MEMS and NEMS
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MEMS and NEMS Poster Session

MN-TuP1 Analysis of Convective Performance in Confined Droplets with Various Working Fluids and Substrates for Polymerase Chain Reaction Applications, ***P.L. Chen****, C.S. Yu, C.C. Yang, Y.H. Lin, Y.H. Tang, M.H. Shiao, C.-N. Hsiao*, National Applied Research Laboratories, Taiwan, Republic of China

Polymerase chain reaction (PCR) is a procedure which repeating thermal cycles with three discrete temperature steps, including denaturation (95°C), annealing (60 °C), and extension (72 °C) for deoxyribonucleic acid (DNA) amplification. It usually takes 1 or 2 hour to complete the PCR process in commercial equipment. In order to reduce reagent solution and increase heat transfer rate, micro-electro-mechanical-systems (MEMS) and microfluidic technologies are utilized to miniaturize the PCR system. Furthermore, a new concept for the development of microchips that uses Rayleigh-Bénard (RB) convection to perform PCR amplification of DNA is rapidly increased in the past few years. However, the challenges for RB-PCR devices involve the control of flowing performance and chemical pollution . The aim of present work is to investigate the convective performance in a 2 µl droplet for the application of real-time PCR with computational fluid dynamics (CFD) techniques. The influence of several major parameters, such as the viscosity and density of working fluid, and the type of substrate on the overall temperature distribution, pressure drop and velocity distribution were all analyzed and discussed. The simulated results show that the steady state was reached in 3 seconds and 30 cycles were completed in 10 minutes inside the droplet by controllable flowing conditions. The droplet based RB-PCR device offers a miniaturized thermal circulation system by natural convention without tedious three steps temperature control or flow control and potentially applicable for real-time DNA microarray analysis.

MN-TuP2 The Study of Convex Corner Compensation for Dry Anisotropic Etching of Single Crystal Silicon in ICP-RIE, ***Y.H. Lin****, Y.H. Tang,* ITRC, NARL, Taiwan, Republic of China*, W. Hsu,* NCTU, Taiwan, Republic of China*, P.-L. Chen, C.C. Yang, M.-H. Shiao, C.-N. Hsiao*, ITRC, NARL, Taiwan, Republic of China

In this paper, the compensation structure assisted the convex corner structures etch in inductively coupled plasma reactive ion etch (ICP-RIE) have been studied. The convex corner structures are widely used in many applications like micro optical devices or micro sensors. There are many researches to discuss the convex corner structure under wet etch, but rare researches for dry ICP-RIE etching. In anisotropic silicon etching, under the Bosch patent, sequentially alternating etch and passivation cycles can easily achieve high aspect ratio silicon structures. The feature size of the convex corner structures is difficult to maintain as original design at the bottom position in deep etch, due to some non-vertical movement plasma. The non-vertical movement plasma caused by collision between plasma ions, pollutants or rebounded from the etching mask. The compensation structure is design in front of the convex corner structure. The compensation structures can obstruct the non-vertical plasma to etch the convex corner structure and reduce the etch lag effect during the etch process leading to better profile at deep etch. The current study systematically investigates plasma condition to verify feasibility of the proposed method, and discusses effect of the gap between compensation structure and convex corner structure at three different gaps of 15, 10, 5µm. It demonstrate the convex corner structure have better profile with compensation structure at 5µm gap than other at deep ICP-RIE etching.

Keywords**:** Convex corner compensation, Inductively-Coupled-Plasma Reactive-Ion-Etch (ICP-RIE), High-aspect-ratio structure

MN-TuP3 Micro Fabrication on Quartz Glass by Inductively Coupled Plasma-reactive Ion Etching and its Optical Application, ***Y.H. Tang****, Y.H. Lin, P.-L. Chen, M.-H. Shiao, C.-N. Hsiao*, ITRC, NARL, Taiwan, Republic of China

The etching characteristics of inductively coupled plasma-reactive ion etching (ICP-IRE) on the micro structure of quartz glass were investigated with a negative photoresist (KMPR 1050) etching mask material. We found that a nearly vertical side wall of the fabricated quartz glass profile with KMPR 1050 mask (negative photoresist). Detailed process characterization was performed by varying the process parameters which include ICP power, bias power and chamber pressure. In the case of KMPR mask, which has excellent material strength and good verticality, the etched micro structure exhibited a depth of 44.6 µm and vertical sidewall angle of 89° by means of ICP power 1500 W, bias power 120 W, and chamber pressure at 10 mTorr under a mixture gas of C_4F_8 and He at 12 and 84 sccm of flow rates, respectively. Moreover, the etching rate was controlled approximately at 0.249 µm per minute, the etching selectivity was more than a ratio of 1:2, and the roughness of etched surface was around 12.9 nm. Furthermore, the advantage of pattern transfer with high resolution and high accuracy has been demonstrated by fabricating subwavelength structure (SWS), achieving broadband antireflection (AR) and increasing the transmittance of incident light across the quartz glass. Consequently, smoothly tapered SWS surfaces with a width of 105 nm and a height of 190 nm could be produced on quartz wafer. This fabricated SWS decreased the surface reflectance to less than 6.75 % in the visible light spectrum.

MN-TuP4 Finite Element Model Verification of High Frequency Piezoelectric Contour-Mode MEMS Resonators Using Laser Vibrometry, ***K.R. Qalandar****, B.A. Gibson, L.A. Shaw, S.Y. Chiu,* University of California, Santa Barbara*, A. Tazzoli, J. Segovia,* Carnegie Mellon University*, M. Rinaldi,* Northeastern University*, G. Piazza,* Carnegie Mellon University*, K.L. Turner*, University of California, Santa Barbara

This paper reports the first FEA model verification of AlN contour-mode resonators (CMRs) using laser Doppler vibrometry (LDV) at frequencies above 1GHz. Full 3D models of UHF resonators are able to determine electrical and mechanical responses, including AF response, admittance curves, and full 3D mode shapes. The modal analysis here differs from previous works [1-3] by making direct quantitative comparisons between measured and simulated responses.

The 1GHz lateral-field CMRs consist of a thin film of AlN patterned with interdigitated metal electrodes on top and a floating electrode on bottom. An AC signal to the electrodes excites the contour-extensional mode through the equivalent d31 piezoelectric coefficient of the AlN [4,5]. The devices are characterized by mechanical and electrical measurements. A Polytec UHF120 LDV captures phase and out-of-plane displacement data, with ±1.4pm resolution down to a noise floor of 4pm (Fig. 1). Spatial scans across the surface generate 3D mode shapes (Fig. 2). By performing frequency sweeps and fitting data to the equations of motion, we extract mechanical parameters such as the linear and nonlinear stiffness and damping coefficients. Electrical measurements further validate simulation results; through the electromechanical coupling coefficient the mechanical measurements can also be confirmed.

The 3D FEA models are developed in COMSOL and used to determine both mechanical and electrical responses. We compare simulated frequency response, out-of-plane displacement, and Q with experimental data to verify the models (Table 1). Fig. 2 shows the 3D mode shape, and the out-of-plane displacement profile of individual fingers is shown in Fig. 3. The maximum seen in experiments is 119.5pm, which agrees well with the simulated value of 117pm. To compare mechanical response, the wavelength λ in the lateral direction is studied. Simulations show a 3.2um and 7.9um wavelength at resonance. Experimentally, a 4um and an 8um wavelength appear. The multiple wavelengths at resonance are the result of a mismatch in acoustic velocity between AlN and Al and their existence in the simulation serves as further validation. Simplified five-finger device simulations show good fit with experimental admittance (Fig. 4). Full 33-finger device simulations, currently in progress, will improve this fit.

The experimental data gives further insight into the operation of the devices and is essential to the verification the 3D FEA models. With confirmed accuracy, these models can be used for predictive modeling of GHz-range CMRs. This allows optimization of geometric parameters such as electrode spacing and anchor performance.

MN-TuP5 Phase Noise-Based Bifurcation Sensing of Nonlinear MEMS Cantilevers, ***L. Li****, L.A. Shaw, K.L. Turner*, University of California, Santa Barbara

The objective of this work is to develop a high frequency MEMS-based mass sensor capable of pushing the limits of sensitivity for the detection of explosive materials. The specific objective is to utilize a nonlinear microcantilever mass sensor functionalized with xerogel-based molecularly imprinted polymers (MIPs) for the selective detection of DNT. This paper reports the implementation of a novel control method for sensing which is based on the phase squeezing phenomenon present in the nonlinear dynamics of a parametrically driven microcantilever. It is expected to significantly improve the mass detection limits compared to bifurcation tracking [1], as well as reduce measurement time by over three orders of magnitude. Sensor speed, sensitivity, and selectivity are all important for ppt level DNT/TNT detection.

Previous work focuses on tracking the resonance frequency shift of the microcantilever due to DNT absorption using bifurcation tracking [1]. Bifurcation sensing is achieved by sweeping the frequency or voltage until a jump event occurs, and tracking is done by repeating the process to detect the frequency shift. However, bifurcation tracking is a time-consuming process which requires time to reset the system back to an appropriate initial condition after each jump event to avoid hysteresis before the next bifurcation occurs. This work reports a new method of sensing which concentrates on monitoring changes in the phase response as the device approaches the bifurcation point. Just prior to bifurcation, noise squeezing occurs due to a slowing down of the response component associated with the bifurcating eigenvalue near the bifurcation point. The statistical variance of the phase response serves as a precursor to activate the feedback control scheme, which employs frequency modulation to stabilize a parametrically-excited sensor at the edge of instability. By maintaining close proximity to the bifurcation, but not allowing the large amplitude growth necessary for existing bifurcation tracking methods, over three orders of magnitude measurement time improvements in the acquisition rate near the location of the bifurcation point can be made [2]. Initial results show that the controller is capable of tracking the resonance frequency based on the phase variance of the microcantilever with close proximity to the edge of instability and control parameters can be tuned to optimize the sensitivity of the sensor. DNT gas sensing using the controller is yet to be experimented and the sensitivity of noised squeezing bifurcation sensing of nonlinear MEMS microcantilever is expected to be presented at the conference.

MN-TuP6 Simulation Study of Processing Parameters for Solder Filled Self Assembled 3D Micro-scale Structures, ***N. Oraon***, International Institute of Information Technology, India, *J.C. Lusth, S.L. Burkett*, The University of Alabama, *M. Rao*, International Institute of Information Technology, India

Solder based self assembled (SBSA) structures are formed by transforming 2D patterns to 3D structures. SBSA processing involves conventional lithography, metal deposition, and etching methods in addition to dip soldering and solder reflow. The processing involves free metals around a fixed metal, when reflowed; the free metal pattern is rotated towards the fixed metal pattern till the solder reaches minimum surface energy. In previous work, we investigated two types of soldering: face and edge-soldered SBSA structures. The 3D structure produces an excess solder when the amount of the solder deposited is more than the 3D volume. The excess solder which is measured from the top of the metal structure to the top of the solder in face-soldered SBSA structures is known as solder standoff height (SSH). SSH is envisioned as being useful as a solder bump that could be used to stack hybrid layers in 3D integration schemes. Experimentally, SSH was found to be heat resistant. The simulation study we performed reflects the effect of processing parameters such as gap-size between metal patterns, solder thickness, and solder coverage on the formation of 3D structures. Formation of 3D structures is influenced by the tilt of free metal towards the fixed metal. Hence tilt angle is considered as one of the output parameters. The processing parameters are analyzed for truncated square pyramid (TSP) and open cube (OC) structures using an open source simulation tool, Surface Evolver.

Surface Evolver is an interactive program for the study of surfaces shaped by surface tension. Simulation results show that as the gap size decreases, the minimum solder energy is attained at lower tilt angles for face-soldered TSP and OC structures. Edge-soldered OC structures follow a similar trend. The tilt angle remains constant for a range of gap sizes for edge-soldered TSP structures. Varying solder thickness varies the minimum energy tilt angle for face-soldered structures. For edge-soldered structures, tilt angle remains constant irrespective of solder thickness. Optimum tilt angle remains constant for solder coverage of 70 % and higher in both TSP and OC structures.

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