Master's Thesis Engineering Technology

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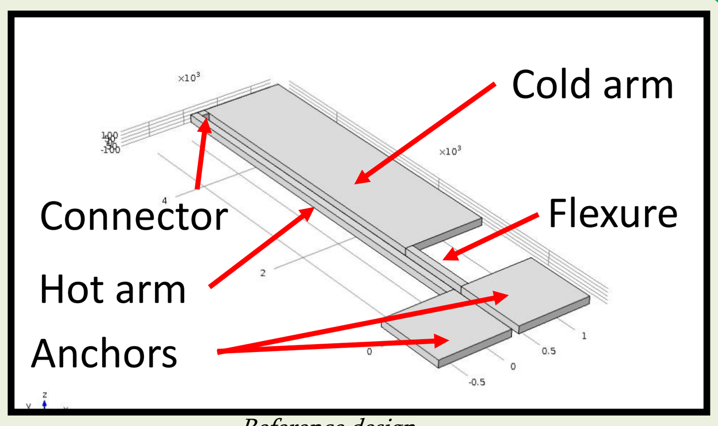
A materials and methods study for the production process of thermal actuator microelectromechanical systems

Bjarne Nilis

Master of Energy Engineering Technology

Introduction

The conventional **production technique** of Microelectromechanical systems (**MEMS**): silicon micromachining, is an **expensive and lengthy** process. **Printing or coating techniques** such as ink-jet printing, screen printing and blade coating could be a solution to this problem, **reducing costs and turnover time.** The goal of this thesis is to **optimize** the **production process** of the MEMS and select a structural and sacrificial material which are compatible. A **reference design** was used as a target.

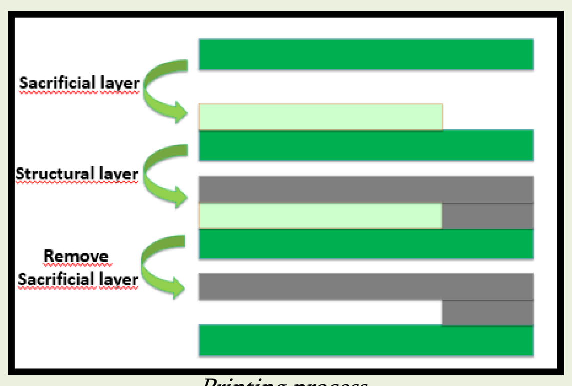


Reference design

Components	Dimension (width*depth*height) µm
Anchor	1000*1000*100
Flexure	100*1000*100
Cold arm	1100*4000*100
Hot arm	100*5000*100
Connector	100*200*100

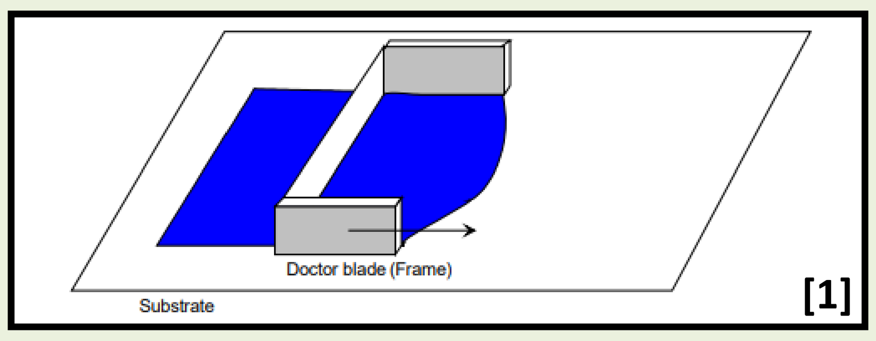
Dimensions of Reference design

Printing and coating techniques



Printing process

The **print** for the MEMS consists of the following **layers**: a **substrate** upon which a **sacrificial layer** is applied. On top of the sacrificial layer **the structural material** is deposited. Lastly the sacrificial material is removed to create a **freestanding** structure.

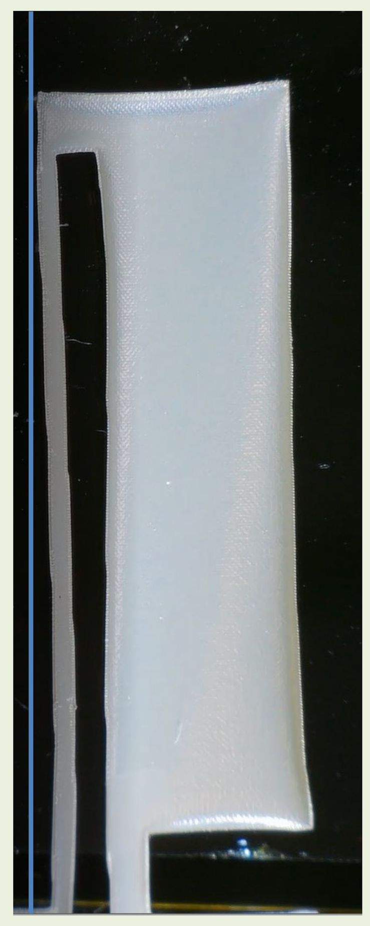


Blade coating process

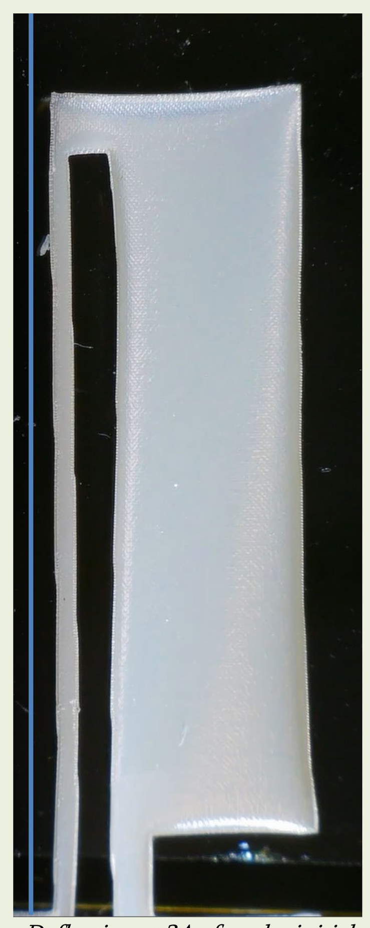
Screen and ink-jet printing allow irregular shapes to be printed. Since **blade coating** does not allow the deposition of complex features it can only be used to apply the **sacrificial layer.**

Proof of concept

MEMS before a current is applied



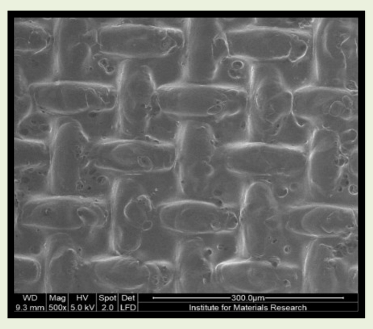
Shrinking of hot arm due to electric sintering (3A)



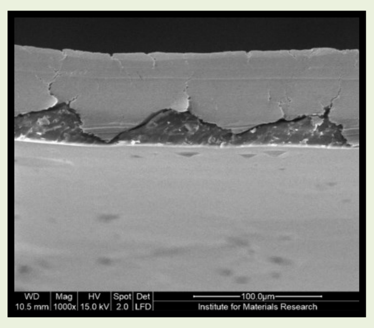
Deflection at 3A after the initial deformation

Results of the Sacrificial layer

Screen printed



Top view of screen printed PVA



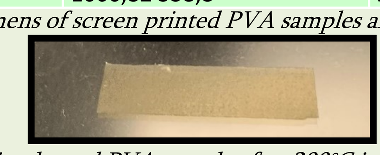
Cross section of PVA&silver stack

#Printed layers	Mesh	Ra (nm)	Layer thickness (µm)
10	165 TPC 31	3014,1	23,6716
10	100 TPC 40	5069,5± 1129,7 nm	28089,7± 3174,1 nm

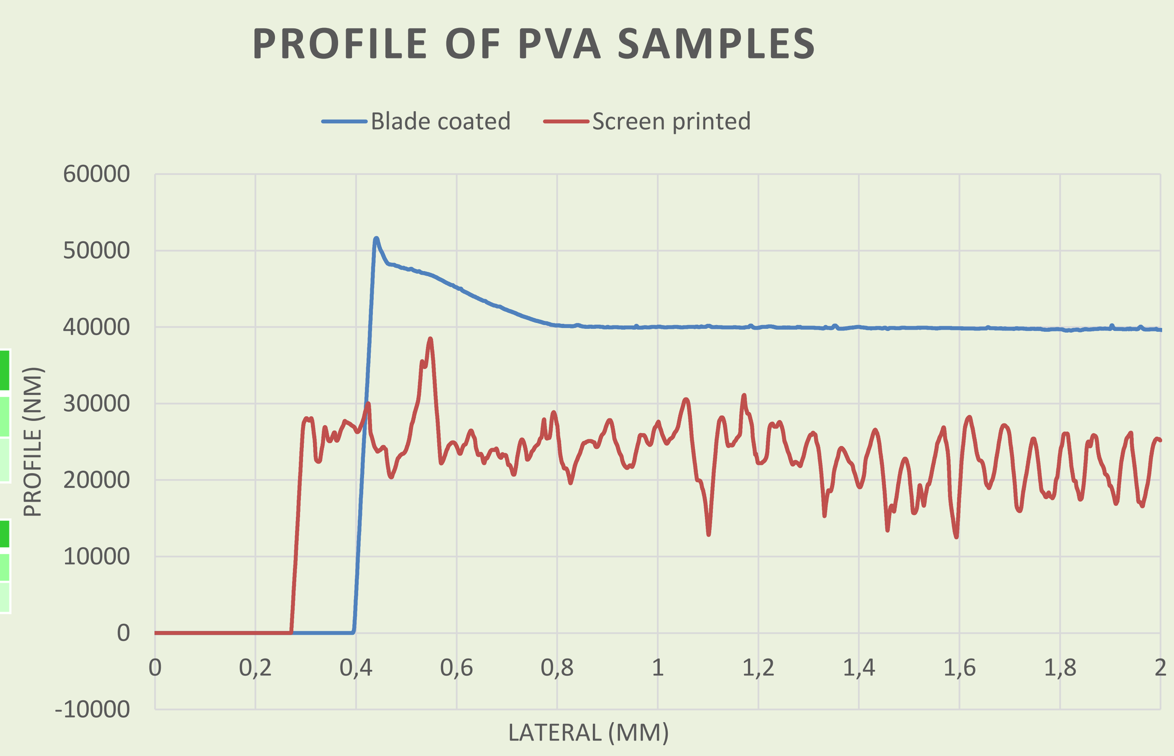
Measuremens of screen printed PVA samples

Temp, and Time	RA (nm)	Layer thickness (µm)
180°C 10 min	1916,3	26,8616
200°C 10 min	1666,8± 338,8	23,6759± 2,4297

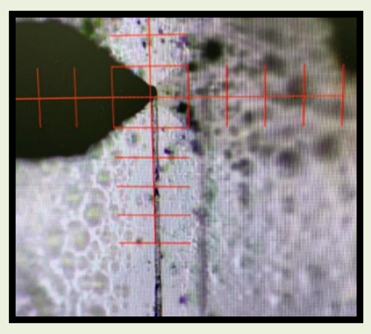
Measuremens of screen printed PVA samples after oven treatment



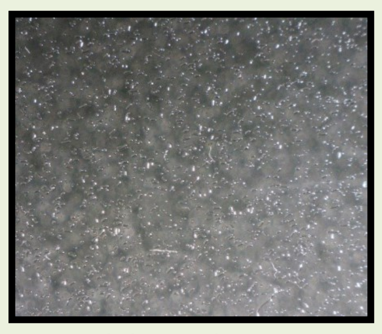
Discoloured PVA sample after 200°C in oven



Blade coated



Blade coated PEO



Blade coated PVA

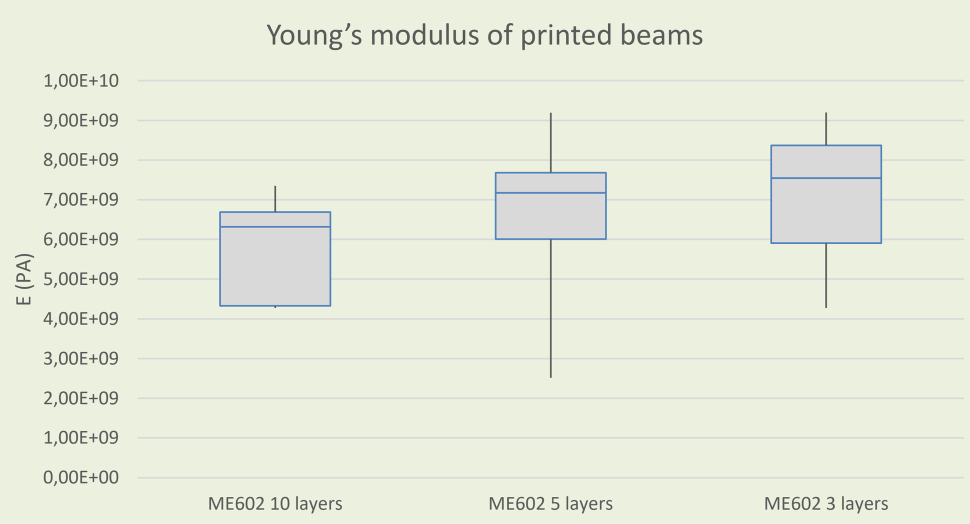
Wet layer (µm)	ASH PVA (µm)	Ra PVA (nm)
100	11,1200±2,0822	112,87±27,3
200	29,9722±3,2878	73,43±10,7
300	38,8937±0,7301	45,79±15,1
400	47,5777±0,3767	66,17±23,9

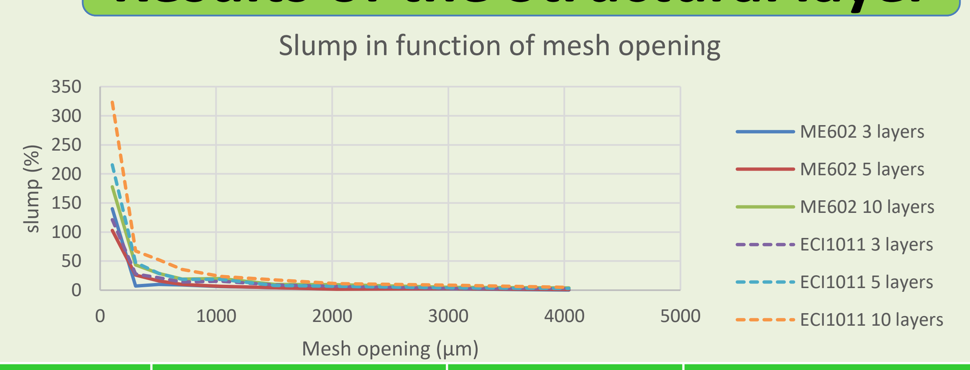
Blade coated PVA 25m% foil ink

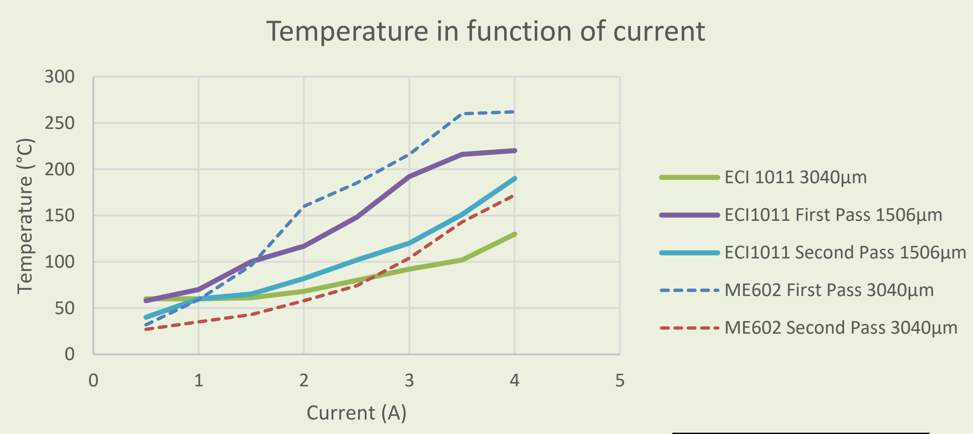
Wet layer (µm)	ASH (µm)	Ra (nm)
100	12,176±0,166	2,1±3,0
150	32,094±1,817	3,0±6,6nm
200	21,502±0,368	0,7±0,2nm

Blade coated PVA 20m% 27 000mw ink

Results of the Structural layer



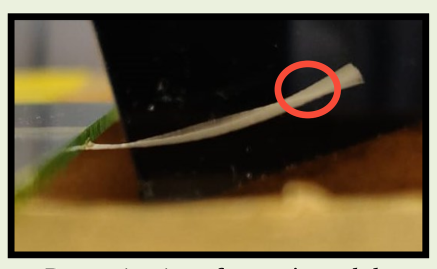




	Sheet resistance (mΩ/□)		Thickness (µm)		Resistivity (Ωm)	
Curing temp	ECI1011	ME602	ECI1011	ME602	ECI1011	ME602
120°C	2,76±0,09	150,45±1,56	33,089	31,434	9,13E-08	4,73E-06
150°C	2,03±0,03	28,4±1,35	39,410	41,081	8,00E-08	1,17E-06
180°C	2,20±0,01	11,7±25,98	37,565	41,081	8,26E-08	4,82E-07

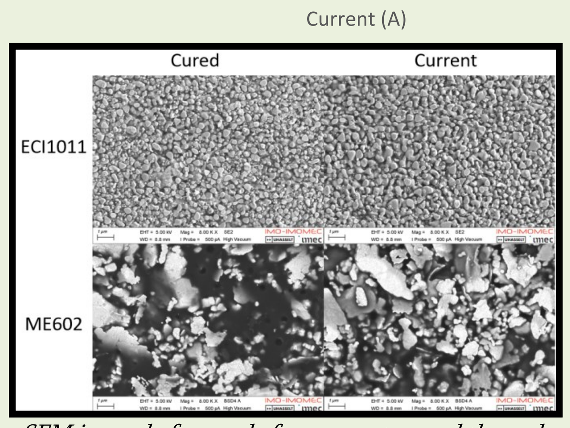
	Thermal conductivity (W/mK)	
Curing temp	ECI1011	ME602
120°C	83,42	101,37
180°C	95,18	135,80

T (°C)	Hot arm length (µm)	Deflection of MEMS (µm)
60	5003,6	59,924
120	5009,0	149,52
170	5013,5	223,94

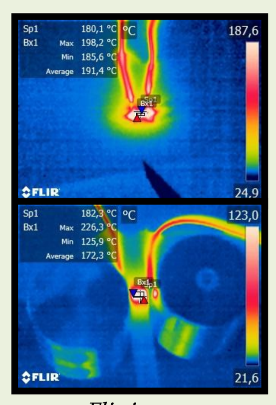


Determination of young's modulus

Curled ECI1011 beam



SEM image before and after current passed through



Flir images

Conclusion

A process and selection was made for the sacrificial layer. **PVA** has all of the desired properties: it is easily **applied** to the substrate by **blade coating**, **dissolves under 15 minutes** in hot water and provides a **smooth surface** to print upon. For the structural layer **both inks** show promising results. Both can be used to **screen print** a **free standing structure**, and both inks **generate enough heat** to realise a simulated **deflection** in the reference design of **up to 224µm**. Due to the slump seen in both inks, it is proposed to **raise** the **minimum feature width to 300µm**. A **proof of concept** was made which achieved **deflections of 100µm**. Further research regarding the dimensions of the MEMS and curing techiques are needed to optimise the devices strength and deflection.

[1] B. A., M. M. and H. Schmidt, "Doctor Blade," in *Sol-Gel Technologies for Glass Producers and Users*, Boston, MA, Springer, 2004, pp. 89-92.

Supervisors / Co-supervisors / Advisors Prof. Dr. Ir. Wim Deferme, Ing. Dieter Reenaers

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