Contributed Paper

2:20

2pEAa2. Silicon microphones: a commercial success? and what comes next? Stephen C. Thompson (Applied Reearch Laboratory, The Pensylvania State University, P.O. Box 30, State College, PA 16804, USA, sct12@psu.edu)

The first silicon microphone commercial product was introduced to the market in late 2005. As of early 2008 the cumulative production is well over a half billion units and the production rates continue to rise. To date the acoustical performance of these microphones is only as good as that of the of the lowest priced miniature electret microphones. Yet acoustical systems manufacturers often prefer silicon microphones because they are compatible with automated insertion and wave soldering assembly methods. Silicon microphones are also more environmentally stable in sensitivity than are electrets which may be important in matched microphone applications. Current research activities are investigating methods to reduce the internal noise improve matching tolerances, and further reduce manufacturing costs. This paper will review the current state of silicon microphones in commercial manufacture, and will survey some of the areas of current research in an attempt to suggest some possible directions of future market development.

Invited Paper

2:40

2pEAa3. Optimization of miniaturized silicon microphones using a two-wafer approach. Jianmin Miao (Nanyang Technological University, School of Mechanical and Aerospace Engineering, 50 Nanyang Avenue, 639798 Singapore, Singapore, mjmmiao@ntu.edu.sg), Chee Wee Tan (Nanyang Technological University, School of Mechanical and Aerospace Engineering, 50 Nanyang Avenue, 639798 Singapore, Singapore, cheewee@ntu.edu.sg), Zhihong Wang (Nanyang Technological University, School of Mechanical and Aerospace Engineering, 50 Nanyang Avenue, 639798 Singapore, Singapore, ezhwang@ntu.edu.sg)

A two-wafer concept is proposed for the fabrication of silicon microphones with emphasis on deep reactive ion etching and wafer bonding techniques. For miniaturized sensor structures with an air gap of 1-2 microns, the viscous damping effect dominates the dissipation mechanism, which can have an adverse influence on the microphone performance, namely frequency response characteristic and mechanical-thermal noise. Therefore, an optimum microphone performance has its origin in a well-designed backplate structure. A silicon backplate with carefully placed acoustic slots and holes is attached to a silicon nitride/metal-based diaphragm. An impediment to achieve high sensitivity is the residual stress that is presented in the diaphragms. Besides the process optimization of less stress silicon nitride layer and the introduction of corrugated diaphragm, an investigation is carried out to determine the effects of sputtering parameters of Cr/Au metal electrode film (thickness, sputtering process pressure and process power) on the residual stress of silicon nitride/metal diaphragm. Details of modeling, fabrication and experimental results will be presented.

Contributed Papers

3:00

2pEAa4. Piezoelectric Cantilevers for Low-Noise Silicon Microphones. Robert Littrell (University of Michigan, 2250 G G Brown Bldg, 2350 Hayward St., Ann Arbor, MI 48109, USA, rlittrel@umich.edu), Karl Grosh (University of Michigan, 2250 G G Brown Bldg, 2350 Hayward St., Ann Arbor, MI 48109, USA, grosh@umich.edu)

Microphones fabricated using microelectromechanical systems (MEMS) technology are one of the fastest growing applications of MEMS. Capacitive sensing has been the dominant detection principle used in MEMS microphones. Piezoelectric sensing, however, offers advantages including simpler accompanying circuitry and the possibility for simpler fabrication. Piezoelectric microphones have been limited primarily by a high noise floor, typically at least an order of magnitude higher than, otherwise similar, capacitive microphones. We present a low noise piezoelectric cantilever microphone to overcome the main limitation of previously constructed piezoelectric microphones. Aluminum Nitride (AlN) has been selected as the piezoelectric material because its piezoelectric coupling coefficient, in combination with its electric permittivity, and its piezoelectric loss coefficient enable low-noise devices. Through both mechanical and electrical optimization, models indicate that by combining several short, thin cantilevers made exclusively of Molybdenum and AlN, microphones with a die size of 1mm x 1mm, 10 kHz bandwidth, 2mV/Pa sensitivity, and noise floor below 40 dBA can be constructed using a simple 4 mask process. Analytical and numerical models and experimental results will be presented.

3:20

2pEAa5. A low-noise biomimetic differential microphone. Ronald N. Miles (State University of New York, PO 6000, Vestal Parkway East, Binghamton, NY 13902-6000, USA, miles@binghamton.edu), Quang T. Su(State University of New York, PO 6000, Vestal Parkway East, Binghamton, NY 13902-6000, USA, be83190@binghamton.edu), Weili Cui (State University of New York, PO 6000, Vestal Parkway East, Binghamton, NY 13902-6000, USA, weilicui@yahoo.com), Stephen A. Jones (State University of New York, PO 6000, Vestal Parkway East, Binghamton, NY 13902-6000, USA, saj0716@gmail.com), F. Levent Degertekin (Georgia Institute of Technology, G. W. Woodruff School of Mechanical Engineering, 801 Ferst Dr. NW, Atlanta, GA 30332-0405, USA, levent.degertekin@me.gatech.edu), Baris Bicen (Georgia Institute of Technology, G. W. Woodruff School of Mechanical Engineering, 801 Ferst Dr. NW, Atlanta, GA 30332-0405, USA, baris@gatech.edu), Caesar Garcia (Georgia Institute of Technology, G. W. Woodruff School of Mechanical Engineering, 801 Ferst Dr. NW, Atlanta, GA 30332-0405, USA, caesar@gatech.edu), Neal A. Hall (Georgia Institute of Technology, G. W. Woodruff School of Mechanical Engineering, 801 Ferst Dr. NW, Atlanta, GA 30332-0405, USA, nahall@alumni.utexas.net)

A miniature differential microphone is described that has a noise floor that is substantially lower than that of existing devices of comparable size. The sensitivity of a differential microphone suffers as the distance between the two pressure sensing locations decreases, resulting in an increase in the input sound pressure-referred noise floor. In the microphone described here, the two sources of microphone internal noise, the diaphragm thermal noise and the electronic noise, are minimized by a combination of novel diaphragm design and the use of low-noise optical sensing. The differential microphone diaphragm measures 1 mm by 2 mm and is fabricated out of polycrystalline silicon. The diaphragm design is based on the coupled ears of the fly Ormia ochracea. The sound pressure input-referred noise floor of this miniature differential microphone has been measured to be less than 36 dBA.