative ecological aspects.
The low temperature-endurance of most plastic foils prevent their use in copying- and laser-printing-machines. This article therefore entirely deals with cellulosic cleanroom-papers.

Like other products for use in the clean technologies, cleanroompapers are subject to a profile of requirements facing a performance-profile. The Profile of requirements results from the odds given by the clean-manufacturing processes and the performance-profile is based an the contigencies of the paper-manufacturing techniques. Fig. 1 shows a comparison of the profiles. In this context there are still a few features which are requested by the clean industries to be improved upon: particle-release and ionogenity; whereas the mecha-

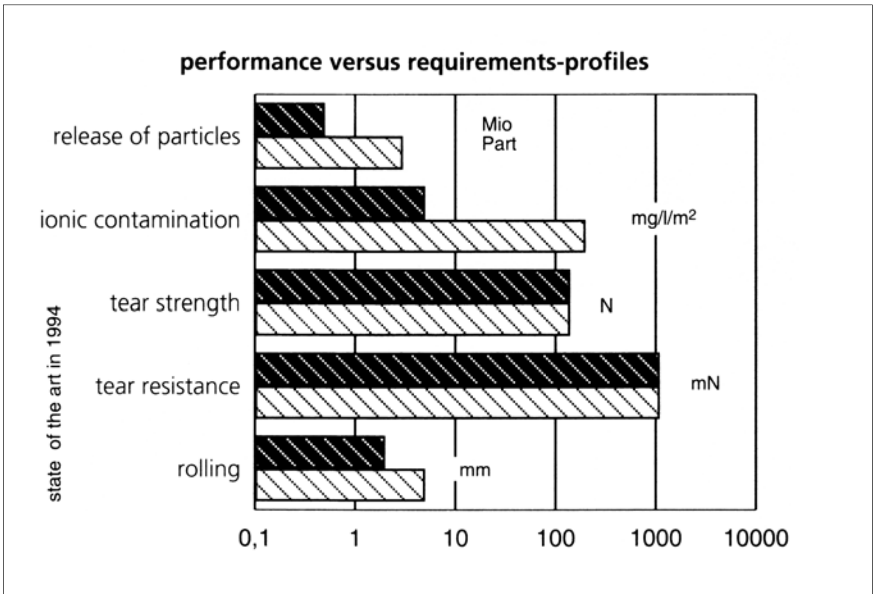

Fig. 1 user-requirements versus state-of-the-art performance in 1994 nical parameters are meanwhile sufficiently developed.

The manufacturing process
In the initial development-stage the kind of fibers to be used and the degree of refining them have to be very carefully assessed. Additives used in the manufacturing-process of standard papers e.g. loading agents of caolin for obvious reasons cannot be used for making cleanroom papers. This similarly applies to all kind of bleaching processes, which are inherently ionogenic.

Cleanroom papers are manufactured to be an rolls of about 5 yards in width. For the ease of handling, those rolls are subsequently sliced into three sub rolls. One production lot is around 50 to 100 tons of raw-paper.

The subsequent process is the cutting of the paper rolls into standard-size-staples (e.g. size DIN-A4) of 250 or 500 sheets. This process is critical regarding the release of particles from the edges of the stapled paper. If the paper is to be of A-grade quality, special cutting-techniques are to be applied in order to reduce the amount of remaining particles and broken fibers. The staples are about 2 1/2 inches in height. For a paper of the size 8,25 x 11,7 inch that amounts to a surface of 93 square-inch. Depending on the chosen method of cutting, the number of resident particles may vary in the ratio of 1 : 5. But even though the best cutting may be applied, the paper should be decontaminated for use in class 10-cleanrooms and below. This is quite often not thought about and yet may cause some problems.

The release of particles
One of the major requirements in connection with the selection of a suitable cleanroom-paper is the know-

The determination of the number of particles resident on the surface of a paper is not possible with known methods.

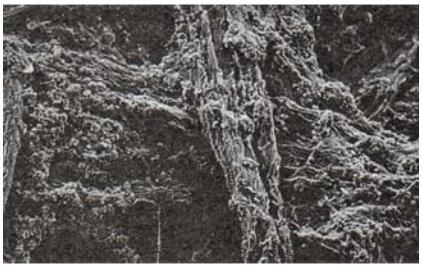

Fig. 2 Standard-Copying-Paper

Abb. 3 Cleanroom-Paper

ledge about the particles to be released from the surfaces and edges of the paper in its practical application. There are three possible causes for the paper to become a source of particle-emission:

1 - the surface-character

2 - the quality of the edge-cutting

3 - the release of unfixed toner particles after the printing-operation.

It is still difficult, to find a suitable method for simulating the quantity of particles released from papers by its handling. In this connection very often the method IES-RP-CC-004-87T is mentioned. However, in accordance with this method the paper-specimen is dipped into DI-water. Thus freed particles are then being counted automatically or by the aid of a microscope, and classified for their size.

This method however, introduces some sources of error.

That particular part of the latex-furnishing of the paper, which for any reason did not form crosslinking in the drying-section, will dissolve when being dipped into the DI-water. A particle-brew is emerging which partly consists of the dissolved Latex-emulsion and on the other part of the cellulose-particles, no longer adherent to the paper web. Depending on the duration of immersion, drip-off-time, forces of agitation and their homogenity of distribution relative to the surface of the specimen, the results to be obtained from this method substantially differ. At the tests, carried out in our laboratory, we paid utmost attention to the closest adherence to set immersion and drip-off-times as well as the measuring-intervals and yet we encountered a manifold of surprise and odd data. The substantial reservation to this method, however, is based on the fact that the nature of the material is changing during this test and also: the material does not even come in contact with water during its practical use.

It is for a fact, that smoother surfaces shed less particles during the practical use of papers than rougher ones. This is particularly true for the use of papers in copying machines and laser-printers, where a continuous surface-friction is an essential part of the operation. Therfore, in general, the surface of a cleanroom-paper should not have a roughness Rz exceeding 12,5 µ on both sides of the sheet. (measured wich a mechanical Mitutoyo surface-tester)

Particles are located on all sides of a paper-staple but more so an the edges. Fig. 10 shows the microphotograph of particles and fibers, removed by the tape-lift-method from the side of a non-decontaminated staple in comparison to a decontaminated staple in Fig. 11. The quality of the paper-cutting obviously very much differs depending an the various manufacturers. Figures 16 to 20 show SEM-photographs of the cut edges of 5 makes of cleanroom paper.

In the process of manufacturng cleanroom-papers a coating with an elastomer is applied an both sides. Normally, carefully selected Latexemulsions are used. This finishing operation is to safely bind the particles to the fiber-web. This way part of the surface becomes sealed. This can be recognised by the reduction of the rate of absorption after the finishing and subsequent drying. The unavoidable Latex-finish an the other hand causes the following Problems:

1 - The determination of the number of particles resident an the surface is not possible with known methods.

2 - The Latex-finish, if not very skilfully selected, increases the gliding restraint of the paper, which may result in a congestion of copying-machines and laser-printers.

3 - The finish with a Latex-suspension normally causes an increase of generating electrostatic charges. A first dass cleanroom-paper should therefore be so adjusted that the

- propensity for triboelectric charges
- the release of particles - and not the least,the
- ionogenic contents

of a paper be optimally in tune with each other.

Some developments for improved cleanroom-papers aim for an abandonment of the Latex-finish and a simultaneous decrease of surface roughness by the application of special fibers. This should result in a decrease of particle-shedding and triboelectricity.

Fig. 4 to 9 clearly show the different manifestations of the surfaces of 5 kinds of cleanroom-paper. Those pictures haue been taken in autumn 1993 and attention has been paid to the requirement that the specimen are of recent make. However, we did not obtain sufficient material to judge the differentes between various lots of production.

To the Best of my knowledge there is no agreed method for the testing of the particle-burden an the sides of a paperstaple. In the absence of this we had to develop the following auxiliary-method:

A hand-roller wich a cylinder, made of semi-cross-linked silicon-rubber would be cleaned of particles and subsequently rolled over the side of the staple, using average pressure. The length of the rolling motion was limited to the circumference of the roller. The roller, now showing particles and fiber-fragments would be placed under an optical microscope and photographed using strong sidelight-illumination. The results are shown in Fig. 10 and 11.

Bernhard Klumpp of the Fraunhofer-Institute in Stuttgart has in connection with his thesis invented an interesting method of determining the number and size-distribution of particles, resident an surfaces. This method may in a slight variation also be applicable for the determination of fiber-fragments. We shall try to carry out experiments an this during 1994/95.

Confocal-laser-microscopy
For the numerical determination of the surface-roughness the secondary electron microscope (SEM) is not particularly suited.

Therefore we have chosen the most advanced method, confocal-laser-microscopy to show the topography of cleanroom-papers in an effective graphical manner and with plain numerical data. With the assistance of *Lasertech Ltd Yokohama and London* we are able to show the following photographs. In this connection we are indebted to Mr. Komiya of *Lasertech London* for his valuable technical. support. This method permits a simultaneous photographical and numerical assessment of the micro-topography of porous surfaces. Fig. 12 shows a topographical height-difference of 25,53 µ. In another way of presentation (fig. 13) the differences in topographical height are marked by a colour-spectrum. In case of this surface-section of the specimen the difference between the highest and lowest point shows 138 µ at a surface-dimension of 153 x 122 µ. Paper 5 with its reduced surface-roughness shows a difference in height of 34,5 µ only (fig 14).

Recognition of e.g. an insufficient flow of the sealing Latex -emulsion on the paper surface shows a higher resolution (fig. 15) with the method of confocal laser-microscopy if compared to the SEM-method. The reason for this is: when presenting fibers of plastic materials with a secondary electron microscope, electrostatic charges cause a substantial reduction of the image contrast.

Lot-dependent variations
Paper is a "living" material and therefore the data and morphological quality of different production lots may vary within limits. Although the typical technical data of paper like thickness, surface weight, tear strength and tear resistance are completely under control with modern production techniques, one cannot assume, that all parameters pertaining to the use of papers in a clean environment show the same data after every production-lot. The surface-roughness could vary somewhat, depending on the composition of the Latex, the speed of application, temperature in the drying section as well as the temperature and humidity in the ambience of production. Also the rolling may vary somewhat in case the Latex is being applied one side after the other in a one-sided-coating-machine. The ionic properties of the paper may vary dependent on the contents of the paper which was manufactured in the previous production-lot of the same machine. Even by extended rinsing it is not possible to reduduce the ion-contents below the values of the rinse water.

The printing process

For a homogenous application of signs and letters onto the paper, a smooth surface is supportive. The printing process by a copying-machine or a laser-printer functions by the fixing of molten toner-particles, shaped to a letter, onto the surface of a paper. This process could function only, if the temperature of the fixing-drum is sufficiently high to ensure the melting of the toper and second, if the surface-character of the paper permits a homogenous temperature-distribution. The differentes between printing onto a rough versus a smooth paper are shown in fig. 21 and 22. A check of the proper temperature of the fixing roller in copiers or laser-printers, used in clean environments, is adviseable from time to time. If those are insufficiently high, parts of the toper may not be fixed to the paper-surface and increased particle shedding would be the result.

images of the surface

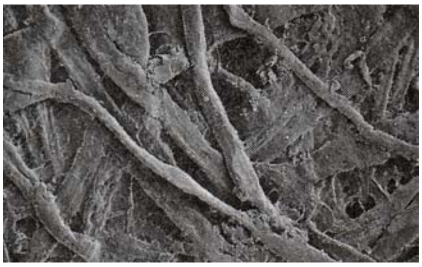

Fig. 4 Paper 1 - the Latex shows excessive viscosity during the finishing operation. See the formation of small lumps

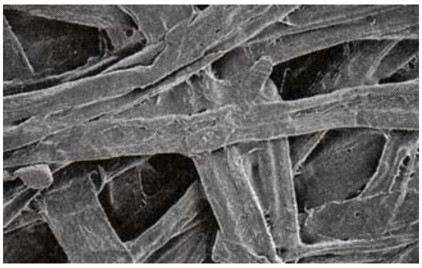

Fig. 5 Paper 2 - the well-known appearence of a paper-surface, finished with Latex, standard pore size.

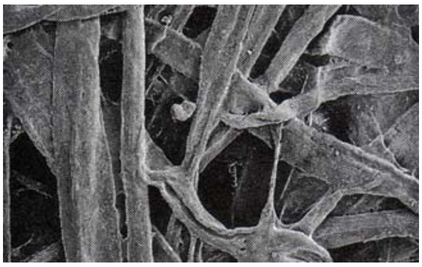

Fig. 6 Paper 3 - the excessive porosity of this surface is not ideal for a reduced amount of particle-shedding.

Viewing the quality of a surface under the microscope permits a conclusion as to the probable propensity of a cleanroom-paper to release more or less particles during its use. Normally rougher surfaces show a higher coefficient of friction and hence, a larger amount of shed particles when run through the copying-machine or laser- printer. The Latex-finish is clearly visible in the SEM-image. All pictures have been taken at 500 times enlargement wich a secondary electron-microscope Akashi SS60.

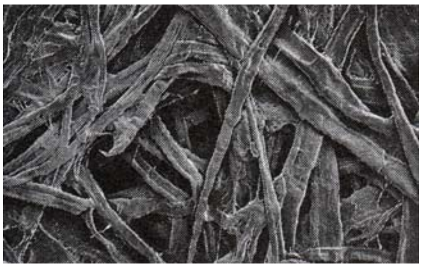

Fig. 7 Paper 4 - confused outward shape by an uneven finish of the Latex-emulsion, medium pore-size.

Fig. 8 Paper 5 - homogenous distribution of the fibers. Here the Latex-finish is evenly applied.

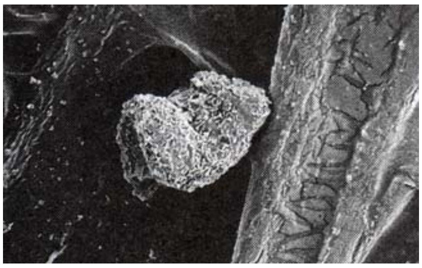

Fig. 9 Very porous papers conceal the danger of being a particle-host, as shown by the above SEM-image.

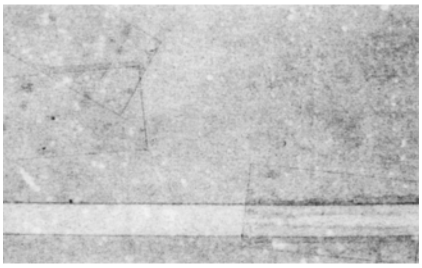

Fig. 10 tape-lift on non-decontaminated edges of a paper-staple (opt. microsc.)

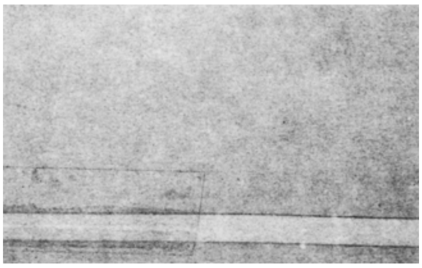

Fig. 11 tape-lift of the same staple after cleaning the edges (opt. microsc.)

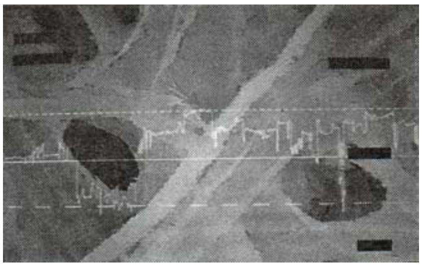

Fig. 12 confoc. laser-mikroskopy

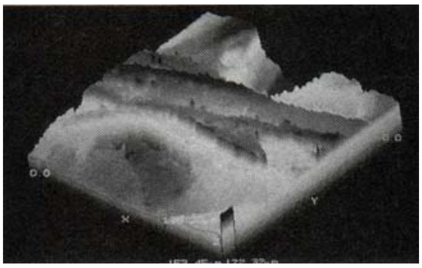

Fig. 13 confoc. laser-mikroskopy

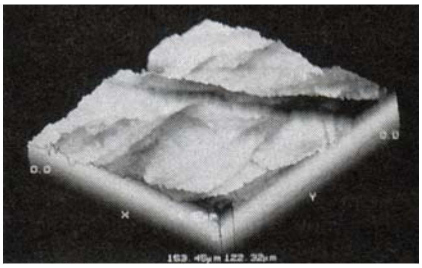

Fig. 14 confoc. laser-mikroskopy

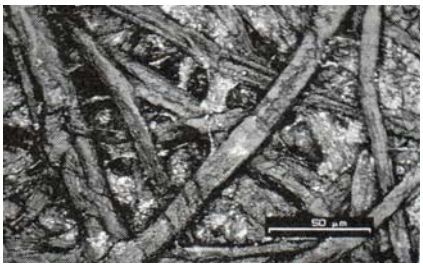

Fig. 15 confoc. laser-mikroskopy

images of the edge-cut

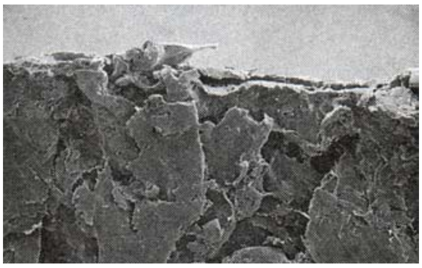

Fig. 16 the edge of paper 1 is queezed-off. This normally results in a large number of loose fibers and particles.

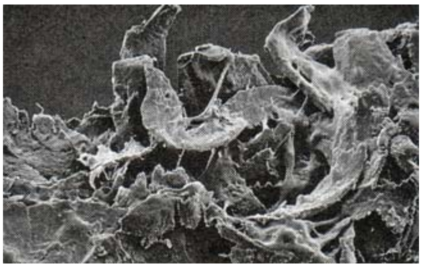

Fig. 17 the edge of paper 2 is more torn than cur. In such case also loose fibres and particles are the result.

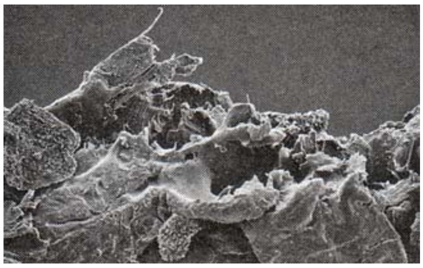

Fig. 18 paper 3 has similary torn edge as known from paper 2. Here also saving methods of cutting were applied.

Fig. 19 the edge of paper 4 is quite even and therefore on a higher quality than the specimen formerly tested.

Fig. 20 paper 5 shows a clean cut, without any loose fibres or particles

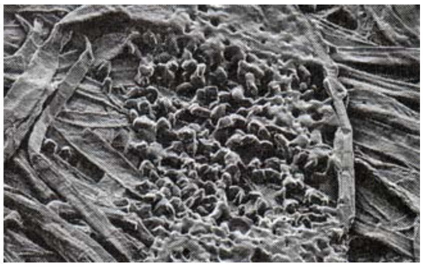

Fig. 21 the unfixed toner-particles are quite apparent on a paper, having a comparatively rough surface.

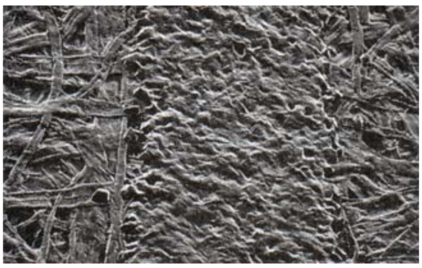

Fig. 22 paper no. 5 with its smooth surface permits a homogenous print without any toner-particles.

The origin of the tested papers
This article is to serve the scientific and technical information in the field of the clean technologies.ln the frame of this context we did not want to disclose the names of the manufacturers of the papers tested. This is also in view of the differences to occur, depending an the variety of consecutive lots of production. We therefore only mention the countries of origin: Paper no. 1, 2 and 3 = USA, 4 = JAP, 5 = Germany

critical parameters of cleanroom-papers

critical parameters	causality	formation at	counter-measures	stand. paper	cleanroom paper	dimension
particle fomation						
on the surface	use of the fillers	production-process	abandonment of fillers	-	-	-
	friction	production-process	surface-sealing	-	-	-
on the edges	cutting-process	guillotine	none	-	-	-
release of particles						
from the surface	frictive motion	utilization	surface-sealing	15,2	2,97...15	M-Part/m²/l > 0,5 µ
	abrasion	utilization	surface-sealing	-	-	-
from the edges	frictive motion	utilization	decontaminating the edge	-	-	-
	abrasion	utilization	decontaminating the edge	-	-	-
electrostatic fields	friction of single sheed	utilization	operator training			v-cm
ion content	use chemical additives	production-process	selected bleaching	155	95...104	mg NaCl-equiv 7 l/m²
release of ionized mat-ter	frictive motion	utilization	surface-sealing	-	-	-
	manual slipping	utilization	operator-training	-	-	-
tear strength	stressing motion	utilization	use of sprcial fibers	105	80...145	N (15 mm specimen)
tear resistance	stressing motion	utilization	use of special fibers	ca. 760	1140...1820	mN
toner rub-off	insuff. tenacity of toner	surface-sealing	suitable copying-machi-nes	- -	- -	- -
colour-rub-off	insuff. tenacity of colour	printing	use of suitable colous	-	-	-
rolling	homogen. fibre distrib.	production-process	special paper-machine	5	10	mm
gliding-restraint	surface friction	transport-syst. in copyer	anti-friction-additives	-	-	N