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Enhanced dielectric pressure sensor by laser ablation assisted manufacturing process for highly optimized sensor components

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Abstract

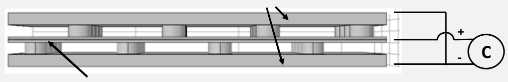
Silicone rubber (PDMS)-based 3D structures serve as mechanically supportive sensor components, enabling highly sensitive compression load sensors utilized on dielectric elastomers. These components function as mechanical converters, translating vertical forces into bidirectional strain within the dielectric film. They also enhance the electroactive surface area and sensitivity to compression loads, as the air gap between dielectric and supportive structure acts as part of the dielectric medium, responding to minimal forces. This study presents a laser ablation-assisted manufacturing process for the rapid and flexible production of these 3D structured sensor components, facilitating various sensor designs for research and development. A CO_2 laser was employed to ablate material from a PDMS film, creating cylindrical structures. A moulded and lasered reference (structures with 1 mm diameter, 0.5 mm in height) and a structure with a reduced aspect ratio (0.25 mm in height) were fabricated. Ablation accuracy was assessed using laser scanning (LSM) and light microscopy, the resulting dielectric sensor were electromechanically characterized. The lasered sensor exhibited a more linear sensitivity to pressure, while capacity change was only decreased by 17 % compared to the moulded reference. The sensor height was reduced by 52 %. Laser processing of compression load sensor components yields thinner sensors while maintaining exploitable sensitivity.

Introduction

Goal: Thin and highly sensitive compression load sensors

- Silicone rubber (PDMS)-based cylindrical 3D structures as sensor component: mechanical converters to enhance sensitivity towards compression load [1][2]
- Classical manufacturing process: moulding
- More flexible and faster manufacturing with laser ablation-assisted process
- CAD of compression load sensor:

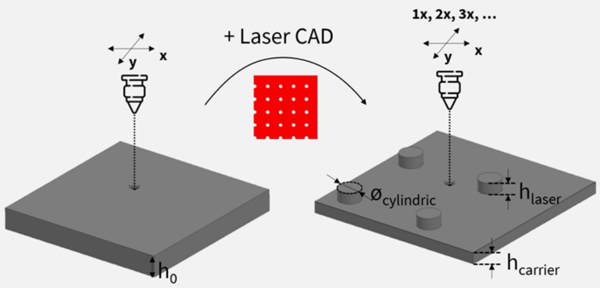
Cylindrical 3D structure, coated with conductive PDMS material: shield (-) electrode



Intermediate sensor layer: potential (+) electrode

Laser process of sensor component

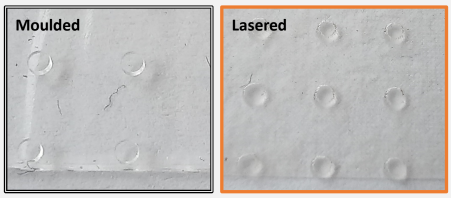
- Laser equipment:
  Epilog Fusion Pro32, CO_2 Laser
- Variation of laser parameters:
  - Laser power
  - Laser speed
  - Resolution (dpi)
  - Number of ablation processes
- Highly flexible ablation design by simple implementation of CAD
- PDMS material: Wacker Elastosil RT601, doctor bladed, with final thickness 0.85 mm and 0.55 mm



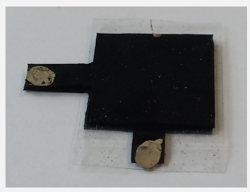
Results and discussion

Dim. in [mm]	Ref_Mould		Ref_Lasered h_0 = 0.85 mm		Thin_Lasered h_0 = 0.55 mm	
	Target	Actual	Target	Actual	Target	Actual
$ø_{cylindric}$	1.00	0.960	1.00	Bottom: 1.523 Top: 0.916	1.00	Bottom: 1.296 Top: 0.787
h_{laser}	0.50	0.484	0.50	0.446	0.25	0.323
$h_{carrier}$	0.50	0.445	0.50	0.40	0.25	0.230

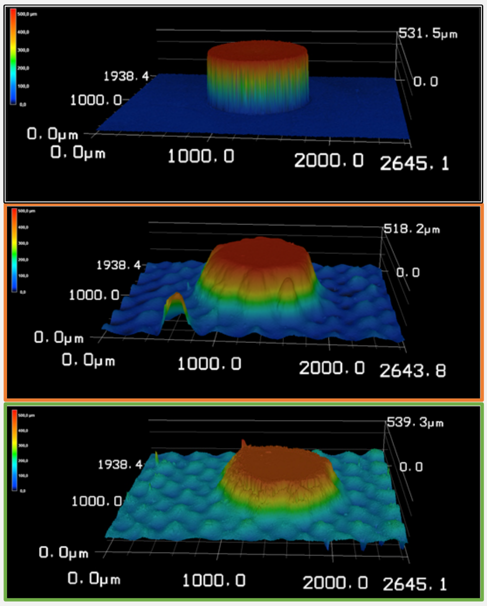
Targeted and actual dimensions of reference (moulded and lasered) and thinner component



Photography of 3D structures: Moulded & Lasered reference



Photography of final sensor: moulded reference



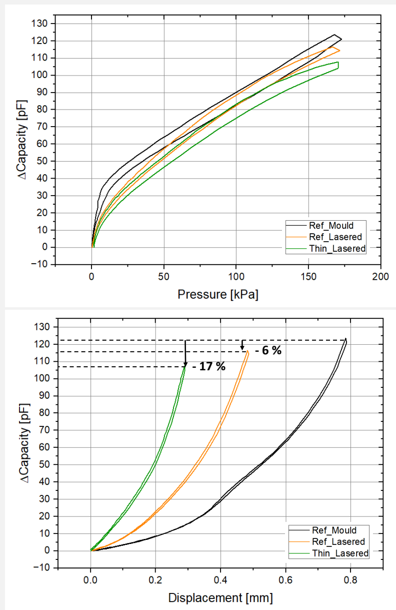
LSM measurement of 3D structures

Evaluation of laser process

- ➢ Moulding provides very precise 3D dimensions
- ➢ Laser process creates 3D structures with lower precision: cylindrical vs. conical structures
- ➢ Laser resolution produces surface roughness: 330 µm lateral / 70 µm in height
- ➢ Dimensions of lasered components fit acceptably with targeted dimensions

Assessment of sensor performance

- ➢ More linear pressure sensitivity with lasered components
- ➢ Sensor behaviour of lasered reference shifted towards lower absolute displacement change
- ➢ Only slight decrease in absolute capacity change (- 6 % and - 17 %) with lasered components, but displacement sensitivity reduces down to 0.5 and 0.3 mm
- ➢ Sensor thickness reduced from 2.14 mm down to 1.82 mm and 1.03 mm (- 52 %)



Electromechanical characterisation of compression load sensors

Conclusion

- ➢ Successful use of laser ablation process for rapid and flexible production of sensor components
- ➢ Reduced dimensional accuracy due to laser ablation process
- ➢ But: More linear sensitivity to pressure of sensor with lasered components

→ **Thin** and **highly sensitive** compression load **sensors**: 52% reduction in sensor height with only 17% reduction in sensor capacity at maximum load
→ **Reduced displacement sensitivity** by thinner components
→ **Positive effect** of surface roughness **on sensor performance**: surface increase, linearisation

References

[1] Böse, H., & Fuß, E. (2014, March). Novel dielectric elastomer sensors for compression load detection. In Electroactive Polymer Actuators and Devices (EAPAD) 2014 (Vol. 9056, pp. 232-244). SPIE.

[2] Ziegler, J., Uhl, D., & Böse, H. (2023, April). Dielectric elastomer sensors adapted for monitoring compression load of clamped battery cells. In Electroactive Polymer Actuators and Devices (EAPAD) XXV (Vol. 12482, pp. 156-170). SPIE

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