IMPRINTING AND BONDING OF THE FLUOROELASTOMER VITON FOR MICROFLUIDICS

G. Sharma, L. Klintberg and K. Hjort*

Department of Engineering Sciences, The Angstrom Laboratory

Uppsala University, SWEDEN

ABSTRACT

The fluoroelastomer Viton provides very low permeability to gases and high resistance to many chemicals, including most hydrocarbons. Microfluidic components were built by stacking sheets of imprinted Viton compounds that bonded during a following postcuring process. Bonding were made either to other Viton sheets or materials such as steel and glass. The potential for this technique was demonstrated by making a stainless steel actuator where a Viton membrane sealed a paraffin filled cavity. Other possible applications for Viton microfluidics are in analytical systems and chemical reactors where leakage or swelling is not acceptable, and also for making gas tight systems.

KEYWORDS: Viton, fluoroelastomer, imprinting, bonding, microfluidics, actuator

INTRODUCTION

In micro total analysis systems it is sometimes desirable that an elastomer material can handle different chemicals or gases without leakage or swelling, e.g. seals, valves, pumps, or stretchable interconnects.

Viton is a trade name of fluorocarbon elastomers. It is used as a sealing in fuel and oil handling systems, in high vacuum systems, in chemical processing when handling chemicals such as acids, alcohols and hydrocarbons, and for high temperature applications. Compared to many other elastomers, Viton has very low permeability to a wide range of gases. It is also highly resistant to aliphatic and aromatic hydrocarbons that make most other rubbers swell. However, standard Viton is not resistant to ammonia, low molecular weight esters and ketones, high pH solutions and oxygenated fuels [1].

Having low permeability to alkanes and high tensile strength (11 MPa), Viton is well suited for paraffin-based microactuators. Paraffin wax has large volume expansion (10-20%) when it melts and liquid paraffin has low compressibility, which makes it an excellent actuation material in valves and pumps for high pressure applications [2].

EXPERIMENTAL

The Viton used here is of type A, a general purpose fluroelastomer used for seals (FKM 17013/FDA, Marconi Special Compounds S.R.L). Pieces of Viton compounds were flattened by pressing between two preheated (140ºC) aluminium blocks using a force of 50–80 kN, to reach a 50 – 80 cm^2 sheet with thickness of about 0.3 mm. The flattened Viton sheet was transferred to a new set of preheated blocks (140ºC) with a heated polydimethylsiloxane (PDMS) mould on top. The PDMS mould was made using a SU-8 master. To imprint the pattern in the mould into the Viton sheet, a force of about 2 kN was applied. The structure with the mould was then precured at 180ºC for 90 minutes or more before the PDMS mould was removed. For bonding evaluations, a precured Viton sheet with an imprinted channel ending in a circular cavity was placed either on a plain partly cured Viton sheet, or stainless steel slides or glass slides. The stack was mildly clamped and then postcured at 240ºC for 24 h. The bond strength was evaluated by rupture load measurements. The circular cavities were pressurized using an external pump and the pressure was recorded.

In order to evaluate if electrical interconnects are easily formed in Viton microfluidics, a thin film of gold was evaporated and patterned by UV lithography. The gold was patterned by wet chemical etching using a potassium iodide solution (100 g KI: 25 g I_2: 1000 ml H_2O). Resist stripping by acetone is not possible, so the resist was removed by first weaken it by flood exposure for 16 s and then stripping for 1 min in its developer solution.

A paraffin actuator was made by stacking two stainless steel stencils and an uncured, flat 0.2 mm thick Viton sheet. Each stencil has a through hole of 2 mm in diameter. In order to define the 0.1 mm thick Viton membrane sealing the cavity, a PDMS mould with a pillar (diameter 1.8 mm, height 0.5 mm) was pressed from the back using a Teflon sheet on the front to make the membrane in level with the top stencil surface. Using the same temperature and curing steps as for the bonding, the membrane was formed, and the Viton sheet was bonded to the steel. Afterwards, the cavity was filled with paraffin and sealed, gluing a third steel stencil with an insulated copper clad polyimide heater in-between, Fig 1.

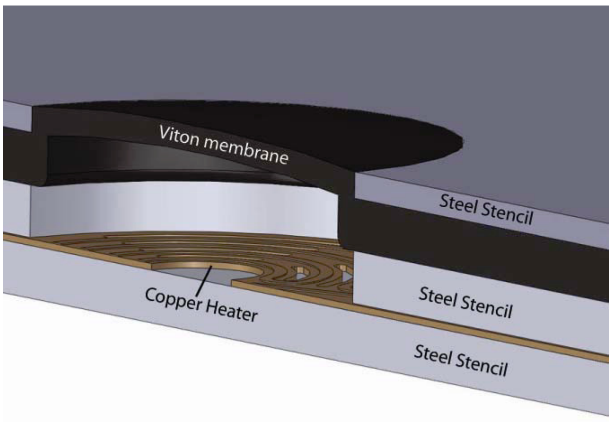

Figure 1: A cross-sectional sketch of the paraffin actuator. The thickness of the stainless steel stencils were 200 µm (lower stencils) and 100 µm (top stencil). To deflect the membrane the paraffin was melted using the heater.

The deflection of the membrane vs. applied heater power was studied both for the unloaded actuator and when the membrane was loaded using a flat 1.5 mm diameter tip. The activation time was also characterized. A Viton membrane with its stencils (similar to Fig. 1, disregarding the copper heater and sealing stencil) was used to evaluate the maximum achievable membrane deflection. A nanoport (6-32, Upchurch Scientific) was glued to the back of the stencil and a pump was used to pressurize the membrane.

RESULTS AND DISCUSSION

Figure 2a shows a pattern of an imprinted Viton sheet. The coil pattern in the original SU-8 master was completely transferred into the Viton using a PDMS stamp replica. Figures 2b and 2c show the good replication ability of the Viton micromolding process.

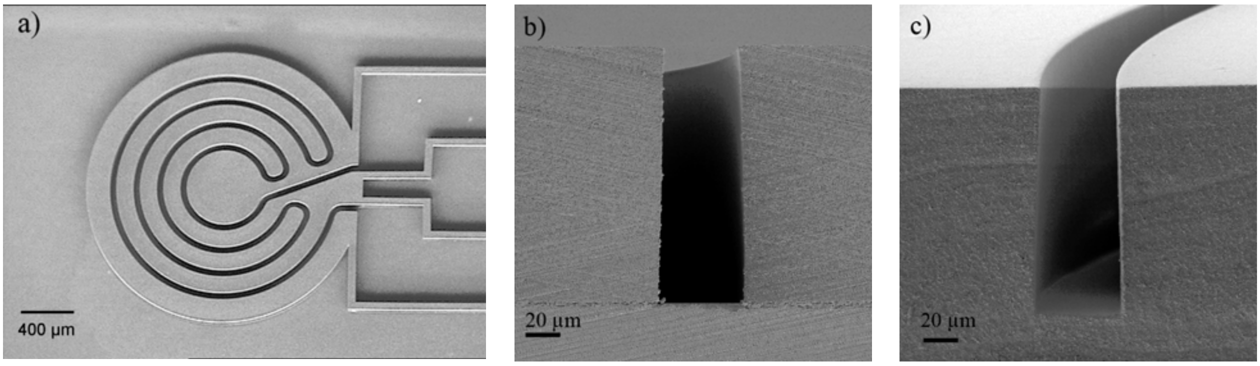

Figure 2: a) An imprint in Viton, b) a close up of its SU-8 template and c) an imprint in Viton at a similar position to that of the template.

The measured surface roughness was 50-60 nm. PDMS eased the mould release since it does not stick to Viton. However, due to the highly elastic PDMS mould we have experienced bending of the imprinted Viton at some places with high aspect ratios.

A cross-section of a Viton channel bonded to a plain Viton sheet showed that the interface was indistinguishable, Fig. 3. The bottom of the channel is bulging up somewhat. The rupture load was found to be different for the three bond interfaces: Viton-Viton, Viton-stainless steel and Viton-glass. As seen in Table 1, the maximum rupture load for Viton-Viton and Viton-steel was about 290 and 205 N/m, respectively. Viton-glass reach low 18N/m but this value should only be seen as indicative. When uncured Viton was bonded to glass or steel, as in the actuator, very high bonding strength was reached and the device ruptured in the Viton when teared apart, and not in the joint. Different adhesive promotors can also be used to considerably improve the bond strength.

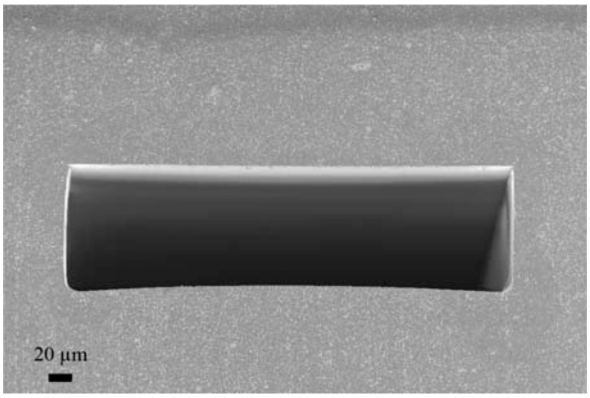

Figure 3: A bonded Viton-Viton channel.

Table 1 Bond rupture load values

Precuring time (min)	Pressure postcuring (kPa)	Viton-Viton	Viton-steel
		Rupture load (N/m)	Rupture load (N/m)
90	3.4	238	--
	6.9	123	98
	10.0	123	115
	13.8	164	134
120	3.4	123	156
	6.9	288	206
	10.0	103	--
	13.8	123	103

Figure 4 shows a coil patterned in gold. Over large surfaces, some cracks in the metal thin films were found, most probably caused by difficulties to fix the sample during the patterning. It is necessary to avoid stretching the sample.

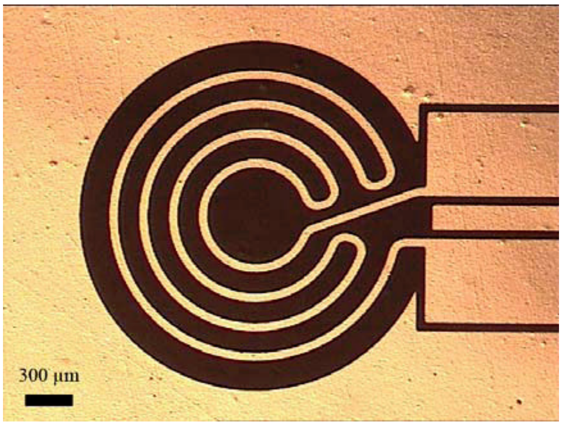

Figure 4: A micrograph of a thin film gold heater patterned on Viton sheet.

The paraffin actuator had a small initial membrane deflection of around 15 µm in unloaded condition and Fig. 5a shows how the actuator responds to different driving power on the heater element. When the actuator was loaded the deflection was significantly lowered. The activation time for the actuator was found to be 2-3 s and the deactivation time was found to be 3-4 s. During the measurements the actuator had low thermal contact with its surrounding. With good thermal contact, the time for deactivation should be possible to decrease below a second. A fully deflected Viton actuator pressurized by water is shown in Fig. 5b. The maximum pressure the membrane could hold was about 0.4 MPa, when the membrane ruptured at a strain of 57 %.

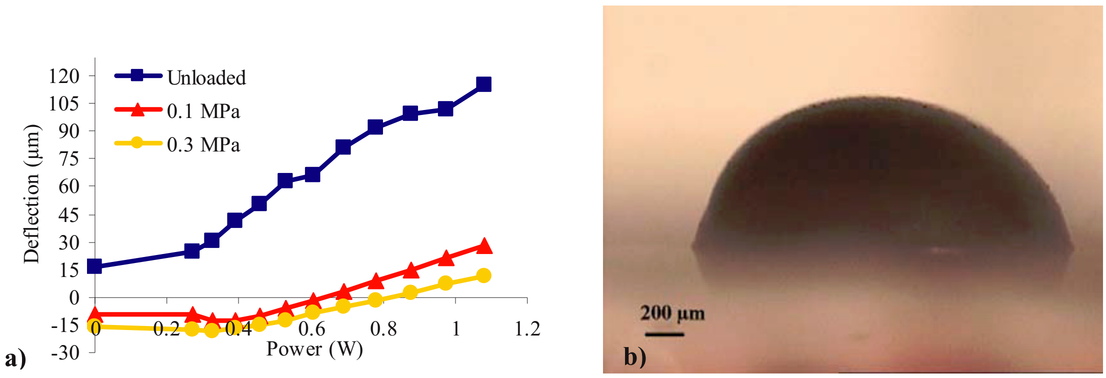

Figure 5: a) Actuator deflection against applied pressure b) An expanded Viton membrane near its rupture limit, actuated by an external pump.

CONCLUSION

We conclude that it is possible to fabricate Viton-based microfluidics by imprinting, bonding and metal patterning. Having low permeability, Viton is a well suited elastomer for paraffin-based microactuators. Viton based microfluidics may find applications in analytical systems or reactors with organic chemicals or gases, when leakage or swelling are not acceptable.

ACKNOWLEDGEMENTS

The Swedish Governmental Agency for the Innovation Systems (Vinnova) and GE Healthcare Bio-Sciences are acknowledged for financing parts of the project.

REFERENCES

[1] Selection Guide, DuPont Dow Elastomers, H-68134-03, www.dupontelastomers.com/viton (2010-06-30).
[2] R. Bodén, K. Hjort, J.-Å. Schweitz and U. Simu, *J. Micromech. Microeng.*, 2008, **18**, 115009.

CONTACT

K. Hjort, tel: +46-18-471 3141; Klas.Hjort@angstrom.uu.se