Report of One Day Seminar on "Hands-on-Experience on Soft Lithography"		
Sr. No.	**Item**	**Description**
01	Agenda of the programe	To give exposure and a hands-on-experience to the participants (the faculty of different Engineering Institutes) regarding 1) The photochemical machining process and the required facility. 2) Step by step procedure of PDMS Microstructure fabrication. 3) Microstructure characterization and the required equipments. 4) Use of COMSOL Multiphysics software for micro-fluidics simulations.
02	Photo of Dias at Inauguration showing IEI Banner	
03	Photos of Speakers	 

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04	Technical notes	**The Institution of Engineers (India)** **Solapur Local Center (Mechanical Engineering Division)** in association with **SVERI's College of Engineering, Pandharpur** organizes **One Day Seminar** **on** **"Hands-on-Experience on Soft Lithography"**

On Sunday, 16-08-2015 (10:00AM to 05:00 PM)
At

SVERI's College of Engineering, Pandharpur
Gopalpur, Tal-Pandharpur-413304

BOOKLET FOR
HANDS-ON-EXPERIENCE PRACTICALS

Schedule of the day

Time	Program	Description
9:30-10:00am Registration		
10:00-10:20am Inaugural Ceremony		
10:20-10:30am	Product Launch: Micro-fluidic Demo Kit	SVERI has developed a Low cost Soft-Lithography based Micro-fluidic demo kit, which will help engineering institutes to demonstrate micro-fluidic phenomenon to undergraduate and post-graduate students.
10:30-11:00am	Keynote Speaker: Research Activities in the field of Micro Domain -Dr. R. Balasubramanium	Dr. Balasubramanium is Scientist at Precision Engineering Division at BARC, Mumbai and is working on various cutting age application in the field of micro-nano. He will brief about these activities and will give guidelines to initiate new research in this field
11:00 - 12:00 noon	Overview of various Soft-Lithography activities at SVERI Dr. Prashant M. Pawar	Dr. Pawar after completing M. Tech from IIT Guwahati and PhD from IISc and Post-Doc from South Korea established various research facilities at SVERI and has fetched research grants worth 6 Crores. He has established well-equipped soft-Lithography lab at SVERI.
12:00-12:30pm	Non-Conventional Machining to develop Moulds for soft-Lithography -	Prof. N. D. Misal has completed his M. Tech in non-conventional machining and has published patent in 3-D Photochemical

	Prof. N. D. Misal	**Machining. He has established various setups for non-conventional machining at SVERI.**
12:30-1:00pm	**Additive approach through 3-D printing – Prof S. A. Jeurkar**	**Er. Shekhar A. Jeurkar is having 32 Years of Industrial and Academic experience and working as Metallurgical Consultant.**
1:00pm-2:00pm Lunch		
2:00-4:45pm	**Hands on Experience on PCM**	**Participants will be divided in four sub-groups and hands on experience will be provided with the help of SVERI faculty members.**
Hands on Experience on Soft-Lithography		
Hands on Experience on Characterization of Soft-Lithography based components		
Hands on Experience on Simulating Micro-fluidic Phenomenon		
4:45-5:00pm Valedictory Function		

Micro fluidics simulation Exercise

COMSOL-simulations

Department of Mechanical Engineering
SVERI's COE, Pandharpur
16 August 2015

Introduction

In all fields of science and technology, there is a common need to generate reliable models, which either aid in the next generation of new devices, or evaluates the performance of existing ones. A variety of modeling tools exist for such studies. You can model and simulate any physics-based system using software from COMSOL Multiphysics software. It is easy-to-use software for modeling and simulation of real world multiphysics systems. It is good analysis tool for engineers, researchers and lecturers in the education and hi-tech product design fields.

This hand on experience session will help in getting acquainted with COMSOL software. It makes use of the Finite Element Method (FEM) for the analysis of the problems. A computer simulation environment is simply a translation of real-world physical laws into their virtual form. The extend of simplification during the translation process determine the accuracy of the results. Here we make use of COMSOL for generating a realistic model for the micro fluidic device used in our experimental lab and then simulation of the same will be done using the software. COMSOL has readymade modules that make it very simple to build up your equations and doing further simulations. During the practical you will study how to go for simulation of a microfludic component. We will also learn about how to generate the velocity and pressure plots.

A typical workflow in COMSOL consists of:

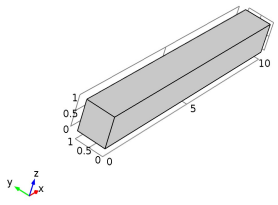
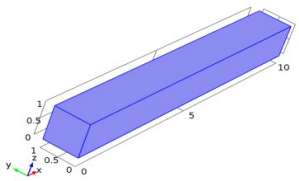
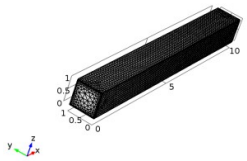
1. Drawing a model for simulation
2. Entering material properties for the model
3. Define boundary conditions for simulation
4. Meshing the model

5. Solving for Simulation
6. Visualization of the results of simulation.

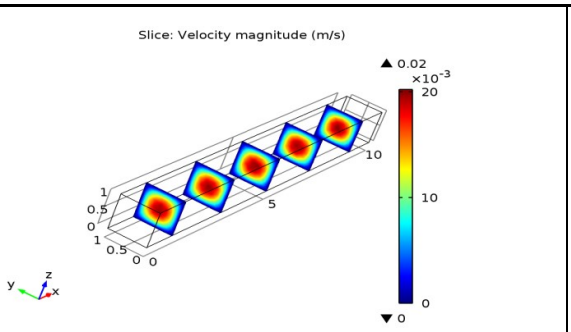
The simulation of a fluid flow in a straight channel using the COMSOL software is done as follows.

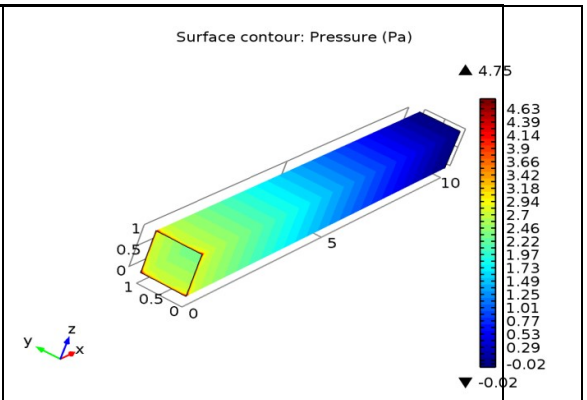
- Open the COMSOL window and Select Model wizard
- Select Space dimension-3D
- Select physics-fluid flow –single phase flow- laminar flow-add
- Select study—stationary—done
- Name the program and save it.
- Select Global definition node and go to parameters
- Enter the name and dimensions of parameters for simulation
- Select geometry node-select proper unit
- Right click on geometry node and select a work plane
- Right click plain geometry and select proper geometry which you want to build on plane with proper dimensions
- Click on Build all to build the geometry
- Click on Material node and select material from library or go for user defined option
- Right click on laminar flow node and select inlet and outlet one by one
- Click on initial values, inlet and outlet and enter the values as per requirement
- Click on mesh node and select physics controlled or user controlled mesh type
- In physics controlled select mesh element size and click build all
- Right click study and click compute

And simulation will be done by the software. The contents of a typical simulation problem for fluid flow in simple straight micro channel when simulated give the results as below.

Geometry	Fluid element	mesh
		

Result -pressure	Result -Velocity





Analysis of Y Shape Micro-Mixers

The basic design for a micro-mixer is represented by Y shaped channel micro mixer. The mixing process in this type of micro mixer is obtained by guiding the two liquids to be mixed in contact through a flow-through channel. It must be noted that, for the basic design of Y shaped micro mixers, mixing solely depends on diffusion of the species at the interface between the two liquids, hence the mixing is rather slow and a long mixing channel is required.

Specification of Problem:

The numerical simulations presented here are performed for a Y-shaped micro-mixer with square cross-sections. The geometry of the micro-mixer consists of two inlet channels, each with a width of 0.1 mm and a depth of 0.1 mm. To obtain minimum mixing length, different modifications to the geometrical setup by adding obstacles like triangular, semicircular and rectangular on the wall of Y shape micro-mixer. The angle between two inlet is $45^{0.}$ For a reduction of the computational domain, shortened inlet channels of length 1mm are used. The length of Y-shaped micro-mixer from the junction is 50 mm long with the same width and depth as the inlet channels as shown in fig. The distance between obstacles is 1 mm, 2 mm and 3 mm respectively for each type of obstacle. The base length and height of triangular obstacle is 0.1 mm and 0.05 mm respectively. The diameter of semicircle is 0.1 mm. The width and height of rectangular obstacle is 0.1 mm and 0.05 mm respectively. The sample fluids used in the simulation were water and Benzoic Acid whose diffusion coefficient is $1x\ 10^{-10}$ m^2/s. The inlet velocity of 0.1 mm/s was assumed to be uniform and constant across the inlet cross-section. The fluid exhausts into the ambient atmosphere which is at a pressure of 1 atm and no-slip boundary conditions are used at fixed walls. The molar concentration of one of the fluid species was set to 0 and the other to 20 to define the mixing length. As mixing takes place the molar intensity on one side of the channel decreases from 20, while on the other side it increases from 0. Near about Complete mixing was achieved when the molar intensity of the two fluids reached to10 ± 0.5 mol/m^3.

Material Properties:

Material properties are defined in material database in COMSOL Multiphysics. Some of the important properties are given below:

Properties of water and Benzoic Acid at 25°C

Fluids	**Viscosity (Pa.S)**	**Diffusion Coefficient(m^2/s)**	**Density(Kg/m^3)**
Water	0.001	$1x\ 10^{-10}$	1000
Benzoic Acid	0.00126	$1x\ 10^{-10}$	500

Boundary Conditions:

A no slip boundary condition was assigned for the wall surfaces, where velocity at wall is set to zero. An average velocity is applied at both inlet (0.1 mm/s) and outlet is kept at atm pressure. A constant inlet temperature was assigned at the channel inlet.

Channel Inlet 1	Velocity Inlet	0.1 mm/s
Channel Inlet 2	Velocity Inlet	0.1 mm/s

Channel Outlet	Pressure Outlet	atm pressure
Channel Bottom	Wall	No slip
Channel Left	Wall	No slip
Channel Right	Wall	No slip
Channel top	Wall	No slip

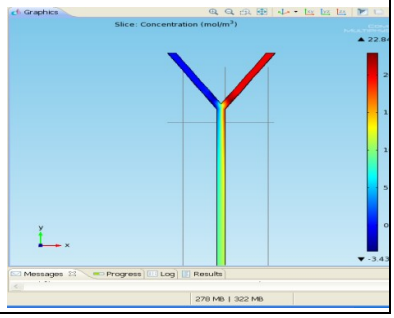
Meshing of Model:

Structured meshing method is used for meshing the geometry in COMSOL Multyphysics. The 3D geometry of Y shape micromixer with different obstacles like triangular, rectangular and semicircular on wall of channel with extremely coarse mesh is used.

Results:

1.1.1.1.1.1.1.1 simulation results

1.1.1.1.1.1.1.2



PHOTOCHEMICAL MACHINING EXERCISE

Photo chemical machining is an engineering production technique for the manufacture of burr free and stress free flat metal components by selective chemical etching through a photographically produced mask. Photochemical machining is also known as photo etching, photo fabrication or photochemical milling.

PCM Process:

The photochemical machining involves mainly seven stages as follows:

1. **Cleaning of Specimen:** The metal surface must be free of contaminants so that there will be good adhesion between metal and photo resist cleaning of the surface thoroughly is carried out by solvent like Trichloroethylene or Acetone to remove traces of Grease or oil. After cleaning, washing the metal plates under running water is carried out.
2. **Photo tool generation:** The photo tool is nothing but a negative film of the image to be produced. Now a day's photo tools are produced by direct printing of the image from CAD drawing.
3. **Coating of photo resist:** There are 4 types of photo resist - wet film positive, wet film negative and dry film positive and dry film negative. Photo resist application is carried out by using an immersion process with the help of a photo resist dip coater followed by drying of the specimen.
4. **UV exposure:** The coated specimen is normally exposed to the ultra violet source in contact with photo tool. Photo resist is sensitive to U.V. radiation & therefore an U.V tube based, U.V exposure unit can be used for exposure.
5. **Development:** After UV exposure**,** specimen is kept in a solvent based developer.

This will remove unexposed areas of the photo resist (Wet film Negative method). The total development time is around 1-1.5 minutes.

6. **Rinsing:** The specimen should be washed in running water with neutral.
7. **Etching:** The process in which metal is chemically dissolved by etchant, their relative importance depends on the process's parameters, such as temperature and dilution of the etchant solution.

Materials and Etchants:

PCM can be carried out on a very wide range of materials. Table 1show the main etchants used in PCM for the related material.

Table 1: PCM Materials and Etchants

1.1.1.1.1.1.1.3 Aqueous Etchants	1.1.1.1.1.1.1.4 Materials etched in the PCM process
• Acidified ferric chloride 1.1.1.1.1.1.1.5	1.1.1.1.1.1.1.6 Aluminium, Alloy 42, copper and copper alloys, HyMu, Inconels, Invar, Kovar, Permalloy, Monel, Mumetal, nickel, Nimonics, phosphor bronze, stainless steels and other steels, tin.
1.1.1.1.1.1.1.7 Acidified cupric chloride	1.1.1.1.1.1.1.8 Beryllium copper, copper and copper alloys including brass and bronze, lead.
1.1.1.1.1.1.1.9 Alkaline potassium ferricyanide	1.1.1.1.1.1.1.10 Aluminium, molybdenum and tungsten.
1.1.1.1.1.1.1.11 Sodium hydroxide	1.1.1.1.1.1.1.12 Aluminium, anodized aluminium.
1.1.1.1.1.1.1.13 Hydrofluoric acid	1.1.1.1.1.1.1.14 Beryllium, columbium (niobium), titanium, zirconium, glasses and ceramics.

Parameters:

There are many parameters that affect the performance of PCM process. The main input parameters (control parameters) are

- **Temperature of etchant**
- **Concentration of etchant**
- **Etching time**

These control parameters are varied during the experimentation to study their effect on the performance measured.

The performance of any photochemical machining process is stated by the following factors

- **Undercut**: During the etching process, the removal of material takes place depth wise in the unexposed portion as well as in the inward direction under the

photoresist as shown in figure 1. The distance etched under the photoresist is called as undercut and the distance etched in the exposed portion is termed as depth of cut. After etching a bigger slot than that of requirement is produced due to the undercut. There is a requirement of consideration of undercut before etching for getting accurate dimension.

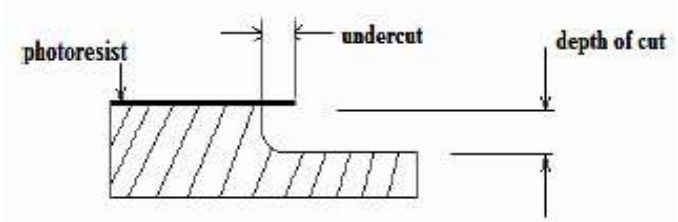


Figure 1: Undercut

- **Material Removal Rate (MRR)**: The higher value of MRR represents better etching performance. The material removal rate can be calculated from the depth of cut and the area etched.
- **Etch factor**: The ratio of the depth of etch to undercut is termed the 'etch factor'. The
  less value of undercut and high depth of etch will give a considerable etch factor.
- **Surface roughness**: The surface roughness value should be always lower to have a better surface.

Applications:

The PCM plays a vital role in the production of a variety of precision parts viz. microfluidic channels, silicon integrated circuits, copper printed circuit boards and decorative items. PCM is used for manufacturing of micro-components in various fields like aerospace, electronics, medical; etc. The products made by using PCM are especially relevant to micro-Engineering, micro-fluidics and Microsystems technology.

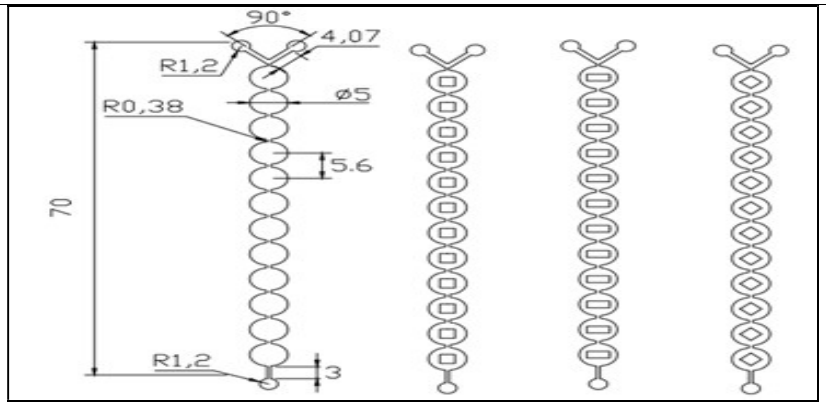
CHARACTERIZATION OF MICRO COMPONENTS EXCERCISE

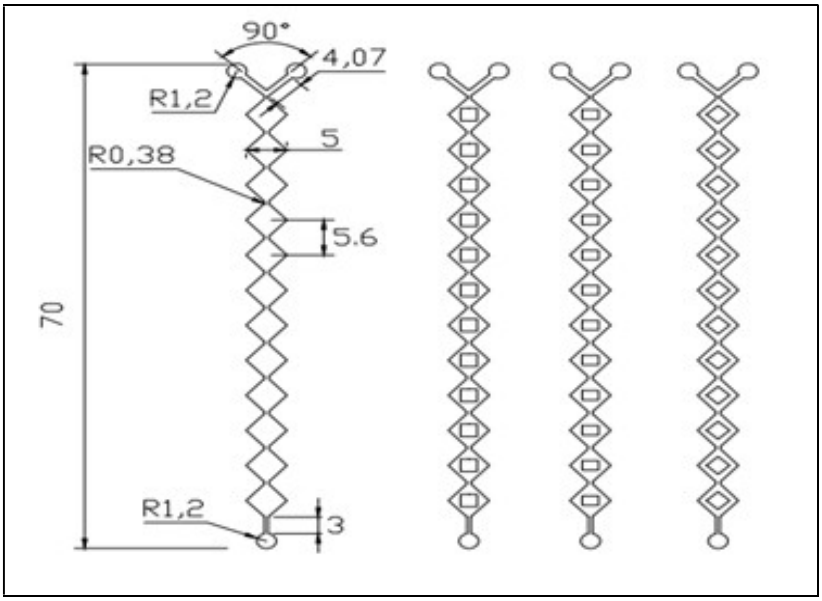
Characterization of PCM based Micro Channel Moulds by using Rapid–I Machine

After PCM process, prepared molds are inspected under Rapid-I Vision Inspection System. Rapid I Vision Inspection system is operated with Rapid I 5.0 software and readings are being taken and snapshot also captured. Following are some drawings of Micro channels along with its dimensions. These channels are manufactured by using PCM process. Once they are manufactured, its dimensions are measured by using Rapid-I machine and these dimensions are compared with standard dimensions of Micro channels to find out the error between them. The important dimensions of channels are shown by figures below.

About Rapid-I Machine:

- Measuring Travels : 200 X 150 X 150 (X x Y x Z)
- Linear Scale : 0.5µm non contact tape encoders
- Graphics : CAD (import/edit/export.dxf)
- Reports : Direct Reports in MS Excel





MCR Rheometer

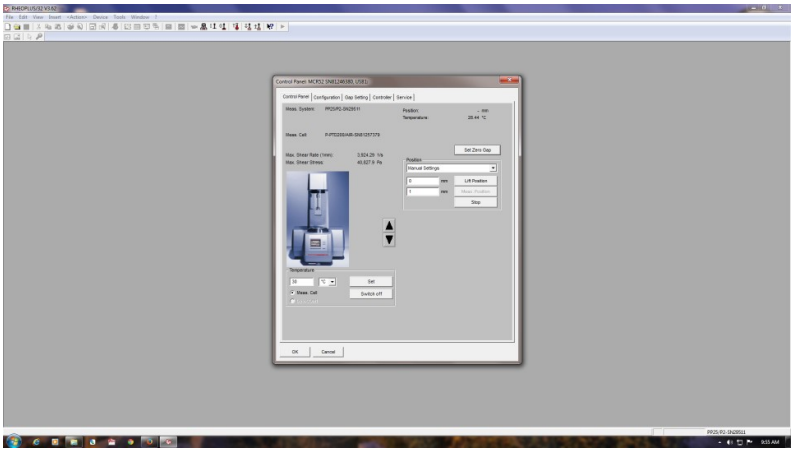
The new **MCR Rheometer** is based on a concept at the cutting edge of technology. The EC motor technique, the low friction bearing and the patented normal force sensor have been optimized over years to satisfy the highest demands of rheologists. Any type or combination of **rheological tests**, both **rotational** and **oscillatory** mode, are possible with the **MCR rheometers**. The modularity of the system allows the integration of a wide range of temperature devices and application-specific accessories. You can also easily connect a wide selection of application-specific accessories for **rheo-optical investigations, tests with additional parameters** such as pressure or a magnetic field – and you can also use your rheometer for **extended material characterization** such as tribology, DMTA measurement and much more.

Stepwise Procedure to use the Rheometer for plotting the Graph of material:

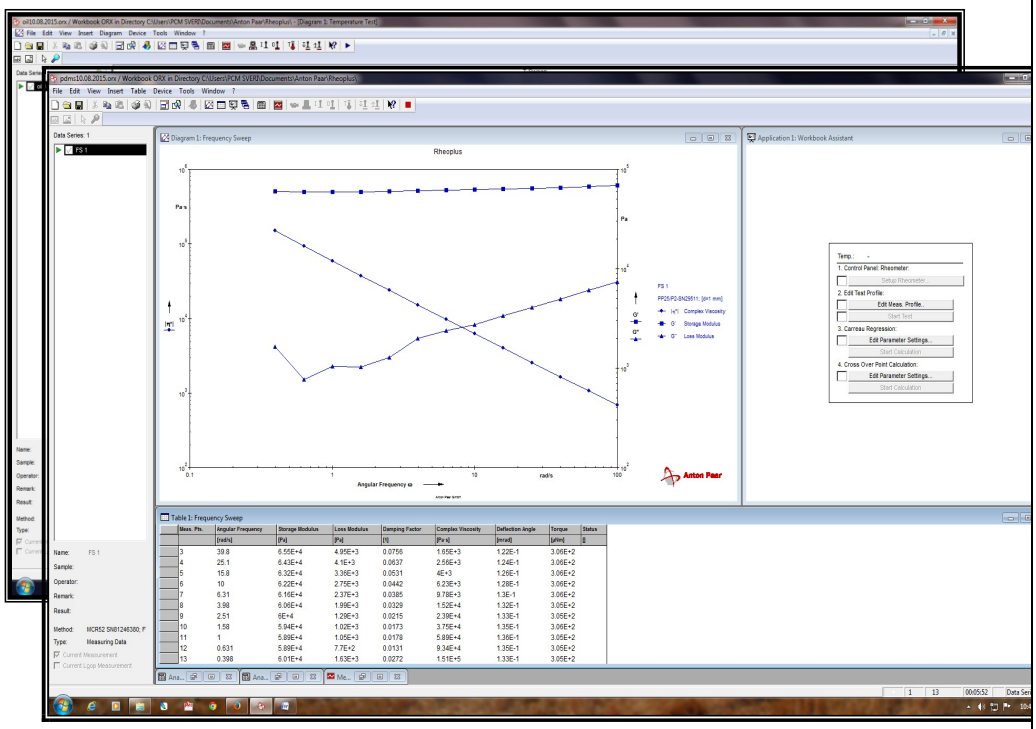
Before starting the test you should do the previous setting of system.

Step 1: Open the Software Rheoplus. For adjusting the measuring system position you need to open control panel with Device→Control panel. Then make sure zero gap is set or not. In position, adjust the lift position and measuring position of

measuring system. And if you want to set temperature then also you can set it in temperature setting. As shown in below:



Step 2: To start the test you click on File→New. Whichever test you want click on it. Start the test. Save this file .orx extension. Here in Data series you can add no. of tests. While testing the material, with the plotting of graph there is reading of each point is available below the graph.



RheoPlus Rheometer Software is a user-friendly, flexible and powerful software. Different users can therefore easily exchange method templates and measuring data.

PDMS MICROSTRUCTURE PREPERATION EXERCISE

Fabrication Procedure of Channel on PDMS

Poly Dimethyl siloxane (PDMS) is a Si based organic polymer that has found wide applications in MEMS and microfluidic device fabrication, soft lithography, contact lens manufacturing and device encapsulation.

PDMS has several desirable properties, which are:

1. Visco-elasticity**:** PDMS is flexible, yet sturdy enough to manipulate across macroscopic scales.
2. Bio-compatibility
3. High chemical inertness
4. Optical transparency
5. Adhesion to metals – applications as inert substrate material

Step-by-step mold making process

Here we use Dow Corning's Sylgard 184 elastomer (dimethyl siloxane oligomer) and curing agent (dimethyl, methyl hydrogen siloxane, cross linking agent). Both the PDMS base and the curing agent come as part of it. It is advisable to take a smaller quantity of the same before beginning the process.

Step 1: Pour the required amount of curing agent, into a clear container on the electronic weighing machine.

Step 2: Carefully pour the required amount of PDMS base – this is 10 times the weight of the curing agent already taken.

Figure 1. Weighing of PDMS base and curing agent

Step 3: Shake this mixture vigorously with a spatula. Thorough mixing (about 10 min of shake) is needed to make sure that the curing agent is uniformly distributed. This will ensure that the final PDMS mould is uniformly mixed. Observe that the final mixture is filled with air bubbles from the whisking process. These bubbles need to be removed

before curing.

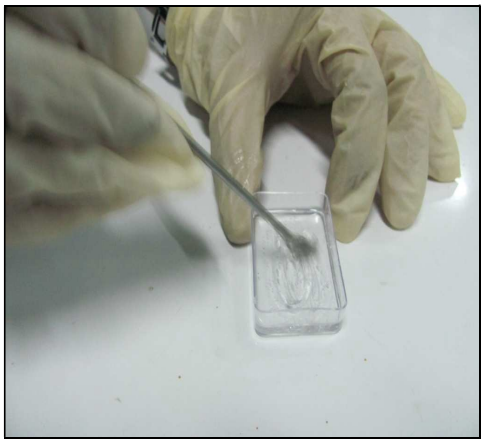
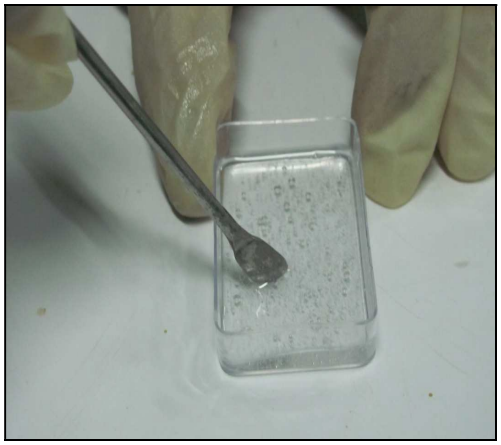



Figure 2 Whisking of mixture with spatula.

Step 4: The mixture must be kept in a dessicator to make the trapped air bubbles escape. Keeping it in a common bell-jar dessicator connected to a vacuum pump for about 1 hour will ensure that all bubbles are removed.

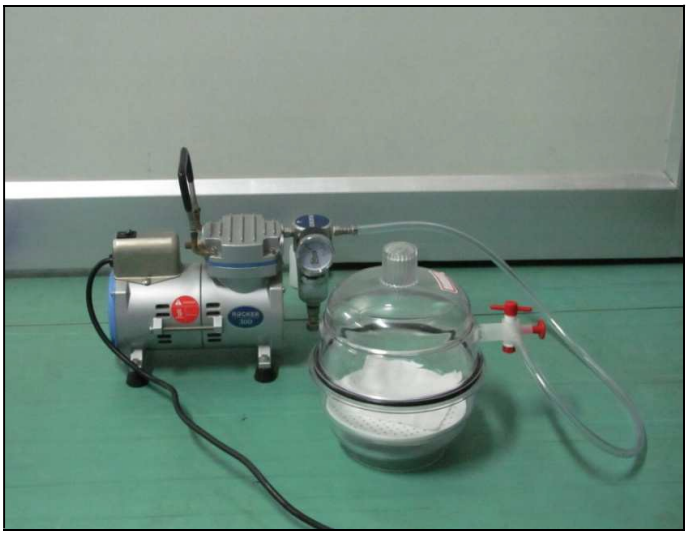


Figure3. Dessicator with vacuum pump

Step 5: Once a clear, bubble free PDMS mixture is obtained, the next step is to pour it into the moulds.

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Figure 4 Pouring of PDMS into mould cavity.

Step 6: Curing of the mould is done at room temperature approximately for 48 hours. But with different temperatures the curing time is different. For example:

Heat Cure 10 Minutes @ 150 Deg C

Heat Cure 20 Minutes @ 125 Deg C

Heat Cure 35 Minutes @ 100 Deg C

Step 7: After curing of PDMS, cut around the edges with a sharp sample holder, trying to get a grip of the PDMS at an edge. If the PDMS is suitably cured by application of a steady pressure will help peal of the PDMS completely with ease.

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05	List of participants giving details about - Name, Organization, Cell No.,E-mail ID	

The Institution of Engineers (India)

List of Participants "Hands-on-Experience on Soft Lithography"
Sunday, 16-08-20154 at SVERI's College of Engineering, Pandharpur

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HEAD,
Dept. of Mechanical Engg
C.O.E. Pandharpur.

06	Dully filled Rpt form	**TECHNICAL ACTIVITY CARRIED OUT BY CENTRES / OVERSEAS CHAPTERS**

Name of Centre / Overseas Chapter:	**SVERI's college of Engineering, Pandharpur**

Title of Activity:	**One Day Seminar on "Hands-on-Experience on Soft Lithography"**		
Activity under Divisional Board	**Solapur local Center**		
Date:	**16/08/2015**	Venue:	**SVERI's college of Engineering, Pandharpur**

Banner for the program

Launching of "**Micro-Fluidica Demo Kit**"

Brief Report (not exceeding 4000 characters – **please use Arial 11 point font**)

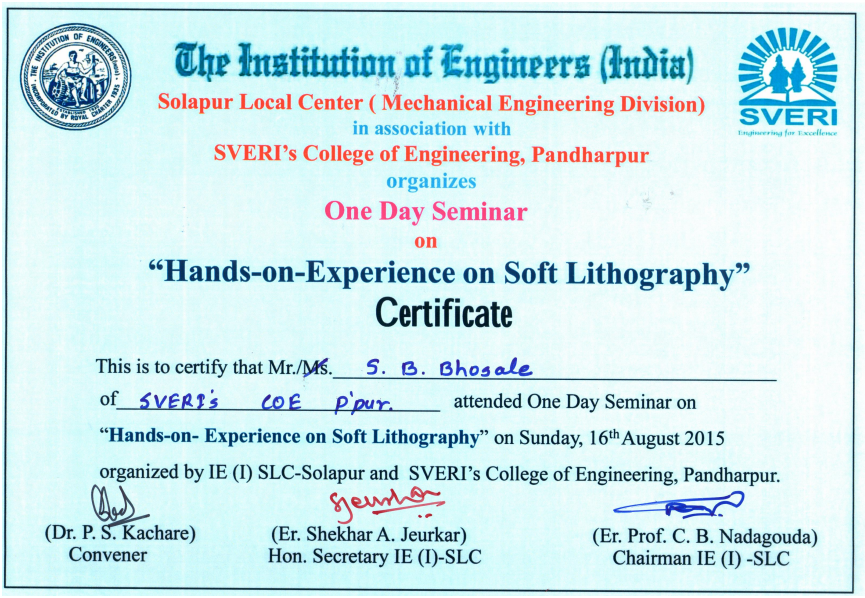
A one day seminar sponsored by Institution of Engineers (India), Solapur Local Center was organized on 16th August 2015 in SVERI's College of Engineering, Pandharpur on the topic "Hands on Experience on Soft Lithography". Hands on sessions were arranged as a part of this seminar on different activities related to Soft Lithography. The seminar was organized with an agenda of giving exposure to the activities in this area, which are being carried out in SVERI's College of Engineering in collaboration with BARC Mumbai, RRCAT Indore etc. The target audience of the seminar was the faculty of other Engineering Institutes of Maharashtra with an aim of promoting the research activities related to Soft Lithography in their respective colleges. The seminar was conducted in two sessions. In morning session, speeches of eminent personalities were arranged related to present research activities in Soft Lithography. Hands-on-experience sessions were conducted in the afternoon session. 71 participants from various Engineering Institutes attended the seminar.

The program started with inauguration ceremony followed by the Product launching of "**Micro-Fluidica Demo Kit**" with the auspicious hands of Chief Guest, Dr. R. Balasubramaniam, an Eminent Scientist at Precision Engineering Division of BARC, Mumbai and Prof. Nadgauda, an eminent academician and President of Institution of Engineers (India) Solapur Local Center. Micro-Fluidica Demonstration kit, developed by Research and Development Department of SVERI's College of Engineering, will help Engineering Institutes to demonstrate micro-fluidic phenomenon to undergraduate and post-graduate students. As a keynote speaker Dr. R. Balasubramaniam guided the participants regarding Research Activities in the field of Micro domain and gave guidelines regarding how to initiate new research activities in this field. Dr. P. S .Kachare, Head of Mechanical Engineering Department of SVERI's college of Engineering also graced the Dias.

Dr. Prashant M. Pawar, a Post-Doc personality from Konkun University in Seoul of South Korea and present Dean R&D of SVERI's College of Engineering, then briefed about the research facilities developed and available at SVERI. Prof. N. D. Misal, Director in SVERI's College of Engineering (Polytechnic), who developed the setups for non-conventional machining at SVERI, shared his view and experience in

		the field for developing Moulds for soft-lithography. Er. Shekhar A. Jeurkar, present Hon. Secretary of Institute of Engineers (India) Solapur Local Center, eminent Academician and Metallurgical Consultant, then guided the participants regarding additive approach through 3-D printing followed by a lunch break. In the afternoon, Hand-on Sessions were arranged on Photo Chemical Machining, PDMS Microstructure Fabrication, Microstructure Characterization and Microfludic simulations for the participants in four different laboratories of SVERI. Prof. Misal and Prof. Wangikar guided the participants in the photochemical Machining Activity. Er. R. B. Kapurkar and Prof. R. R. Gidde demonstrated the participants about the fabrication of the PDMS Microstructures. Er. Ms. Sarika Hazare and Er. Avinash Parkhe guided the participants regarding characterization procedure of Microstructures using the characterization facilities available at SVERI. Prof. A. B. Shinde and Prof. S. V. Jadhav then demonstrated the use of COMSOL Multiphysics software for the simulations of micro-fluidc problems. In the Valedictory function, different participants put forward their views about the program,where most of the participants expressed their satisfaction about arrangement of such an event in this region. Certificates were issued to all the participants and the program was concluded with vote of thanks.

Certificate Distribution:



The Institution of Engineers (India)

Solapur Local Center (Mechanical Engineering Division)

in association with

SVERI's College of Engineering, Pandharpur

organizes

One Day Seminar

on

"Hands-on-Experience on Soft Lithography"

Certificate

This is to certify that Mr./Ms. S. B. Bhosale

of SVERI's COE P'pur. attended One Day Seminar on

"Hands-on- Experience on Soft Lithography" on Sunday, 16th August 2015

organized by IE (I) SLC-Solapur and SVERI's College of Engineering, Pandharpur.

(Dr. P. S. Kachare) Convener

(Er. Shekhar A. Jeurkar) Hon. Secretary IE (I)-SLC

(Er. Prof. C. B. Nadagouda) Chairman IE (I) -SLC

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