## MEMS and NEMS
## Room: Central Hall - Session MN-TuP

## MEMS and NEMS Poster Session

**MN-TuP1 Tangential Momentum Accommodation Coefficients in Coated Microtubes**, *M. Hadj Nacer, I. Graur, P. Perrier, J.G. Méolans,* Aix-Marseille Université, Ecole Polytechnique Universitaire de Marseille, France, ***M. Wüest***, INFICON Ltd, Liechtenstein

The experimental setup based on the constant volume technique is developed to measure the mass flow rate through microtubes under isothermal stationary flow conditions. Four different working gases (helium, nitrogen, argon and carbon dioxide), and two surface materials (Stainless Steel and Sulfinert) are considered.

The Knudsen number calculated for the experimental conditions varies from 0.0001 (hydrodynamic regime) to 0.1 (slip regime). In this range the approach based on the analytical solution of the Stokes equation subjected to the first order velocity slip boundary condition is used. The velocity slip coefficient and the Tangential Momentum Accommodation Coefficient (TMAC) are extracted from the experimental data of the mass flow rate using their analytical expressions.

The results are summarized in the tables representing the accommodation coefficients for the corresponding gas-surface material combinations. The influence of the molecular mass on the tangential momentum accommodation coefficient is discussed.

**MN-TuP3 Development of Deposition and Etching Processes of Thick ZnS Films for Pixel Level Packaging of Infrared Focal Plane Arrays**, ***B. Glück***, ST Microelectronics, France, *G. Rodriguez, G. Dumont, S. Barnola*, CEA, LETI, MINATEC Campus, France

Because of its transparency in the medium and long wave infrared light (MWIR and LWIR) zinc sulphide (ZnS) is an attractive material to make optical windows for infrared devices. Moreover, its relatively low optical index can be used advantageously in association with high index material such as Germanium (Ge) to create an anti-reflecting coating.In our application a thick ZnS film of about 1.2µm is deposited on top of the Ge to create the infrared window of a micro packaging structure for micro-bolometer devices in 200mm. This window has to be opened at the end of the process flow to realise the contacts. This study focuses on the deposition of ZnS by electron beam evaporation and its reactive ion etching to form the first layer of the IR-window. The integration of these processes in the fabrication of infrared focal plane arrays is presented in this work.In particular structure and morphology of the deposited ZnS films were investigated by X-ray diffraction, X-ray reflection, atomic force microscopy and scanning electron microscopy. Spectroscopic ellipsometry measurements were done to determine the optical properties. Concerning ZnS etching we developed a HBr based etch process that is also applicable to etch the Ge layer underneath using the same mask. The main process trends were investigated to maximise the etch rate and the selectivity to photoresist.

**MN-TuP4 Low Damage Etching Process for Fabricating Micro Electro Mechanical Systems (MEMS) Devices using Neutral Beam**, ***K. Miwa***, *Y. Nishimori, S. Ueki,* BEANS Laboratory, Japan, *M. Sugiyama,* The University of Tokyo, Japan, *T. Kubota, S. Samukawa*, Tohoku University, Japan

We have developed low damage etching process suitable for fabricating micro electromechanical systems (MEMS) devices based on silicon by using neutral beam. For cutting edge three-dimensional (3D) MEMS devices, high aspect ratio structures are indispensable. In addition, the surface of the silicon device is required to be smooth enough to achieve excellent properties as electromechanical or optical devices. However, conventional processes using reactive ion enhanced etching (RIE) of silicon are likely to have rough surfaces called scallops or ripples on sidewalls. Furthermore, conventional plasmas used for etching process cause damages on the etched surfaces by ion and electron fluxes (charges) or vacuum ultraviolet/ultraviolet (VUV/UV) light emission from etching plasmas. In turn, neutral beam etching technology is able to achieve ultra-low damage etching and to obtain atomically flat silicon surfaces. Therefore, by using neutral beam we have developed novel dry process to fabricate silicon MEMS devices of which surface is smooth enough and have damage-less surfaces. The neutral beam was produced from an inductively coupled plasma (ICP) of pure $Cl_2$ gas in an etching tool. The ICP was generated by radio frequency (RF) wave (13.56 MHz) and the RF was time modulated at 10 kHz and the duty ratio was 50% (50µs ON/ 50µs OFF). Ions in the ICP were accelerated toward a carbon aperture and neutralized by colliding onto the aperture which was biased by applying 450 kHz alternating voltage. Two types of apertures are used for the experiment. The apertures have many small holes of its aspect ratio is approximately 10 and 20, respectively. We have found that the etched silicon trench profile by the neutral beam depend on bias voltage and aspect ratio (AR) of the aperture. In addition, mask material can change the trench shape.By optimizing these conditions to produce neutral beam, we have obtained silicon trenches which have perpendicular trench profile of its width is around 200 nm. No defects or damaged layer are seen in transmission electron microscope (TEM) observation of the trench sidewalls. The study was supported by new energy development organization (NEDO). Authors would like to thank to NEDO and project members in BEANS Laboratory.

**MN-TuP5 Deveropment of Test Instrument for the Mechanical Strength of Micro-nano Wires**, ***A. Kasahara***, *M. Sasaki, H. Suzuki, M. Goto, M. Tosa*, National Institute for Materials Science (NIMS), Japan

Recent nano-technology researches have created various advanced micro-nano materials.

In particular, there have been many reports on nano-meter-scale tubes and wires such as carbon nanotubes

and silicon wires.

We have prepared long crystal silicon wires with a diameter of several tens of nano meters at a temperature lower than 523k by using the low-pressure low-temperature CVD method too. To use these as materials for application to micro-nano electromechanical system, we need to fully understand their electric, chemical and mechanical properties.

However, we have not yet to see a genuine, flexible methodology for evaluating the key characteristic of mechanical strength essential to micro-nano structural materials development the nano scale equivalent of mechanical strength testers for ordinary materials.This time, we are developing the device which could support a bending or shearing test.We will discuss our recent results on mechanical strength measurement of micro-nano wires in diameter several nm through several thousand nm and in length several mm by means of prepared micro-nano mechanical strength measurement device.

**MN-TuP6 Tin-Oxide Nanostructured Arrays Based Integrated MEMS Device for Low Temperature Hydrogen Detection**, ***R.N. McCormack***, University of Central Florida, *N. Shirato,* University of Tennessee, *U. Singh, S. Das, A. Kumar, H.J. Cho,* University of Central Florida, *R. Kalyanaraman,* University of Tennessee, *S.S. Seal*, University of Central Florida

In the pursuit of an alternative fuel source, hydrogen gas appears to have the best potential. All hydrogen gas related processes require accurate monitoring for leaks during the storage, transportation and usage. The problem that arises with the use of hydrogen is its tendency to leak along with being highly explosive at 4-vol%. Most of the current metal oxide based chemi-resitors in use as detectors operate at elevated temperature (above 100 degree Celsius) in order to aid their sensor's response kinetics. This becomes a safety concern due to its proximity to the highly explosive hydrogen gas. The search for low temperature sensitive hydrogen sensing device is at the forefront of our research endeavor.

$SnO_2$ was deposited on $SiO_2/Si$ substrates through the method of pulse laser deposition (PLD) to form thin film. Through the process of nanosecond pulse laser interference irradiation of the thin film, successfully architectured $SnO_2$ nanoarrays were developed. These nanowire-like $SnO_2$ structures fabricated were uniformly distributed along the surface of the substrate. Dimensions of the nanostructure were obtained through Atomic Force Microscopy (AFM) and Scanning Electron Microscopy. Results obtained illustrate that the nanoarray's nanowires were ~8 nm in cross-sectional height and tens of microns in length. Both thin film and nanoarray were then incorporated into MEMS device. Tests of chemi-resistors were conducted at room temperature within the concentration limits of 300 to 9000 ppm under dynamic condition, simulating the actual environments of exposure. In comparison to $SnO_2$ thin film, the nanoarray illustrates a significantly larger electrical response upon exposure to concentrations as minimal as 600 ppm. Nanoarray exhibited a (drop in resistances by 2 orders of magnitude) 150 fold increase in electrical response in comparison to that of the thin film.

$SnO_2$ nanoarray incorporation into the MEMs platform has successfully produced a low temperature hydrogen sensor. The performance of the nanoarray showed promising applicability due to it fast response time, high electrical response and its robustness. Theoretical models of the depletion layer and the diffusive characteristic within $SnO_2$ were developed in order to exemplify the combined sensing mechanism due to the nanoarray's geometry. This research endeavor therefore combines aspect of interdisciplinary materials design and integration alongside MEMS design, experimental conduction and modeling of device mechanism in the development a gas detector.

**MN-TuP7 Nanoimprint Block Co-polymer Enhanced Nanostructure Lithography**, ***J. Zendejas**, B. Wong, S. Franz, R. Candler*, UCLA

As the demand for higher densities in microelectronic devices increase, the strain on current lithographic technologies becomes great. To achieve greater performance, smaller feature sizes are necessary and will require innovative lithographic technologies. One technique, called Nanoimprint Lithography (NIL) differs from traditional lithography in the exposure and development process, which is replaced by a process in which a resist on a substrate is imprinted by a patterned mold. The nano-scale reproducible patterns allow for a high-throughput technique that saves much processing time and cost. At the UCLA NRF, we are developing baseline recipes for producing nanoscale pattern transfers using PMMA and mr-I (Micro Resist Technologies) polymers. The ability to mass produce nanoscale patterns (C.D.<100 nm) will have a great impact on projects ranging from microelectronics to bioengineering. Using the NIL techniques learned at the UCLA NRF, two target applications have emerged. The cost effective means to produce nanoscale

patterns has made it possible to readily investigate; block copolymer (BCP) lithography and nanoimprint assisted DNA sequencing.

**MN-TuP9 Electrostatic Deposition of a Micro Solder Particle Using a Single Probe by Applying a Single Rectangular Pulse**, ***D. Nakabayashi**, K. Sawai, P. Hemthavy, K. Takahashi, S. Saito*, Tokyo Institute of Technology, Japan

Recently, demands for micromanipulation techniques have increased in order to realize highly functional microdevices such as MEMS. A technique to deposit a conductive microparticle onto a conductive substrate by using a single conductive probe as a manipulator has been proposed as one of the techniques. The technique can be used to increase the yield of a ball-grid-array (BGA), which is used for IC packaging, by fixing the individual soldering defect. Adhesional force between the probe and the microparticle is dominantly greater than gravitational force on the microparticle due to scaling law. Thus, repulsive force must be generated to detach the microparticle from the probe. In the technique, a solder particle with a diameter of 20–30μm, initially adhering to the probe tip, is detached and deposited onto a substrate by applying a voltage between the probe and the substrate to exert an electrostatic force on the particle. However, when a constant voltage was applied, the detached particle mostly went out of the microscopic view due to the excessive impact of the collision between the particle and the substrate. In the previous research, a voltage sequence was optimized in order to reduce the excessive impact. The success rate of the particle deposition in the previous research was 44%, and is not sufficient for industrial applications. In this study, a technique to deposit the particle on the substrate by applying a single rectangular pulse is proposed, and the mechanism of the deposition by the proposed technique is described. In the mechanism, an electric discharge between the probe and the particle when the particle reaches the substrate plays a dominant role in the particle deposition. The current of the electric discharge generates the Joule heat due to the contact resistance between the particle and the substrate. The small part of the particle which contacts the substrate is melted by the Joule heat, and the melted part absorbs the impact of the collision between the particle and the substrate. Consequently, the particle is successfully deposited onto the substrate. Moreover, the mechanism of the proposed technique is verified by experiments of particle deposition, which are observed by using a high-speed camera (645,000 frames per second), a scanning electron microscope (SEM) and an oscilloscope. The success rate of the particle deposition has improved to 93% by the proposed technique. Furthermore, the Joule heat and the volume of the melted region are evaluated as indicators of the damage to the particle caused by the electric discharge using an RC circuit model, and the applicability of the proposed technique is discussed.

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