



Simple fabrication process for organic piezoelectric resonators: application to viscosity measurement

Pierre-Henri Ducrot, Isabelle Dufour, Fabrice Mathieu, Liviu Nicu, Martin Heinisch, Bernhard Jakoby, Cédric Ayela

► To cite this version:

Pierre-Henri Ducrot, Isabelle Dufour, Fabrice Mathieu, Liviu Nicu, Martin Heinisch, et al.. Simple fabrication process for organic piezoelectric resonators: application to viscosity measurement. 13th International Workshop on Nanomechanical Sensing (NMC 2016), Jun 2016, Delft, Netherlands. hal-01301323

HAL Id: hal-01301323

<https://hal.science/hal-01301323>

Submitted on 28 Aug 2016

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

SIMPLE FABRICATION PROCESS OF ORGANIC PIEZOELECTRIC RESONATORS: APPLICATION TO VISCOSITY MEASUREMENTS

P.H. Ducrot¹, I. Dufour¹, F. Mathieu², L. Nicu², M. Heinisch³, B. Jakoby³, C. Ayela¹

¹Laboratoire de l'Intégration du Matériau au Système UMR 5218, CNRS, Université de Bordeaux, France

²Laboratoire d'Analyse et d'Architecture des Systèmes UPR 8001, CNRS, Université de Toulouse, France

³Institute for Microelectronics and Microsensors, Johannes Kepler University, Linz, Austria

pierre-henri.ducrot@ims-bordeaux.fr

Silicon-based Micro Electro Mechanical Systems (MEMS) success is incontestable as they are widely present in new technologies. However, technologies based on organic electronics are emerging because they are interesting in terms of fabrication costs, with a large panel of functional properties available, and are very attractive for flexible devices [1]. In this context, organic piezoelectric resonators based on a simple low-cost fabrication process are presented in this work for viscosity measurements. The results show the potential of organic resonators in liquid media for further biological and chemical sensing.

FABRICATION

A rapid and extremely low-cost fabrication process has been developed for the elaboration of piezoelectric organic resonators [2]. Piezoelectricity has been chosen as it enables the integration of both actuation and read-out at the same time thanks to the reversibility of the piezoelectric effect. Thus, polyvinylidene fluoride-trifluoroethylene (PVDF-TrFE), which is a piezoelectric polymer, is used as it presents the best piezoelectric properties [3]. Fig. 1 presents the different steps for the elaboration of the resonators. Polyethylene naphthalate (PEN) serves as substrate with a thickness of 25 μm . Then, the bottom electrode of aluminum (300 nm) is evaporated through a shadow mask. After that, the PVDF-TrFE layer is spin-coated (4 μm) and annealed at 140 $^{\circ}\text{C}$, which increases the PVDF-TrFE crystallinity and so its piezoelectric efficiency. The top electrode is evaporated in the same condition as the bottom one. Finally, the shape of a cantilever is defined by xurography [4] and the resulting device is glued on a glass slide, leaving the cantilever part free to move.

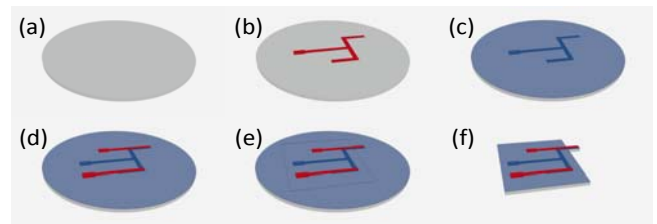


Fig. 1: Fabrication steps of the organic resonators. (a) PEN substrate, (b) evaporation of the bottom electrodes of aluminum, (c) spin-coating of the PVDF-TrFE layer, (d) evaporation of the top electrodes of aluminum, (e) cutting of the shape, (f) the device with the free cantilever and its unreleased counterpart.

The typical dimensions of the cantilever are 2 mm in length and 1 mm in width. Actually, two cantilevers are fabricated on the same substrate: one is free to move while the other one is unreleased. This architecture is used in the electric scheme for the resonance spectrum measurements.

APPLICATION

In this work, the organic resonators are used as viscosity sensors in liquid media. In that case, a polydimethylsiloxane (PDMS) layer (10 μm) has been added by spin-coating before the cutting step to passivate the electrodes. In order to measure the resonance spectrum, a dedicated electronic scheme is developed and presented Fig. 2. The two cantilevers (the free one and the unreleased one) constitute a capacitive half-bridge. The signal from the common electrode is sent to a charge amplifier and then goes to an IQ demodulator that gives the modulus and phase spectra. This strategy enables a good compensation of the parasitic capacitance due to the dielectric layer (PVDF-TrFE) lying between two conductors (the electrodes). Thanks to this electronics, measurements

in liquid media become possible.

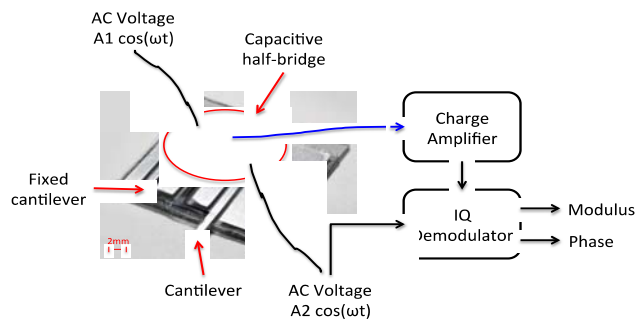


Fig. 2: Electronic scheme principle with a picture of a resonator.

In order to determine the viscosity without knowledge of the mass density, the resonance frequency and the quality factor must be measured and six parameters (m_1 , m_2 , m_3 , c_1 , c_2 and c_3) must be calculated [5]:

$$1/(2\pi f_r)^2 = m_1 + m_2\rho + m_3\sqrt{\eta\rho/(2\pi f_r)} \quad (1)$$

$$1/Q = 2\pi f_r (c_1 + c_2\eta + c_3\sqrt{2\pi f_r\eta\rho}) \quad (2)$$

with f_r the resonance frequency, Q the quality factor, η the viscosity and ρ the mass density of the liquid. It means that a calibration with three liquids whose mass densities and viscosities are known is necessary to determine these coefficients. Then, the viscosity can be analytically determined for liquids with unknown mass densities. So, measurements of the resonance frequency and the quality factor have been made in water-glycerol mixtures for different concentrations of glycerol. In order to validate the concept, the first measurements are made with a vibrometer for the first out-of-plane mode and the results are presented in Fig. 3. The viscosities determined with the resonators are compared with the ones measured with a viscometer. The results with the resonators are consistent with the viscometer and prove the efficiency of organic resonators for measurements in liquid media. Afterwards, measurements have been made with the electronic scheme but for a resonance mode that is a combination of flexion and torsion, as it is the one that presents the best electrical response. However, due to the electrical coupling that is not entirely compensated, the measurements of the quality factor are misrepresented and it is impossible to determine the viscosity without knowing the mass density. But, knowing the mass density and using (1), the viscosity

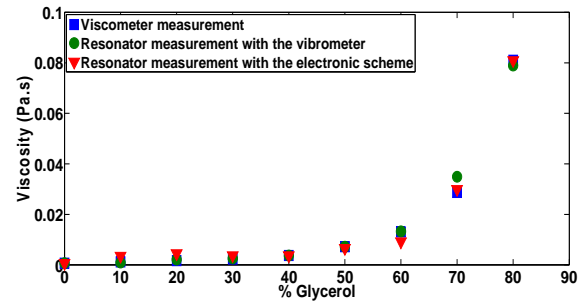


Fig. 3: Comparison of the viscosity measurements with a viscometer and with a piezoelectric MEMS resonator with the vibrometer for the first flexural mode and with the electronic scheme for another mode.

has been calculated and the results are also consistent (Fig. 3).

CONCLUSION

Here is presented a simple and low-cost fabrication process for the elaboration of organic piezoelectric resonators. Their performances have been demonstrated through measurements of viscosities in liquid media. However, improvement of the electrical measurements must be achieved in order to totally compensate the coupling and thus have a significant quantification of the quality factor, which is necessary to determine the viscosity independently from the knowledge of the mass density. Nevertheless, this work is promising for further biological and/or chemical applications.

ACKNOWLEDGMENTS

The authors acknowledge financial support by the CNRS and the University of Bordeaux (project MEMOCELL, joint call Idex Bordeaux-CNRS PEPS 2015).

REFERENCES

- [1] C. Liu, "Recent developments in polymer MEMS," *Adv. Mater.* 19, 3783-3790, 2007.
- [2] P.H. Ducrot, I. Dufour & C. Ayela, "Optimization of PVDF-TrFE processing conditions for the fabrication of organic MEMS resonators," *Sci. Rep.* 6, 19426, 2016
- [3] K.S. Ramadan, D. Sameoto & S. Evoy, "A review of piezoelectric polymers as functional materials for electromechanical transducers," *Smart Mater. Struct.* 23, 2014.
- [4] E. Lemaire, D. Thuau, B. Caillard & I. Dufour, "Fast-fabrication process for low environmental impact microsystems," *J. Cleaner Prod.* 108, 207-216, 2015.
- [5] M. Heinisch, T. Voglhuber-Brunnmaier, E.K. Reichel, I. Dufour & B. Jakoby, "Reduced order models for resonant viscosity and mass density sensors," *Sens. Actuators A* 220, 76-84, 2014.