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MEMS Test Structures for Residual Stress Measurements

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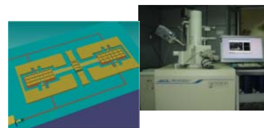

Outline

- Motivation
- Theory
- Results and Discussions
- Summary
- References

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MEMS Test structures*

- **Displacement Type: T, H shape structure**
- **Buckling Type: Beams, Cantilevers, Gückel Rings, Diamond structure**
- **Rotation Type : Pointers, Bent-beam, Lancet structures**

Residual Stresses

* B.P. van Drieenhuizen, J.F.L. Goosen, P.J. French, Comparison of techniques for measuring both compressive and tensile stress in thin films, Sens. Actuators A. 37/38, 756–765 (1993).
Q. He, Z.X. Luo, X.Y. Chen ,Comparison of residual stress measurement in thin films using surface micromachining method, Thin Solid Films 516, 5318–5323 (2008).

Theory

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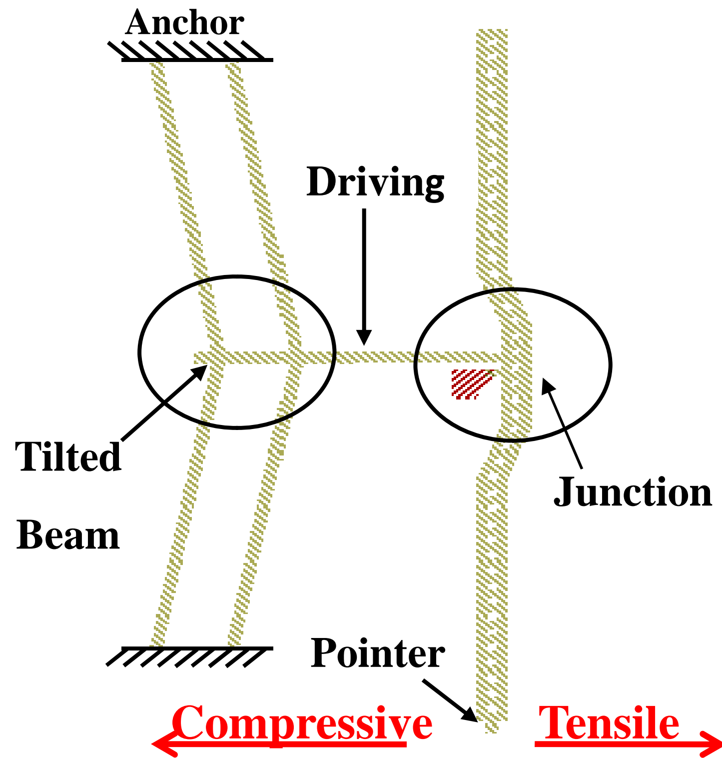
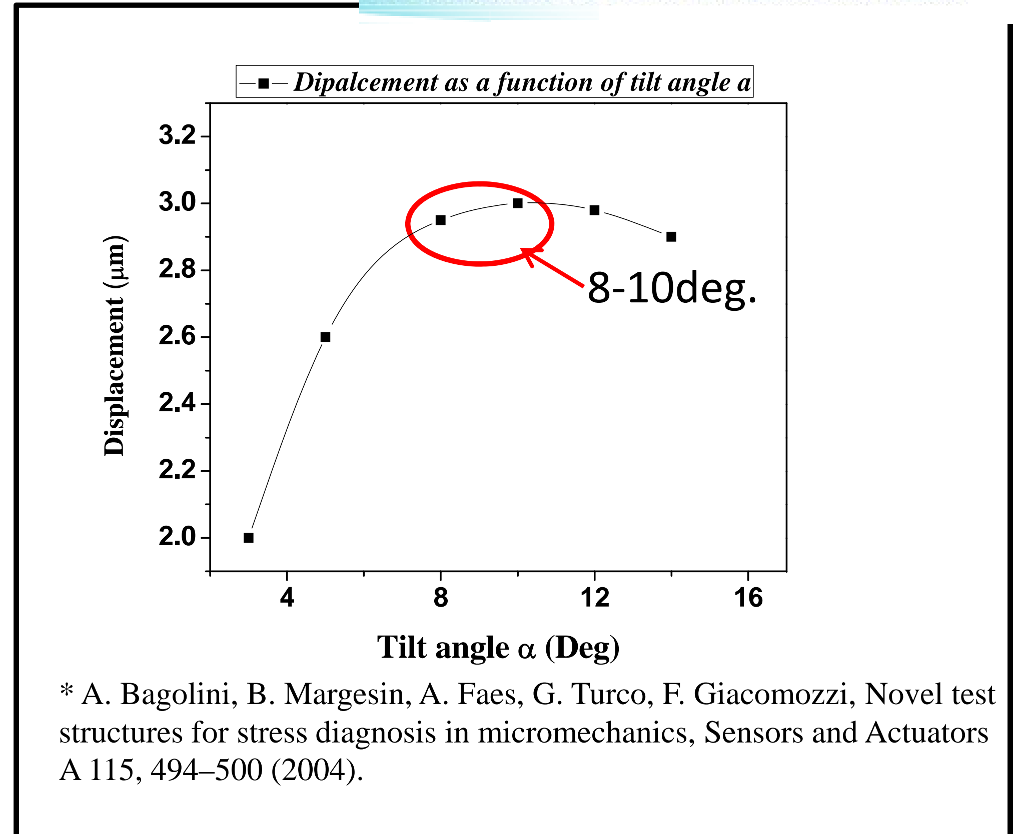
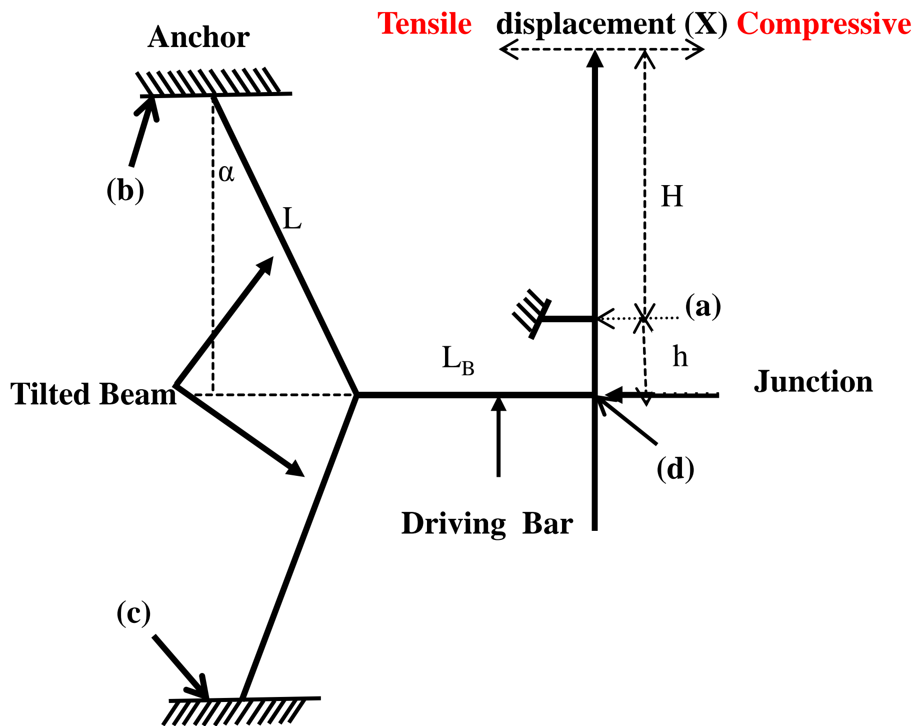


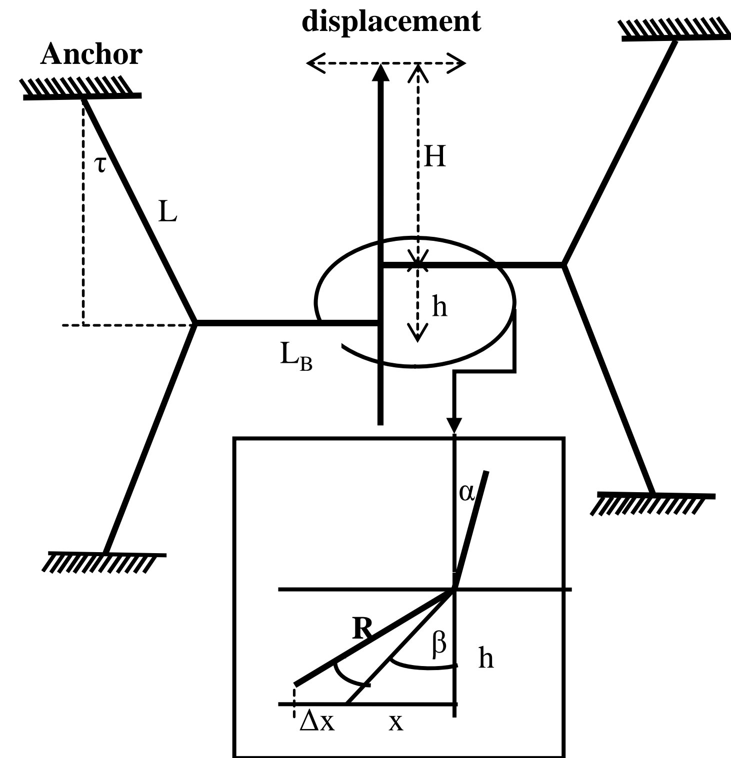
Basic Layout of Lancet



* A. Bagolini, B. Margesin, A. Faes, G. Turco, F. Giacomozzi, Novel test structures for stress diagnosis in micromechanics, Sensors and Actuators A 115, 494–500 (2004).

Schematic of modeling sequence





A. Conceptual schematic of the asymmetric lancet

B. Conceptual schematic of the symmetric lancet

displacement $X = \frac{H}{h}\left\{\Delta L_B + (L+\Delta L)\times \sin\left[\arccos\left(\frac{L\cos\alpha}{L+\Delta L}\right)\right] - L\sin\alpha\right\}$

displacement = H sinα $= H\sin\left[\arcsin\left[\frac{x+\left\{\Delta L_B + (L+\Delta L)\times \sin\left[\arccos\left(\frac{L\cos\tau}{L+\Delta L}\right)\right] - L\sin\tau\right\}}{h/\sin\beta}\right] - \beta\right]$

Results and Observations

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Subdomain: von Mises stress [Pa] Boundary: Total displacement [m] Deformation: Displacement

Asymmetric pointer structure with single junction layout

Cont…

Subdomain: von Mises stress [Pa] Boundary: Total displacement [m] Deformation: Displacement

Max: 9.286e-7 Max: 2.172e8

Min: 0 Min: 1.862e-5

Asymmetric pointer structure with double junction layout Cont…

Subdomain: von Mises stress [Pa] Boundary: Total displacement [m] Deformation: Displacement

Max: 2.213e8 Max: 3.505e-6

Min: 1.554e-5 Min: 0

Asymmetric Lancet pointer structure with single junction and electrical read out Cont…

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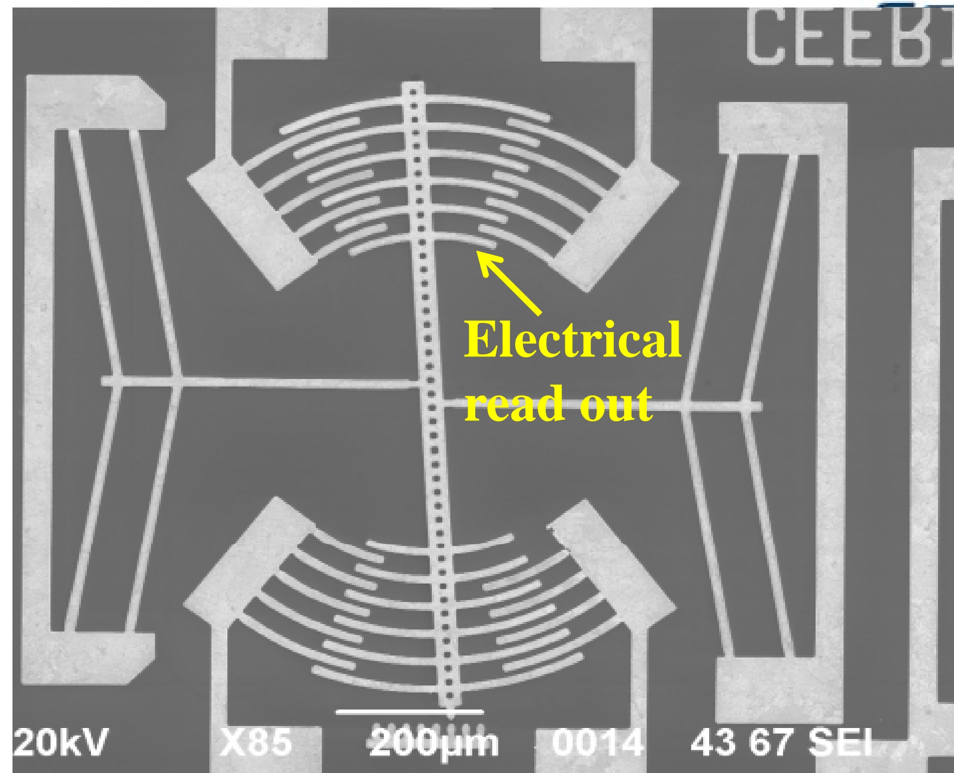
Subdomain: von Mises stress [Pa] Boundary: Total displacement [m] Deformation: Displacement

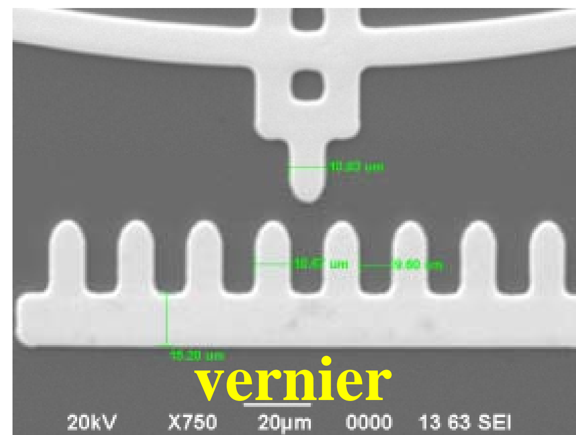
Max: 2.28e8 Max: 6.728e-6

Min: 0 Min: 0

Symmetric Lancet pointer structure with double junction and electrical read out

Cont…





SEM image of fabricated symmetric lancet

Cont…

Summary

Type Structures	Displacement (μm)	Stress (MPa)	Stress Type
Asymmetric Pointer	0.3	239	Tensile
Symmetric Pointer	0.9	217	Tensile
Asymmetric Lancet Pointer	3.5	221	Tensile
Symmetric Lancet Pointer	6.7	228	Tensile

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[1] B.P. van Drieenhuizen, J.F.L. Goosen, P.J. French, Comparison of techniques for measuring both compressive and tensile stress in thin films, Sens. Actuators A. 37/38, 756–765 (1993).

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[5] A. Bagolini, B. Margesin, A. Faes, G. Turco, F. Giacomozzi, Novel test structures for stress diagnosis in micromechanics, Sensors and Actuators A 115, 494–500 (2004).

[6] A. Bagolini, A. Faes, B.Margesin, Analytical model for magnified displacement Stress test structures,DTIP of MEMS & MOEMS, TIMA Labs/DTIP Montreux, Switzerland, 01-03 June (2005).

[7] B. Margesin, A. Bagolini, V. Guarnieri, F. Giacomozzi, A. Faes, R. Pal, M. Decarli, Stress characterization of electroplated gold layers for low temperature surface micromachining. in: Proceedings of the DTIP 2003, France, 402–405, (2003).

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Thank You!