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Zhang et al.

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(54) **MEMS SENSOR WITH DYNAMICALLY VARIABLE REFERENCE CAPACITANCE**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | |
|--------------|---------|-----------------|
| 4,951,236 A | 8/1990 | Kawate et al. |
| 5,352,918 A | 10/1994 | Thomas et al. |
| 6,158,280 A | 12/2000 | Nonomura et al. |
| 6,308,569 B1 | 10/2001 | Stewart |
| 6,892,576 B2 | 5/2005 | Samuels et al. |

(Continued)

FOREIGN PATENT DOCUMENTS

| | | | | |
|----|-----------------|---------|-------|-----------|
| JP | 05248976 | 9/1993 | | G01L 9/12 |
| KR | 10-2009-0117004 | 11/2009 | | |

(Continued)

OTHER PUBLICATIONS

Robinson, Mark (Authorized Officer), Notification of Transmittal of the International Search Report and the Written Opinion of the International Searching Authority, or the Declaration; PCT/US2013/044333, 9 pages, Sep. 23, 2013.

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(57) **ABSTRACT**

An MEMS device has a dynamically variable reference capacitor that provides a reference to a sense capacitance. In some embodiments, a 3-axis accelerometer includes a proof mass suspended above a substrate from an anchor, and a cantilevered Z-axis reference capacitor arm suspended above the substrate from the same anchor. In some embodiments, the proof mass is suspended from a plurality of anchors, and each anchor also supports one or more cantilevered arms, the cantilevered arms forming a dynamically variable reference capacitance.

20 Claims, 10 Drawing Sheets

