



US006128961A

# United States Patent [19] Haronian

[11] **Patent Number:** **6,128,961**  
[45] **Date of Patent:** **Oct. 10, 2000**

[54] **MICRO-ELECTRO-MECHANICS SYSTEMS (MEMS)**

[76] Inventor: **Dan Haronian**, P.O. Box 2091, 90435 Efrat, Israel

[21] Appl. No.: **09/101,014**

[22] PCT Filed: **Dec. 24, 1996**

[86] PCT No.: **PCT/IL96/00190**

§ 371 Date: **Aug. 24, 1998**

§ 102(e) Date: **Aug. 24, 1998**

[87] PCT Pub. No.: **WO97/24915**

PCT Pub. Date: **Jul. 17, 1997**

### [30] Foreign Application Priority Data

Dec. 24, 1995 [IL] Israel ..... 116536

[51] **Int. Cl.<sup>7</sup>** ..... **G01B 7/16**

[52] **U.S. Cl.** ..... **73/774; 73/777**

[58] **Field of Search** ..... **73/763, 768, 774, 73/777, 780, 718, 721**

### [56] References Cited

#### U.S. PATENT DOCUMENTS

- 5,115,292 5/1992 Takebe et al. .
- 5,357,807 10/1994 Guckel et al. .
- 5,381,696 1/1995 Ichinose et al. .
- 5,656,785 8/1997 Trainor et al. .... 73/862.46
- 5,661,235 8/1997 Bonin ..... 73/105

#### FOREIGN PATENT DOCUMENTS

- 63-116478 11/1989 Japan .
- 05227590 9/1993 Japan .

#### OTHER PUBLICATIONS

- Haronian, D., et al., Sensors and Actuators 53:288–298, 1996.
- Rogers, E., J. Acoustical Society of Ame., 34:883–893, 1962.
- Puers, B., et al., IEEE Transactions on Electron Devices, 35:764–770, 1988.

- Kuhnel, W., Sensors and Actuators, 25:521–525, 1991.
- Bassous, E., IEEE Transactions on Electron Devices, 25:1178–1185, 1978.
- Shaw, K.A., et al., Sensors and Actuators, 40:63–70, 1994.
- Li, Y.X., et al., MEMS'95, pp. 398–403, 1995.
- Stoev, I.G., et al., Sensors and Actuators, 19:183–197, 1989.
- Wu, X.P., et al., Sensors and Actuators, 2:309–320, 1982.
- Wortman, J.J., et al., J. Applied Physics, 35:2122–2131, 1964.
- Wortman, J.J., et al., J. Applied Physics, 37:3527–3530, 1966.
- Goetzberger, A., et al., J. Applied Physics, 35:1851–1854, 1964.
- Chaudhuri, A.R., et al., J. Applied Physics, 33:2736–2746, 1962.
- Holland, M.G., et al., Physical Review, 128:30–38, 1962.
- Nathan, M.I., et al., Physical Review, 128:38–42, 1962.
- Mason, W.P., et al., J. Acustical Society of America, 29:1096–1101, 1957.
- Zhao, G., J. Applied Physics, 73:1832–1837, 1993.
- Hauser, J.R., Proc. of the IEEE, pp. 743–744, 1965.
- Haronian, D., et al., J. Micromech. Microeng., 5:289–296, 1995.
- Tran A.T.T.D., et al., IEEE Photonics Technology Letters, 8:393–395, 1996.
- Benitez, A., et al., MEMS '95, pp. 404–407, 1995.
- Sikorski M.E., et al., Rev. Sci. Instrum., 33:1130–1131, 1962.

*Primary Examiner*—Max Noori  
*Attorney, Agent, or Firm*—Mark M. Friedman

### [57] **ABSTRACT**

A microelectronics deformation sensor including at least one stress sensor directly integrated on at least one of an extremity of a supported deformable structure and a support of the deformable structure, the deformable structure being constructed of a single crystal material, the at least one stress sensor sensing a stress in a vicinity of the extremity and thereby sensing a deformation of the deformable structure.

**27 Claims, 24 Drawing Sheets**









































































