HIGH RESOLUTION INKJET TECHNOLOGY FOR MAKING PHOTOLITHOS

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ABSTRACT

Screen printing is the most widely used decorating technique in the ceramic sector. It is true that recent years have witnessed the appearance of new technologies that enable decorating ceramic tiles with a greater quality and speed, reaching flush to the edge of the piece, even adapting to reliefs and leaving the register in the troughs or valleys of the relief, but screen printing still remains in widespread use as a printing system for ceramics.

One of the current systems competing with screen printing as a printing system is flexography. Flexography requires a photopolymer sheet as the medium for transmitting the design, in which the corresponding dot pattern has been produced by curing.

Preparing printing screens and photopolymer sheets requires making photolithos that serve as masks in the curing process. The current method for making these photolithos consists of a filming system with laser technology and a subsequent development stage.

The present paper sets out the results obtained with an alternative system to filming for making high-quality photolithos. This is based on the inkjet system and provides a series of advantages that heighten its appeal. The most noteworthy of these are the absence of consumables or toxic waste, and the system's rapidity, versatility and price.

1. INTRODUCTION

The objective of this communication is to set out the results of a study conducted by ALICER in collaboration with a group of companies from the ceramic sector. The collaborating companies in this study are using the system with very satisfactory results.

This project was developed in the frame of the programme for process innovation, in the plan for consolidation and competitiveness of SMEs funded by IMPIVA. The action undertaken in the project could be defined as technology transfer from graphic arts to the ceramic sector.

The result of this study is not only the outcome of the actions conducted in the project. ALICER's activities include technological monitoring tasks within the frame of a technology transfer project that has been in course since the year 2000, in which the present system had already been identified as a potentially transferable technology, and which was followed up by the first feasibility tests.

2. NEED FOR MAKING PHOTOLITHOS

When we look at a photograph made on photographic material, the image appears in a uniform way before our eyes, whether we observe it through a magnifying glass or thread counter.

However, when we wish to reproduce this by means of mechanical printing systems, it is necessary to turn the image into a pattern of tiny dots which are no longer perceived at a certain distance, giving the viewer the feeling of the original photograph again.

This requires creating a certain number of sheets that contain the necessary percentages of each ink to be applied. The sum of all these percentages during the printing process will again re-create the feeling of the original image.

The way of transmitting this pattern of tiny dots onto the printing screen or the photopolymer sheet is by the photolitho.

The basic principle on which photolitho image transfer to the sheet is based is light. On exposure to a light beam, a polymerization reaction occurs in the material, which cures in those places where the light strikes, i.e., those places that are transparent in the photolitho and let the light through.

3. PHOTOLITHO PREPARATION TECHNIQUES

The most widely used techniques for making photolithos in recent years have been as follows:

3.1 REPROMASTER SYSTEM

This system, now no longer used, has been the forerunner of the present filming system. A specially designed camera is involved, for photographing large-size originals. This system allows making photolithos of the size of the original, and enlargements or reductions of the original by adjusting the optics.

To make the photolitho, the system needs an original on transparent or opaque paper. The quality of the original will determine that of the photolitho.

To produce a patterned photolitho, a template is placed between the photolitho and the original, which will define the shape, angle and resolution of the dot pattern.

This method requires a processor for the development of the photolitho and special lighting conditions to keep undesirable veiling effects from occurring as a result of local light.

3.2 FILMING SYSTEM

The filming system is the most commonly used system at present, and enables obtaining photolithos directly from the computer. The main difference with the photographic system lies in the fact that to obtain the patterned photolitho, an RIP (Raster Image Processor) using complex algorithms tells the laser head of the filming equipment on which dots it should strike.

The high speed of this head and its high resolution allow obtaining sensitized paper which, after development, becomes a high-quality photolitho.

Current filming system resolution depends on system quality, but 2540 DPI, i.e., 1000 dots/cm may be considered a typical resolution.

4. ALTERNATIVE SYSTEM STUDIED FOR MAKING PHOTOLITHOS

The photolitho preparation system proposed in this study is based on inkjet technology. In order to obtain photolithos of appropriate quality for the needs of the ceramic sector, a series of points were established on which the study focused. These points were as follows:

- Printing system.
- Film or sheet for photolitho printing.
- Ink used.
- Data transfer system (RIP).

4.1 PRINTING SYSTEM

When it comes to choosing an appropriate printing system, the system needs to be able to print at a minimum resolution to enable representing the photolitho patterns with sufficient accuracy.

This minimum printer resolution will need to be higher as the ruling of the photolithos to be made rises. As is well known, the screen ruling typically used in ceramic screen printing does not exceed 25 dots per centimetre, sometimes reaching slightly higher values (30-35 dots/cm) in very concrete works. It has been verified that with a printer that attains a maximum resolution of 567 dots/cm, photolithos with higher rulings are made of excellent quality.

On the other hand, the mechanical system of the printer must be of sufficient quality to assure the dimensional stability of the photolithos to be printed.

The eligible printing system will be conditioned by the maximum width of the photolithos to be made. Printers of sufficient quality are available on the market, provided our maximum working width is A2 (42 cm). If wider photolithos are to be made, we shall need to incorporate the appropriate plotter as printing technology.

4.2 FILM FOR PHOTOLITHO PRINTING

The printing film must display a series of features that have nothing to do with a normal substrate or paper. These are as follows:

- Transparent. This is necessary to allow the light of the curing system to pass through perfectly in the curing process and polymerize the emulsion on the screen.
- It must be able to retain the ink that the printer deposits without register defects owing to lack of absorption by the paper.
- Stability on ageing, lightfast and inalterable on exposure to water.

In order to be able to estimate the quality of the different printing materials, a series of tests was run to define the technical characteristics of these materials.

The following tests were performed:

4.2.1. Resistance to water

The tests were conducted by depositing drops of water on the printed surface of different substrates for 24 hours. After this time, the surface was dried (if necessary) and the results were visually assessed.

This led to the conclusion that the use of special papers for transparencies and similar materials was not advisable, since the image was affected by direct contact with water and ambient humidity with time.

Special substrates need to be used, consisting of a permeable polyester adhered to an impermeable one, with a chemical product in between both, which fixes the ink, thus ensuring stability on exposure to water and other agents.

The results of the water resistance tests conducted on these materials can be considered excellent.

4.2.2. Value of transparency

It is important for paper transparency to be high, since the curing principle is based on a difference of transparency between printed and non-printed areas.

In order to compare transparency, density was measured by a transparency densitometer. Density is defined as the decimal logarithm of the ratio of input light to output light, i.e., opacity.

These measurements have been conducted on two sheets typically used for filming and on the four printing sheets studied. The resulting values are set out in the following table:

TYPE OF PAPER	DENSITY VALUE
FILMING SHEET 1	0.040
FILMING SHEET 2	0.070
PRINTING FILM 1	0.055
PRINTING FILM 2	0.085
PRINTING FILM 3	0.055
PRINTING FILM 4	0.070

The results detailed in the previous table enable inferring:

- There are differences in the density values between the filming sheets and also between the printing films. These differences are inherent to the processing system of each company and are of a low order of magnitude, which should not affect the quality of the colour values of the photolitho.
- The density displayed by commercial printing films is of the order of magnitude of filming sheets, so that in terms of transparency, any one of the tested commercial printing films can be considered to display the same quality as that of the sheet used in filming.

4.2.3. Colour fastness to UV light and sunlight.

Film colour fastness on exposure to sunlight and UV light emitted by the UV lamp has been determined. The following tests were conducted:

- Prolonged exposure to sunlight. The samples were exposed to sunlight for a period of fifteen days.
- Multiple exposure to UV curing lamp light. The samples were exposed to 10 typical printing screen curing cycles.

A transparency densitometer and a colorimeter were used to measure density and colour (in Lab) before and after the foregoing tests.

The measurements showed that there was no variation in opacity or colour in any of the evaluated commercial samples.

4.2.4. Price of the printing film

Given the enormous similarity in the results obtained between the four evaluated commercial samples, price was considered a variable to be taken into account.

Very important variations in price of up to 300% were found between suppliers. Specifically, prices ranged from 9 to 30 euro/m2. The lowest price material is comparable in price to that found in the market for film sheets.

On the other hand, the efficiency in the use of the material offered by the printing system is much greater, as process rests are minimal and these rests can be reused in later printings. The filming process usually wastes larger amounts of film, which are of course non-recoverable.

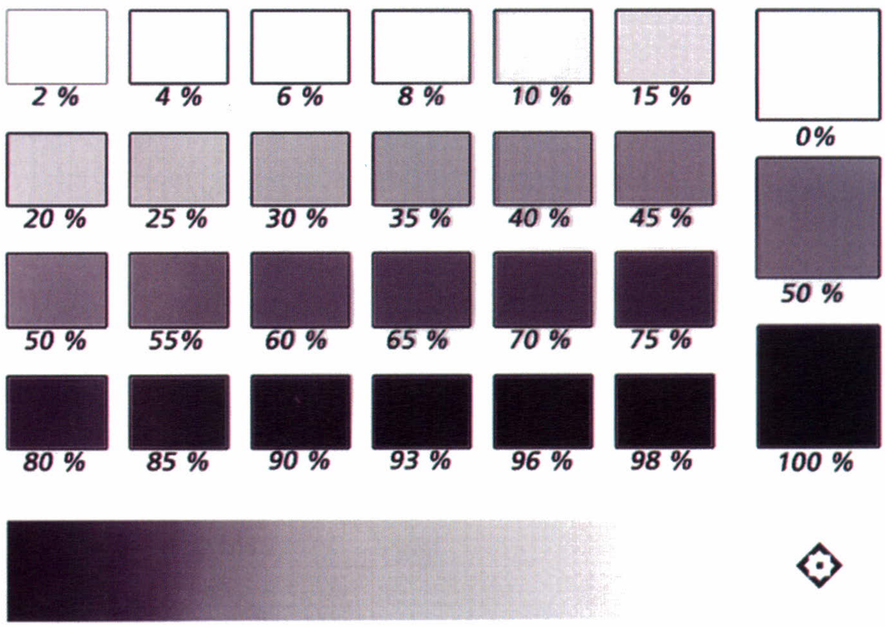
4.2.5 Ink used

The printing ink must have sufficient opacity to keep the light emitted by the curing system from traversing it, and avoid polymerizing the emulsion of the printing screen in these areas.

A special ink for jet printers has been identified in the market, which provides superior opacities to those obtained with traditional inks.

In order to verify the difference in opacity and evaluate the improvements resulting from using a more opaque ink, photolithos were made and printing screens were prepared with these photolithos.

To prepare the photolitho and printing screen, a test photolitho design was used with areas of different dot density, so that the results could be compared across the entire range of dot densities. The test design is shown below:



Three photolithos were made with this design for:

F1: Processing by means of filming equipment.

F2: Processing by means of a printer with opaque ink.

F3: Processing by means of a printer with normal ink.

First, ink density was measured with a transparency densitometer. The results obtained were as follows:

	F1	F2	F3
DENSITY	5.26	5.12	3.35

Secondly, the real dot density values were measured with a transparency densitometer in each of the theoretical designs in the photolithos. The following results were obtained:

Theoretical dot density	Actual values in F1	Actual values in F2	Actual values in F3
2	1	3	3
4	3	6	5
6	5	8	7
8	6	10	10
10	9	12	12
15	13	17	16
20	18	22	20
25	23	26	26
30	28	30	30
35	33	35	34
40	38	39	39
45	43	44	44
50	48	48	47
55	54	52	52
60	58	57	57
65	63	64	63
70	66	67	67
75	71	72	73
80	77	77	78
85	83	83	83
90	88	88	90
93	92	91	92
96	95	94	95
98	98	97	98
100	100	100	100

These results allow drawing the following conclusions:

- The opaque ink (d=5.10) produces practically the same opacity as the photolitho made by the filming system (5.26). Therefore, using the special opaque ink we are assuring opacity values similar to those of a filming system.
- The opacity produced with the normal ink (d=3.35) is considerably lower than that obtained with the special ink (d=5.10). A priori, this lack of opacity compared to that produced by filming or the special ink suggests there will be substantial differences in register when it comes to preparing a screen.
- The photolithos made with the special ink and the normal ink exhibit no substantial differences in the readings of the transparency densitometer. As mentioned, the densitometer readouts might have been expected to give different percentage values, but this was not the case.

After preparing and analyzing the photolithos, a series of screens was made as set out below:

P1: Screen cured with F1 (filming equipment) and F2 (printer with opaque ink). With this test it was attempted to compare the results of the filming system and the jet printing system.

P2: Screen cured with F2 (printer with opaque ink) and F3 (printer with normal ink). This test was intended to determine whether it was necessary to use this special ink or whether the standard printer inks were sufficiently opaque for the work, and in which terms.

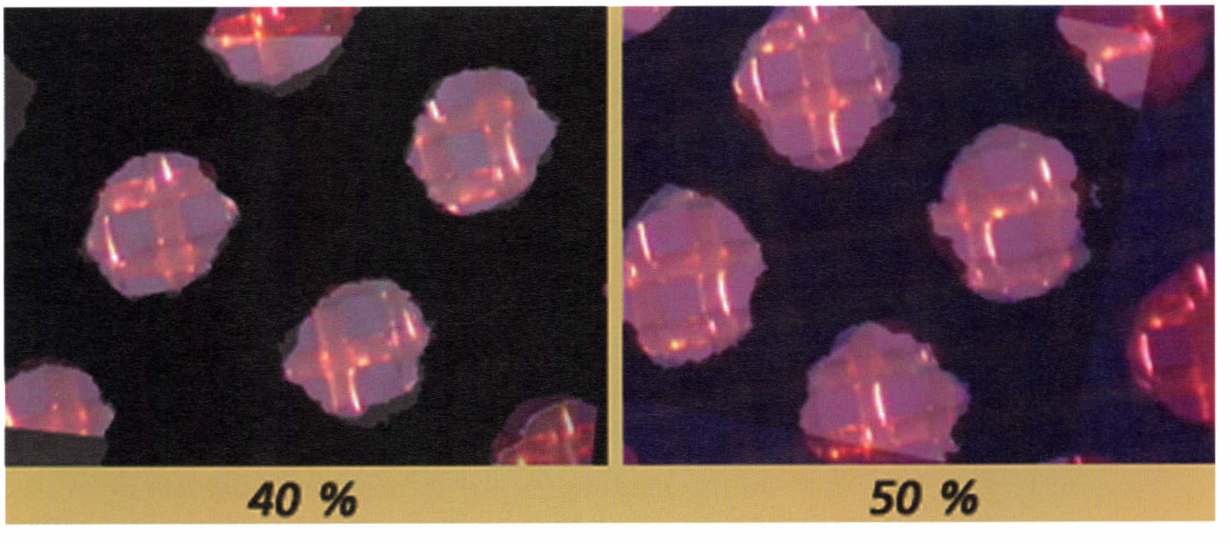
The photolithos to be compared were cured on the same screen to eliminate any possible variable inherent to the printing screen preparation process.

To enable comparing the curing results on each screen, a diameter of 10 dots of the screen pattern was measured in each dot density area to obtain a mean diameter value. The table below presents a representative sample of the values obtained:

	P1		P2	
	Dot diameter in F1 (μ)	Dot diameter in F2 (μ)	Dot diameter in F2 (μ)	Dot diameter in F3 (μ)
10 %	118	125	127	125
30 %	216	219	221	218
50 %	284	286	288	289
70 %	342	348	349	346

In order to better visualize the comparative results of the photolitho made with normal ink and the photolitho made with opaque ink, an arrangement has been devised by means of image treatment software. This arrangement involves superimposing one photolitho on the other to determine whether the size of the dots on the screen is the same, independently of the photolitho used.

The results were as follows:



Analysis of the results obtained in the measurements enables drawing the following conclusions:

- Independently of whether the photolitho is made by filming or jet printing, the resulting dot size on the printing screen is the same.
- The results obtained using a normal ink or a special opaque ink on the screen are the same. This observation can be explained by the following theoretical

reasoning: normal ink has a density of 3.35. Since density is the decimal logarithm of the ratio of emitted light to received light, a value of 3 means that the emitted light is 1000 times greater than the received light, i.e., the ink absorbs 99.90% of the light. Of course, if the value of density is 5, light absorption is 99.9990% and theoretically the result is better, but in fact this difference is inappreciable.

4.2.6. Data transfer system (RIP)

When referring to the preparation of photolithos at the outset, the need was remarked to turn the image into a pattern of tiny dots. To do this, the printing system needs to deal with the graphic information in the appropriate form, by hardware or software, in order to turn it into an appropriate dot pattern for each ink, without losing or altering the original information.

In the approach adopted in the present system, this software is necessary because the working printer is a non-postscript printer, i.e., a printer that does not have the appropriate hardware to perform this transformation. The term hardware should not be misunderstood, as this is really a computer with RIP software on its hard disk.

In recent years a great number of programmes have appeared on the market (software), which perform the RIP functions of the filming equipment without needing to have it implemented in the printing system.

Determining the most appropriate software for one's work environment depends on many variables, which include maximum work format, maximum work resolution, type or types of grid to be used, response speed, volume of memory required to process the image, quality of the transformation, number of working inks, price of the software, etc.

In this part of the project, we analyzed these variables, with a view to identifying the best software on the market for our purposes.

a) Printing format

In this section we generally find software programmes developed in two versions, a more economical one for formats with a maximum width of A2 (42 cm) and a more expensive one, which however enables printing larger-size photolithos using a plotter as a printing system.

b) Reproduction faithfulness

The reproduction in the dot pattern sequence generated is exactly the same as that generated by the filming equipment. It is therefore not only possible to make new photolithos, but exact replicas of photolithos can be made from the graphic file from which these were generated.

c) Working speed

Working speed refers to the period of time that elapses from giving the print command until the printer starts printing. Depending on the programme used, this time ranges from about 5 seconds to one minute for an A4 format design.

Printing working speed is always the same with all the programmes and corresponds to that of the maximum quality of the printing system used.

d) Postscript work resolution

The postscript pattern is one that is always used in screen printing ceramics. The working resolution is limited by the printing system, not by the software. The tests conducted have allowed us to work at postscript resolution of 30 dots per centimetre without any problems.

Occasionally, it is the software version that limits the maxima resolution, since this may not allow the printer to work at optimum resolution.

e) Compatibility with usual design software in the ceramic sector

The operation of these programmes is very simple, since it is the image processing software that automatically puts it into operation when printing, after the printer configured for this purpose has been manually selected from the printing menu. It thus becomes an application that enables printing photolithos from any image processing software typically used in the sector. In particular, operation with CORELDRAW, PHOTOSHOP, FREEHAND and WORD has been verified. The evaluation using all of these programmes in their latest versions was always positive.

Again it should be noted, that each software is developed at a given time for the then existing platforms and systems. Care should therefore be taken when it comes to selecting a programme, ensuring it is compatible with the system in which it is going to be installed, and that it complies with the minimum requirements.

5. ADVANTAGES OF THE JET PRINTING SYSTEM COMPARED WITH THE FILMING SYSTEM

The main advantages of the jet printing system as opposed to that of filming are as follows:

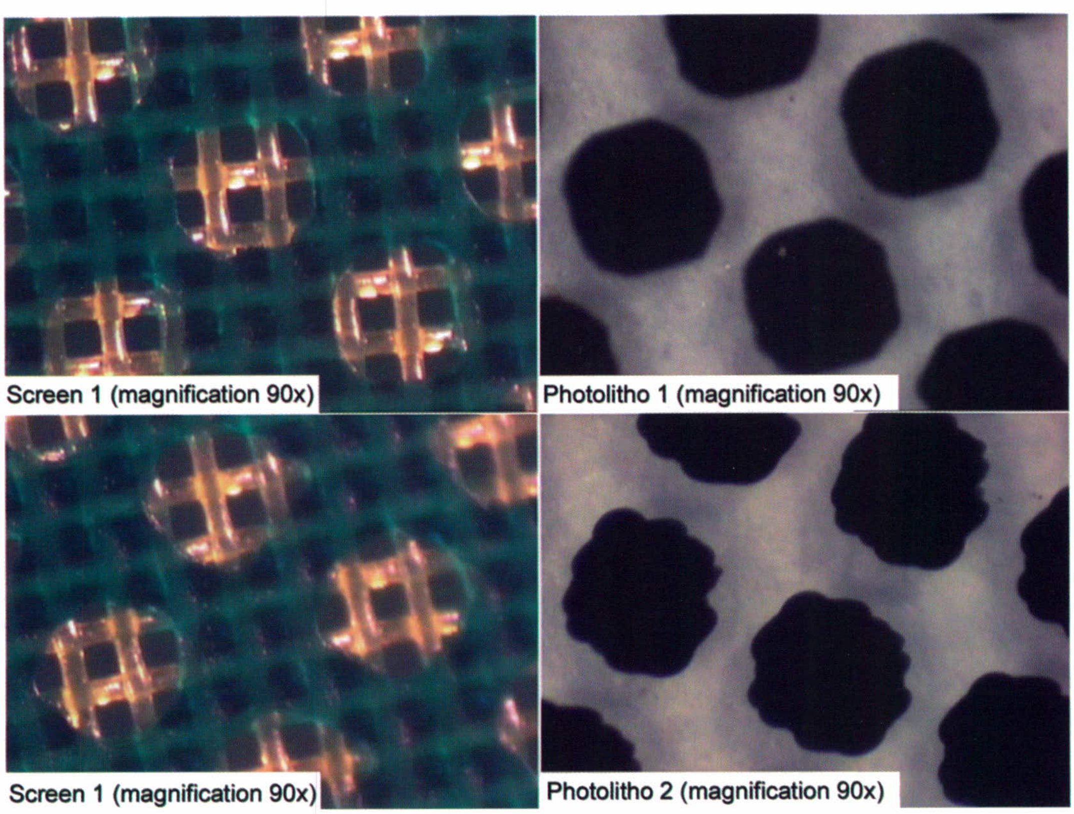
- Economical. The investment required is much smaller than that for filming and development equipment, as it only involves the purchase of a printer and computer software. On the other hand, the consumables involved are an ink and a special film, and the cost per unit surface area photolitho is much less than the cost of these items in filming.
- Clean. No toxic products are used. The traditional developing process uses developing and fixing products that contain hydroquinone. This substance is classified as a carcinogen mutagen of type 3 (verified in animals but not in persons) by the European Union. Moreover, it is a skin irritant, and excessive exposure to this substance can lead to problems of sight. It requires the use of gloves and safety glasses.

  The jet printing system generates no toxic wastes, so that no waste handler is needed for waste disposal. In contrast, developing and fixing processes do generate wastes that are considered toxic, particularly because of the presence of a dissolved silver thiosulphate complex.

- Rapid. The time required for making a photolitho is the same as the time needed to make a maximum quality print. The filming process involves two stages, film sensitization and development, which considerably extend processing time.
- Versatile. The printer can be used in a conventional way when not used for making photolithos. However, the filming system can only be used for making photolithos.
- Space saving. While the space occupied by a printer is minimal, the filming equipment and developer occupy a much greater space. In addition, because of the toxicity of the products used in developing, a specially conditioned space (ventilated and insulated) is required.
- Savings in maintenance. Filming systems require control and periodic replacement of developer liquids, while any malfunctions are usually much more expensive to troubleshoot. In contrast, the printing system just requires a change of ink when the cartridge runs out.
- Greater process reproducibility. Each printing system model just requires a curve adjustment. However, filming systems must be periodically calibrated, in addition to when liquid developers are replaced, since important variations occur in colour values.

6. COMPARATIVE ANALYSIS OF BOTH SYSTEMS FOR THE PARTICULAR CASE OF CERAMICS

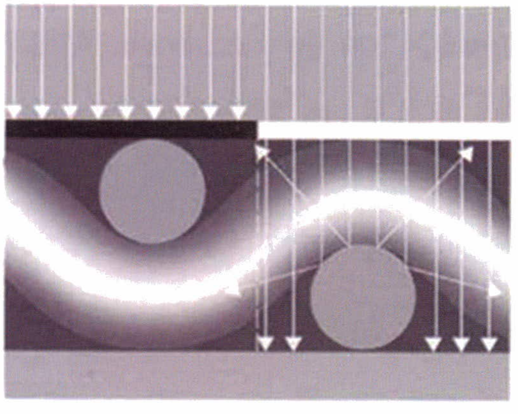
The intention of this study has not been to demonstrate that the photolithos obtained by the jet printing system are of greater quality than the ones made by the filming system, since that would be a serious error on our part. In this sense, it suffices to simply observe both amplified photolithos to confirm this:

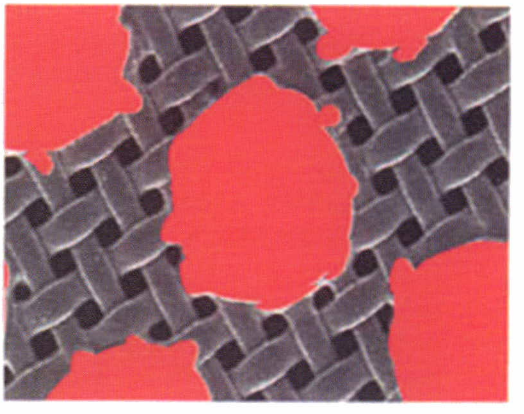


It has however been attempted to demonstrate that the quality obtained on the ceramic piece by means of the inkjet printing system is the same as that produced by the filming system.

The nature of the ceramic inks forces to us to work with screen printing fabrics of a relatively low mesh count, so that we must pattern the photolithos to very low resolutions to obtain better graphic results. These low work resolutions, together with the firing process inherent to ceramic materials, favour the use of jet printing technology, which affords many advantages compared with the filming system.

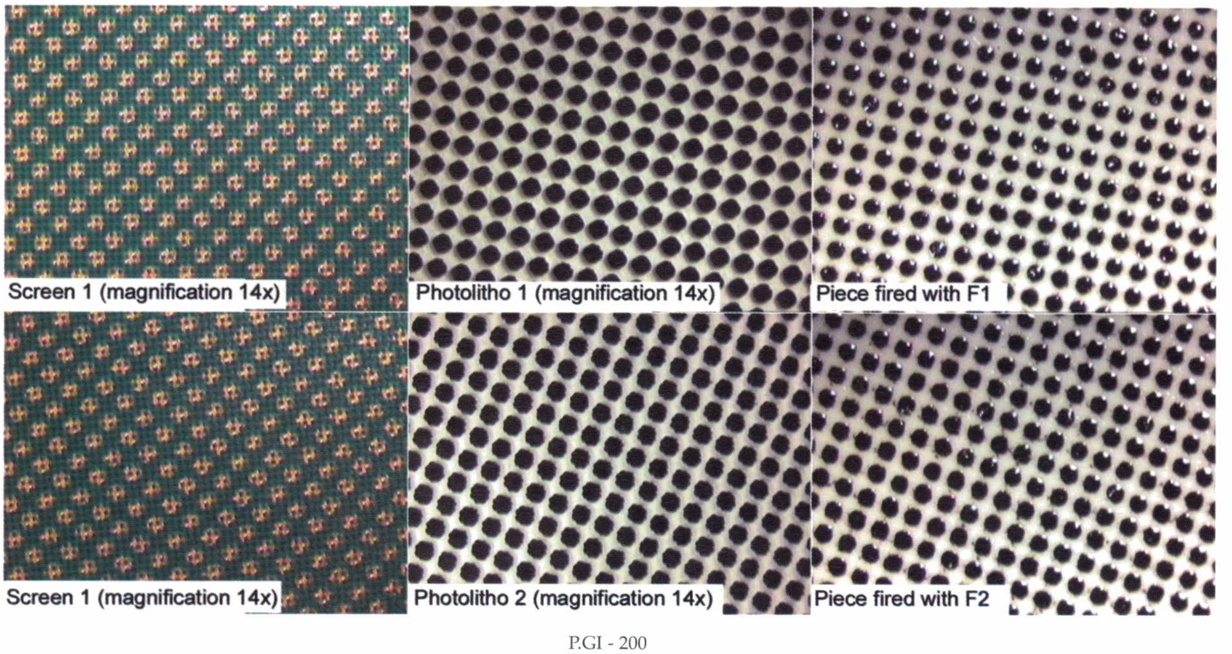
The previous image enabled appreciating the differences between photolithos made by one technique or the other. This image already shows that these differences are highly attenuated on the printing screen. This is because of the light reflection phenomenon that occurs in the curing process. This phenomenon, as may be observed in the bottom image, produces hardening of the emulsion in areas in which this should not in principle happen.





As a result, small flaws occur on the perimeter. This phenomenon is inherent to the process, unless coloured fabrics are used to avoid this reflection.

If we now go on to see a dot pattern area, however at much more reduced magnification (14x), and in addition include the result on the fired piece, we obtain the following image:



This demonstrates that at natural size and in normal working conditions on an already fired piece, the small dot profile flaws caused by the impact of the drops of ink on the film are quite negligible.

7. CONCLUSIONS

The main conclusions to be drawn from the study are as follows:

- The use of jet printing technology for making photolithos with rulings below 30 dots/cm is feasible.
- There are important savings in costs and investments compared with the filming system.
- The jet printing system uses no toxic products, nor does it generate these.
- The system has been implemented in the companies collaborating in the study and is currently their customary system for making photolithos.

8. ACKNOWLEDGEMENTS

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