MANUAL SCREEN PRINTING

1. **Manual screen printer SP1.S-general**

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3. **Description of device and its function**

4. **Screen SP1.S**

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6. **Processing method**

BVT Technologies

1. Manual screen printer SP1.S - general

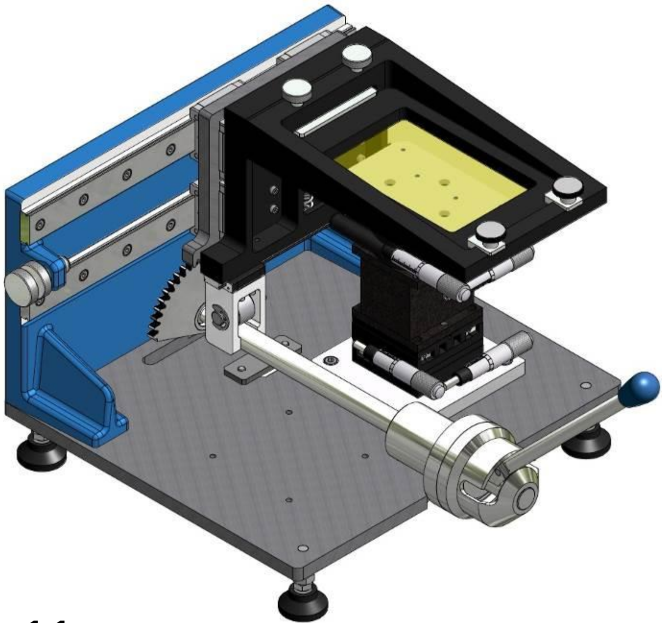


Fig.1.1

SP1.S is a manual high precision screen-printing device, which can be used for carrying out R&D and small-scale production activities. Pastes, inks, paints and other viscous / thixotropic materials can be printed on different substrates. Printing of enzyme materials, other active substances on the screen-printed sensor-working electrode can be carried out very effectively and efficiently using this printer.

The standard maximum dimensions of the substrates, which can be used with the SP1.S are: T 0,63 mm, L 34 mm and W 10,0 mm. However the clamping table is a de-mountable part and other specific clamping tables can also be used to process substrates having other dimensions.

The thickness of the printed layer depends on the distance between the screen and the substrate, thickness of the screen, force pressing printing materials etc. The quality of the printed elements is also dependent on the screen quality, material viscosity & thixotropic nature, environmental temperature, moisture etc. **REMEMBER: Screen orienting is 90% science and 10% art. The skilled handling is the secret of successful use.** BVT assures the training in screen printing (see www.bvt.cz) Under optimal conditions printed elements having atypical dimensions (line gap) 100μm can be achieved. Using special screens ("fine line") the resolution 50μm can be achieved. Using "FODEL" technology the resolution limit is 20 μm. Short introduction in the screen printing technology is chapter 2.

Tab.1 Technical specification

Sr No.	**Model Type**	**Technical Parameters**	**Description**
01	SP1.S	Mass	8 kg
		Dimensions (Length) (Width) (Height)	 300 mm 340mm 250 mm
		Clamping	Vacuum
		Positioning	X = 13mm Y = 13mm Z = 10mm φ = 0-360 fine-tuning ± 5 degrees
		Printing	Manual Ink slice

2. THICK FILM TECHNOLOGY

Introduction

Thick Film Technology (TFT) is considered as one of the oldest microelectronic technologies with it's origins traced back to 2000 years ago when it was used in simple graphic display and decoration(1). World war II applications in the production of proximity fuses for bombs saw the initiation of TFT in the modern world. The potential of TFT was further realised in simple preparation of printed circuits in large quantities at a relatively low cost. The first aim involved integration of simple electronic devices in lower volumes and one step production of conductors and resistors(2). Further integration included capacitors, thermistors and some special layers such as electroluminiscent thick films, ferroelectric thick films, ferromagnetic thick films, high temperature superconductors and conductive polymers (3). The eighties and the beginning of nineties saw a decrease in the importance of TFT in field of microelectronics. Three main reasons for this occurrence may be cited as – Development of classical PCBs which offer similar density structures as TFT – Development of monolithic integrated circuits enabling higher circuit density – New technologies such as chip on board, surface mount technology (SMT) etc. This resulted in diversification of TFT as an auxiliary technology in PCB, SMT and monolithic integrated circuit packaging. In last few years TFT as an independent technology has found new application areas such as chemical sensors, gas sensors which reflect greater convenience in production and usage.

The physical end economical limitation in large scale integration of electronics lays emphasis on dimensions lower than 0.1 micrometer. Such dimensions can be achieved through monolithic technology only. But there are other applications where the preferred dimensions lie in range 10 – 100 micrometers. E.g. Systems consisting of complicated analytical devices and sensors containing channels, filters, pipes, micropumps. Of course monolithic technology can be also used for producing the systems in this larger dimensional range but their use is cumbersome and very expensive due to lengthy depositing time, etching time & sample preparation. The more important trend in TFT is to cover the applications with conductor width, channel width, sensor active parts in size range 10 - 100 micrometers. The competitive technologies to TFT are PCB, SMT, Thin film technology and Monolithic technology. While Thin film technology which normally involves vacuum deposition technology can offer significant improvement in performance and provides very good properties for planar structures with dimensions ranging in the size 1 -100 micrometers, the thickness of deposited layers higher than 1 micrometer is normally expensive. The costs of materials and equipment are also considerably higher than those required for TFT.

TFT is conceptually a simple process, which can be semi or fully automated. This advantage is namely obvious in comparison with classical chemical sensors, electrodes or other hand made chemical equipment production methods. Consequently, the manufacturing facilities that can be established vary from inexpensive semi-automated low volume production to fully automated facilities [3].

Classical TFT

The concept of forcing a viscous fluid medium (paste, ink) through a mesh-reinforced stencil is apparently simple but the quality of the print is influenced by many processing variables. The most important of these are the rheological properties of the paste. The control of printed medium flow through the screen is necessary to ensure homogeneity, of printed geometry and homogeneous thickness of the printed layer. In addition the flow has to be stopped immediately after printing to assure the geometry precision. This means essentially that the material must be thixotropic in nature and velocity of the squeezing process has to be precisely controlled. Another precondition is that the paste should be hydrophilic in nature. The paste must wet printed material and it must not stick on the screen the paste must be hydrophilic to printed substrate and hydrophobic to screen material. Fig. 2.1 describes the principle of the printing process.

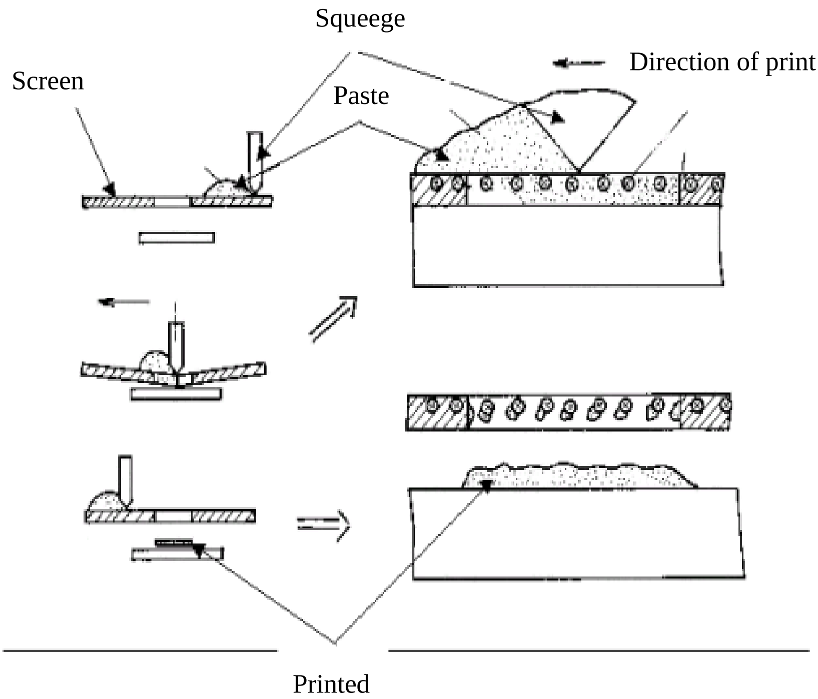


Fig. 2.1 Principle of the screen printing process

The pastes are not normally capable of flowing through the screen by the action of gravity or surface tension. A pressure has to be applied on the paste to ensure the flow movement. This action causes reduction in the viscosity of the material due to its mixing. The dynamic pressure is generated within the bulk of paste by squeegee movement, forcing the flow of paste through the mesh openings. The quantity of the paste has to be sufficient, in order to completely fill each opening before the squeegee edge passes over it. The velocity of squeegee, its pressure on the screen and volume of the paste has to be optimised in such a way that the downward pressure of squeegee assures a close contact of the screen with the workplace. The paste wets the substrate surface. with the fibres of the screen having hydrophobic behaviour, after printing negligible quantity of the paste rests on the screen and the fibres leave a relatively invisible pattern on the printed structure due to increased fluid nature of the paste. When the print is ready the workplace is placed in quiet for some time to ensure creation of a homogenous thickness caused by the paste surface tension.(typically 10-20min) After a brief time interval, the process is stopped, by drying of the printed sample. The run of the paste viscosity during printing process against time is on the fig. 2.2

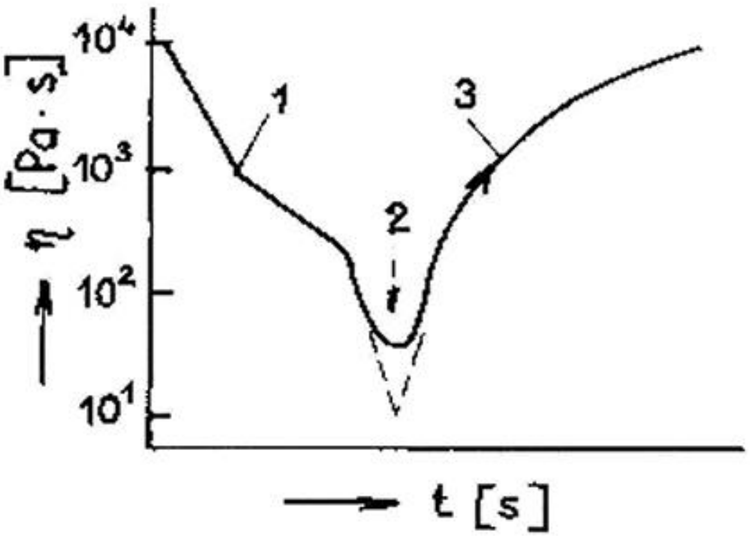


Fig. 2.2 Viscosity changes during printing process

During the printing as the squeegee is moving towards the printed point the paste is increasingly influenced by dynamic pressure and mixing and the paste results into fluid form (viscosity reduction from point 1 to point 2). At the point 2 the paste flows through the screen and is printed on the substrate. During this process the edge of the squeegee is directly above printed point. At Point 3, the fibres of screen are withdrawn from the paste and the paste levels itself to a final uniform deposit thickness. The viscosity of the paste returns to its original value.

After printing the layer is dried. It can be reused for new printing process or it can be fired as the situation demands. The firing process stabilises the layer. The materials are sometimes very sensitive to the firing conditions and a precise control of the temperature is required. During the firing process a number of important reactions occur which define the resultant electrical, mechanical and chemical properties of the layer. The reaction can be divided into two main groups:

- High temperature process
- Low temperature process

The high temperature process contains next steps.

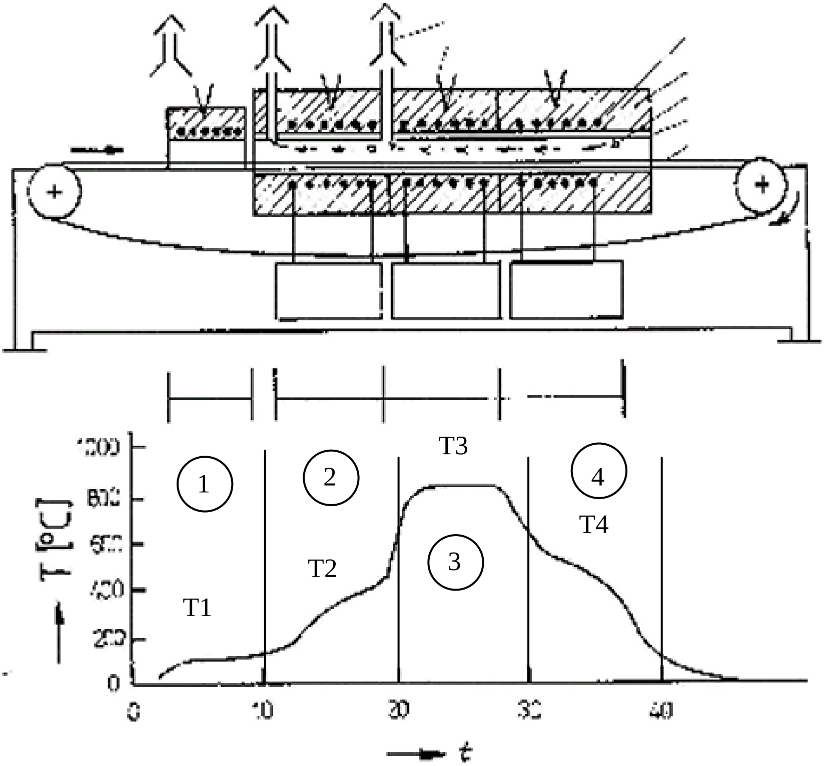
1. Draging of the layer (t1, T1)
2. Removal of the organic printing vehicle (t2, T2)

3. Melting of the frit and development of the bond with substrate (t3, T3)
   (The paste contains particles (nanoparticles) of metal or dielectric material and special glass. The special glass is named frit. The frit is designed in such manner that its melting point is lower than metal or dielectric grains and it react with grains and layer on which it is printed. At temperature T3 is created compact composite material.)

4. Re-crystallisation is not used at all printed materials. If it is used then after appropriate thermal process the melting print of frit is significantly increased. This enables to use the printed layer for next printing process without change of its properties. (t4, T4)

5. Cooling (t5,T4)
   Cooling is very important process. During cooling all internal tensious must be removed. This assures the mechanical stability of printed layer.

   Different pastes have different contents of frit, aditives and active parties depending on the application and hence only some or all of above-mentioned reactions may be present. The typical firing profile is depicted on the fig. 2.3



<u>Fig. 2.3</u> Typical TFT firing profile and zone belt oven structure.

The drying of the substrate is often made in one technological step with firing (fig. 3 - 1). The removal of the organic binder takes place during the early stages of the firing cycle (fig.3-2). In special materials t2 can be up to tenth of hours. Next steps is firing. The frit development, development of bonds between active particles of the paste which will bear the final properties, chemical reaction in layer & between layers (fig.3-3). Uses (In special applications t3 can be 14 days!) The re-crystallisation, which enables repeated firing, occurs during the final stages (fig. 3 - 3,4). The cooling process is by t5, but sometimes the cooling process takes hours. A Schematic view to the thick film belt furnace has also been depicted on the fig. 3 too. It consists of different zones with specific parameters set according to the processing stages. The optimum firing process is sometimes the most valuable know how. Very frequently the temperature must be maintained with a precision of $\pm 1^{o}$C.

The producers of pastes recommends the optimum values of all times and temperatures including the screen parameters. Start by recommended parameters each technological optimization of printing process.

The requirements in precision of geometrical patterns is much higher in applications concerning preparation of active parts of sensors (the response depends on the active electrode area) or channels for CE (the homogeneity of channel and its wall smoothness influence the quality of separation) as compared to the electronic industry needs. Therefore the influence of screen quality on these parameters has to be discussed [(6)].

Four basic types of screens and printed layer structures are depicted in fig. 2.4. The upper row shows the cross section view on the screen. Below it the hole adhering to the substrate filled by paste can be seen.

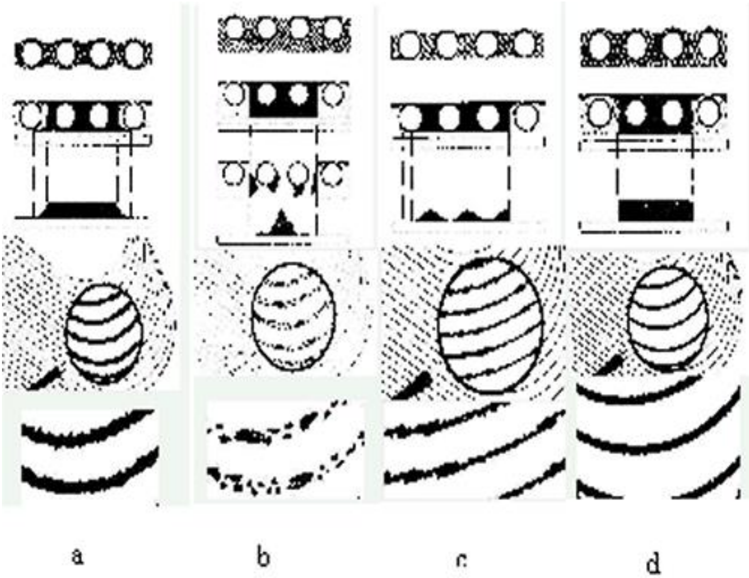
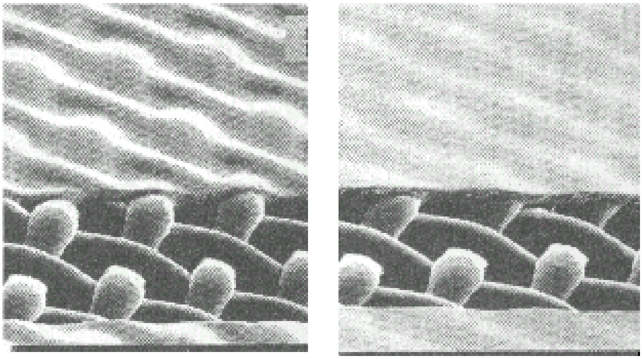


Fig. 2.4 Structure of the print for different types of screens

Next row shows the structure of the printed layer on the substrate. The last two parts of the picture show the printed motif and the detailed structure of the printed line at high magnification. In case of (a) the thickness of the emulsion is too small while in case of (b) the thickness of the emulsion is too big. Fig. (c) depicts the case where geometrical motif is improperly oriented to the structure of the fibres in screen. Fig (d) depicts the optimal screen structure. It assures a precision of the print in 1-5 micrometers (slope of the sides of printed structure) and thickness homogeneity of about 1 micrometer (per layer). The optimal screen structure is strongly bound to the rheological properties of the paste. The microphotography of screens of type (a) and (d) are shown in fig. 2.5.



a d

Fig.2.5 Microphotography of the screen with low thickness of the emulsion (a) and the optimal thickness of the emulsion (d)

Finally the reliability of the process depends on many factors including the inbuilt design safety factors, number of joints and cleanliness [7] of the manufacturing process. The last factor includes the cleanliness of raw materials such as substrates, the quality of chemicals used, the quality of cleaning and water purity, operator garments and the manufacturing unit perimeter cleanliness.

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3. DESCRIPTION OF DEVICE AND ITS FUNCTIONS

Steel Base Plate (1)

This is the base / foundation element of the device. All the other parts of the device are installed on this plate. It assures the rigidity and stability of device.

Movable Screen Holders (2), (3)

Sreen holder (3) is mounted on bearing plat (2) which moves in x and z axis. End position on x-axis are fixed by magnets (7) (The position is adjusted by producer do not change it)

Moving unit (5)

The movement of the screen is done by handle (5). When the handle is moved to P1 position, the screen is in right end position. Then the movement of handle to P2 position moves the screen downto printing position. The movement handle back to P1 moves the screen up. The movement to I1 position enable insertion or including the substrate on which it is printed.
The optional position 0 is prepared for tampo print or other sophisticated printing methods. ,

Co-ordinate table (6) –detailed picture-Fig 3.2

The co-ordinate table is located on the steel base plate (1). This table allows x-y-z axial displacement of the substrate holder with respect to the printing screen. The displacements can be carried out using the screws (6a) (6b) and (6c) with precision 1 μm. Additional screw (6d) allow rotation of the co-ordinate table around the vertical axis with precision <1°.
After substrate positioning a positions can be fixed by screws.

Vacuum attaching plate (8)

The detail/substrate which is printed on in fastened in clamping desk (8) using vacuum. The detail must placed in grove in the working table. The printed surface is in the same hight as the surface of clamping table.

The manual printer must be placed on rigid table in horizontal level. It can be checked by libela.

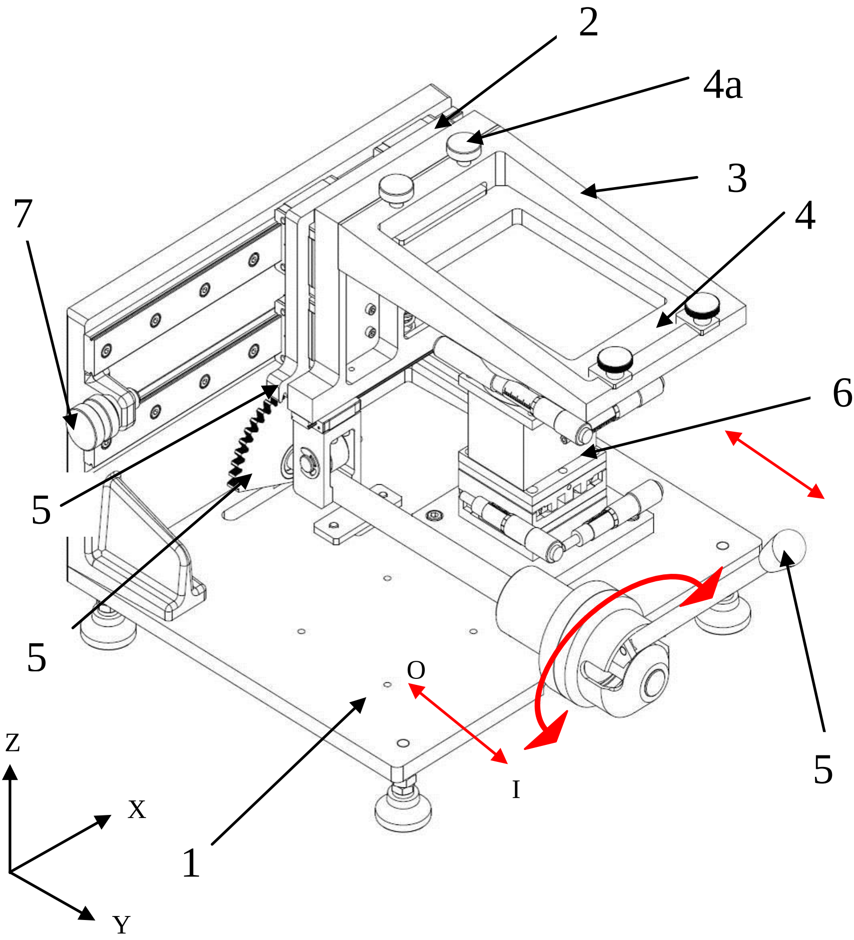


Fig. 3.1

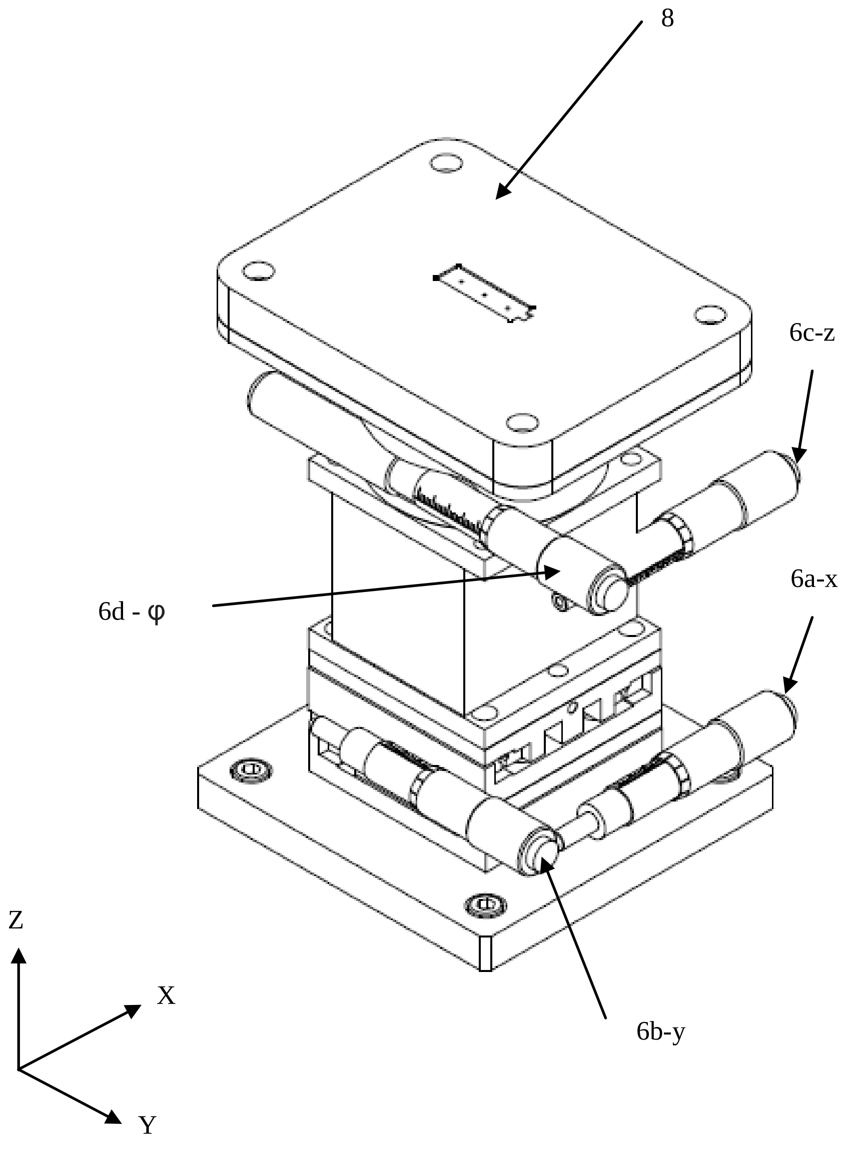


Fig. 3.2

4. Printing screen unit SP1.S

The Printing screen unit SP1.S is of standard dimensions, which can be used with the manual screen printer SP1.S. The foil has a design in the exact shape and dimensions of the working electrode structure of sensor AC1. Thus exact printing of active materials on the sensor-working electrode can be ensured with this printing screen. All informations about screens are archived by BVT. The number of screen is on the right corner of frame. In positioning of the screen in the printing machine it is necessary to put the screen in such position that the number is on right side. In case of more complicated structures the print quality depends on the orientation of the screen. We are able to assure for you more than 100 different types of sieves from plastic, more than 10 different sieves from stainless steel. All of them can be equipped by different emulsions in different materials.
The parameters of standard screen SP1 are

Plastic sieving
110 - 34Y

Mesh :		1 : 1
Number of fibers per cm	[n/cm]	110
The size of window (the side of square)	[μm]	54
The diameter of fiber	[μm]	34
The theoretical open area (percentage of total area)	[%]	35.5
The thickness of sieving	[μm]	55
The tolerance of thickness	[μm]	+/-3
The volume in the sieving	[cm^3/m^2]	19.

5. Other accessories

The other accessories provided with the manual screen printer consist of squeegee. The printed material is forced through the printing screen onto the substrate surface with the help of the squeegee.
It is delivered the standard hardness at square. It necessary other hardness can be delivered or other geometry of square edge.

6 . Processing Method

1. Place the device on rigid stable table. Check using libela it is in horizontal level.
2. Move the screen holder to left position (Fig. 6.1-Fig6.3)

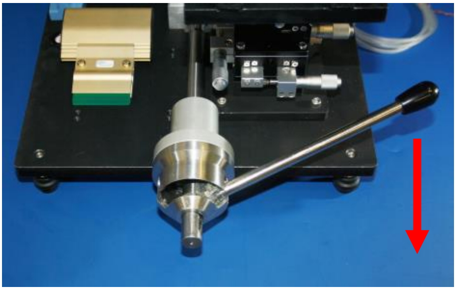


Fig. 6.1 – printing of handle red arrow-movement up of screen

Fig. 6.2 – of screen from printing position (red arrow)-movement of screen to left position

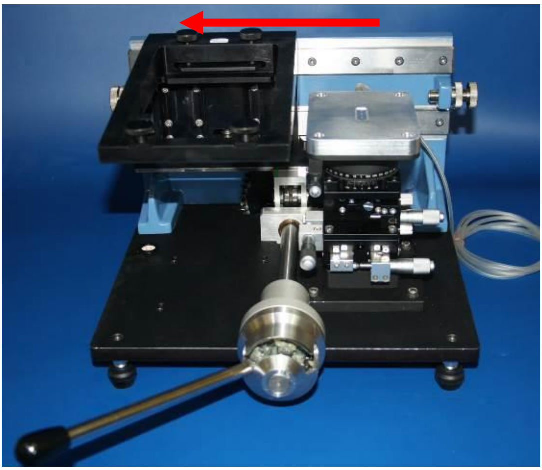
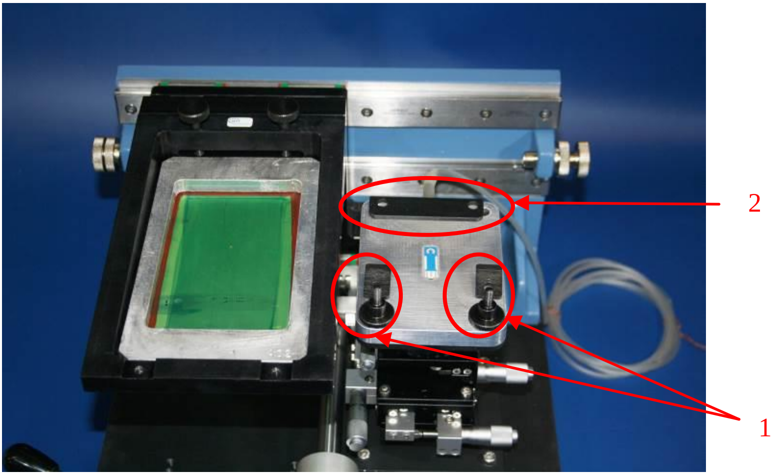


Fig. 6.3 The screen holder is in left position prepared for screen insertion

3. Insert the screen holder to left position (Fig. 6.4) and fasten is by screws.



<u>Fig. 6.4</u> The screen is placed in holder and screws for its fastening are prepared.

4. Move the clamping table to its down position (z=0) by micrometric screw (Fig. 3.1-6c) and move the screen to printing position (Fig. 6.5-Fig. 6.6)

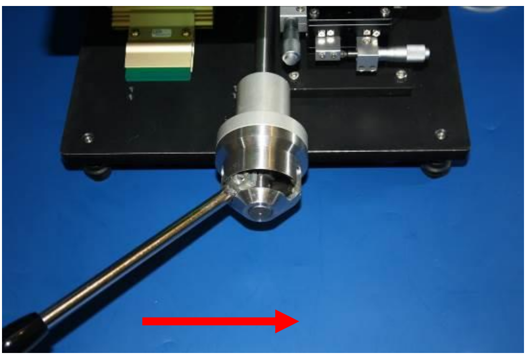
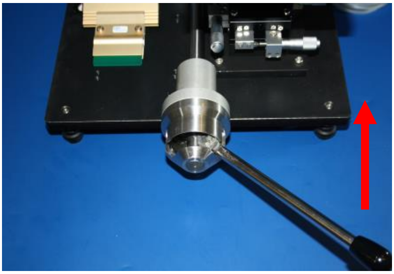


Fig. 6.5 Move the screen to right position (the z axis =0, The working area is in low position.)



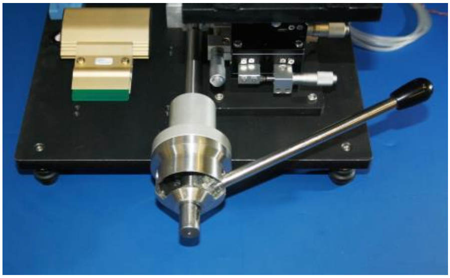


Fig. 6.6 move screen to printing position

5. Adjust the gap to optimum value (500 µm) (Fig. 6.7)

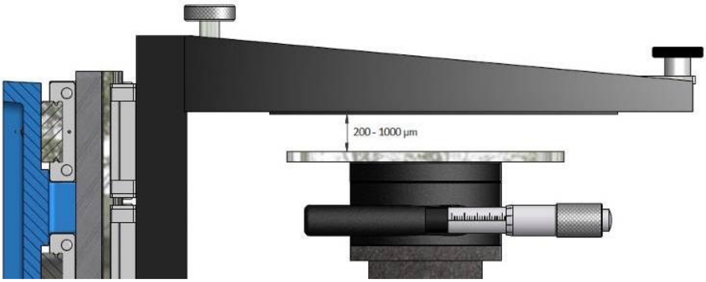


Fig. 6.7 Adjustment of gap between screen and substrate (move the working table in z axis unit is touch the screen. Then move the table down to adjust optimum gap.
The recommend gap to start printing is 500µm).

6. Adjust the gap on the screen to the printed substrate (Fig.6.8 Fig 6.9) using the micrometric screws on the x-y-z table.

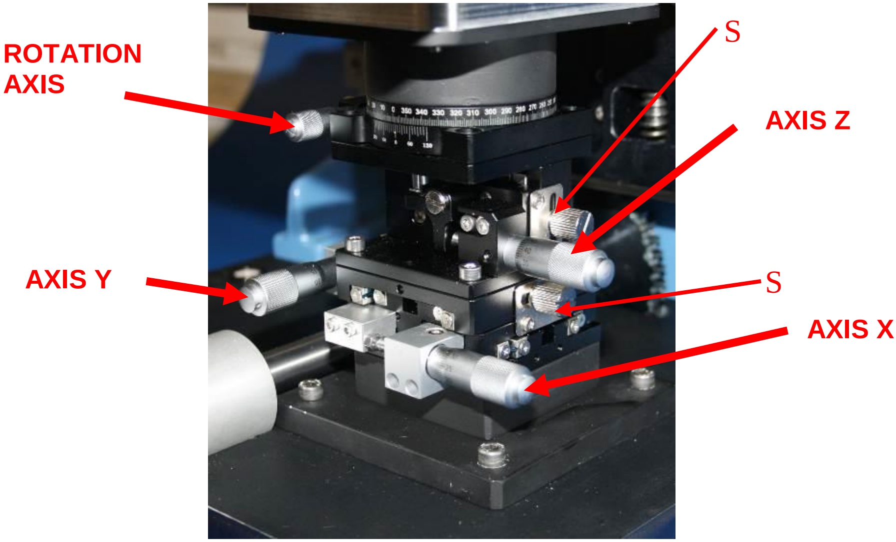


Fig. 6.8 Adjust the screen with respect of substrate to assure right geometry of printed motive. When the position is adjusted safe the position by screw S.

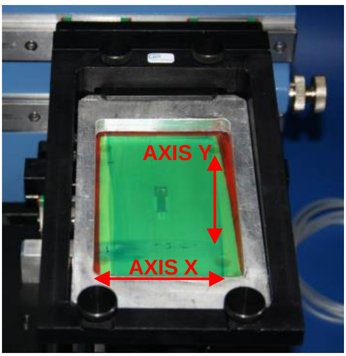


Fig. 6.9 The device is prepared to print.

7. Insert the sensor, element or substrate must be printed on in the slit on the working table. Remember: The substrate must be moved to upper left corner and then fixed by vacuum. If it is not done then the freedom of movement in holder will decrease the printing precision. (Fig 6.10). Move the screen to the printing position (Fig .6).

Fig.6.10 Insert substrate in the holder (The ceramic substrate for AC1 sensor on fig)

8. Mix thoroughly The paste and spread it an the edge of squeegee (Fig. 6.11)

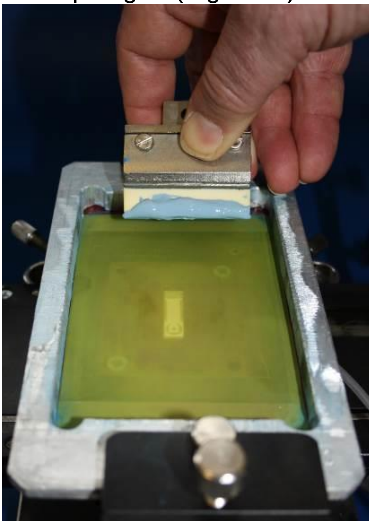
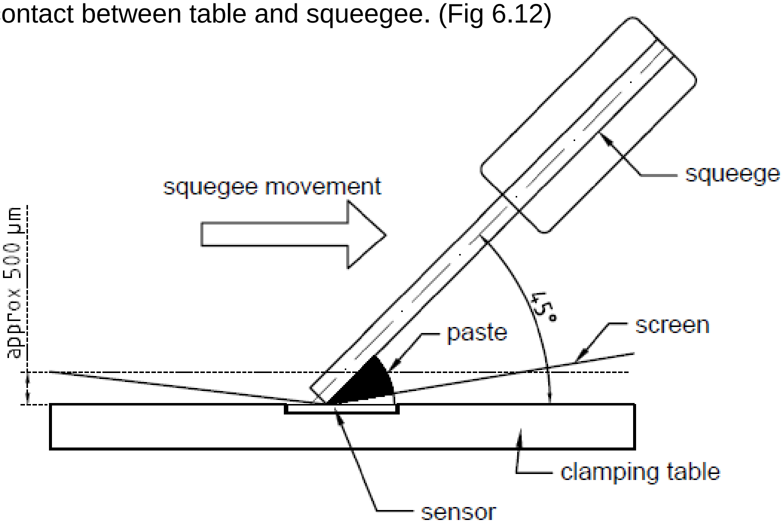


Fig. 6.11 Spreading of paste are the square.

9. Grab the squeegee by both hands and press gently to feel the contact between table and squeegee. (Fig 6.12)



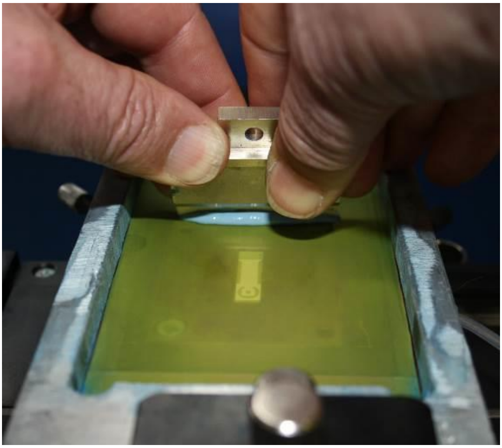


Fig. 6.12 Printing

10. Move the screen to the left position (Fig. 6.3) and with draw the product with printed layer (Fig. 6.13)

Fig 6.13 End of printing –with draw the final product.

The Printing is made by repetitive of steps 8-10.
After end of printing the screen must be removed and carefully washed by solvent. Most frequently alcohol is used but each paste has its optimum solvent in its data sheet.
Example of paste datasheet (DP6160-conductor) is in attachment. Note that it contains all important information including compatibility. Remember not all pastes are compatible. The use of incompatible pastes generate strange or nonstandard properties of final product. The origin this problem is difficult to identity.

Screen printing is a part of powerfull microelectronic technology, as Thick Film Technology (TFT). BVT is prepared to help you with your specific problems or to assure training of TFT use in your cinditions.