Multifunctional and Hybrid Microsystems
Room Ballroom A - Session MC-ThP

Multifunctional and Hybrid Microsystems Poster Session

MC-ThP-1 Integrated Magnetic Bio-MEMS for High-Speed, Trajectory-Based Microparticle Classification in Laminate Microfluidic Channels*, Muhammad Tahir,* ***Umer Hassan,*** Rutgers, The State University of New Jersey

Microfluidic diagnostics increasingly depend on microsystems that combine sample handling, physical actuation, optical readout, and data analysis within one workflow. We present a magnetically actuated bio-MEMS platform that uses particle motion, rather than fluorescence or impedance, as the primary signal for distinguishing magnetically responsive microparticles in flow. The approach integrates a laminate polymer microchannel, an external permanent magnet, high-speed brightfield imaging, and automated video analysis, making it relevant to multifunctional microsystems where sensing, actuation, and signal processing are co-designed.

The device was constructed from three laser-cut polymer layers to form a transparent channel with a 35 mm length, 150 µm width, and 87 µm height. Nonmagnetic polystyrene beads and magnetic beads, both approximately 5–5.9 µm in diameter, were used as model negative and positive particle populations. Samples were introduced at 5 µL/min, producing an estimated particle velocity of 6.4 mm/s. Motion was recorded at 3,030 frames/s with 324 µs exposure over a field of view of approximately 600 µm × 162 µm. A computer-vision pipeline converted the image sequence into particle centroids, reconstructed paths, and extracted trajectory slope as a compact metric of magnetically induced lateral displacement. COMSOL Multiphysics modeling guided the microsystem geometry before testing. Simulations examined magnet-channel spacing from 0–10 mm, magnet width from 3.175–9 mm, and channel widths from 250–750 µm. The model showed that smaller magnet-channel separation, larger magnet width, and narrower channels improved deflection within the imaging window; for example, mean simulated slope decreased from 0.151 to 0.005 when the magnet was moved from the channel edge to 10 mm away.

Later, experimental data confirmed that trajectory-derived signatures can separate the two particle groups. Using a slope threshold of 0.03, 240 of 393 magnetic particles were classified as deflected, compared with 53 of 347 control particles. This corresponded to 61% deflection for the magnetic population and 15.2% apparent deflection for controls. Mean trajectory slope shifted from -0.01 ± 0.059 for control beads to 0.039 ± 0.062 for magnetic beads, demonstrating measurable motion contrast between populations. This work demonstrates an integrated fluidic-actuation-imaging-analysis platform for magnetic microparticle classification. With improved tracking and antibody-labeled cell validation, the system could support compact bio-MEMS workflows for cell phenotyping, surface-marker-linked magnetic response, and low-cost diagnostic microsystems.

MC-ThP-2 Internal Friction, Creep, and Mechanical Behavior of Zr-Based Metallic Glass Thin Films for MEMS/NEMS Applications*, KAI-AN YANG, Yan-Wei Chang,* National Chung Hsing University, Taiwan*; Hsiang-Yu Hsieh, Chen-Jia Wang,* National Chung Hsing University, Taiwan*; Tra Anh Khoa Nguyen,* ***Ming-Tzer Lin,*** National Chung Hsing University, Taiwan

Zr-based metallic glass alloys exhibit high hardness, wear and corrosion resistance, ductility, high strain toughness, and low Young's modulus, making them attractive candidates for MEMS and NEMS devices. Yet, research on the internal friction characteristics, creep behavior, and fracture mechanisms of metallic glass thin films remains limited, and the fundamental processes of internal friction and shear band slip within their amorphous structure are not fully understood. In this study, Zr-Cu-Ti metallic glass thin films are employed to investigate anelastic mechanical behavior, creep resistance, and fracture response across a broad temperature range from room temperature to elevated conditions. Internal friction measurements and bulge tests are conducted to quantify energy dissipation, structural relaxation, and crack propagation resistance. In addition, Zr-Cu-Ti metallic glass thin films are also examined before and after annealing to investigate the effects of phase transformation from amorphous to crystalline states. Preliminary results indicate that annealing-induced crystallization alters internal friction and mechanical performance, establishing correlations between atomic-scale structural evolution and macroscopic reliability. These findings provide new insights into the reliability of metallic glass thin films, enabling their integration into MEMS/NEMS devices where durability, adaptability, and long-term stability are critical. This work directly supports the MEMS and NEMS area of interest by advancing knowledge of thin-film mechanical behavior under structural transformation.

MC-ThP-3 Influence of the Structural Regions of a Si_3N_4 Membrane Window on the CMOS Image Sensor Signal*,* ***Kamil Baranowski****, Michał Krysztof, Michał Zychla,* Wroclaw University of Science and Technology, Poland*; Rupert Schreiner, Matthias Hausladen,* Ostbayerische Technische Hochschule (OTH) Regensburg, Germany*; Mathias Bartl,* Ostbayerische Technische Hochschule (OTH) Regensbur, Germany*; Alexandr Knápek,* Institute of Scientific Instruments of the Czech Academy of Sciences, Czechia

1. Introduction

A CMOS sensor coated with a copper layer can be used to detect an electron beam [1]. Incoming electrons are decelerated within the layer, generating Bremsstrahlung X-rays, which the sensor records and converts into a beam's image. The target application is the detection of an electron beam in a gaseous environment [2]. A silicon nitride (Si_3N_4) membrane separates the vacuum environment of the electron-optical column from the gaseous environment of the sensor, maintaining the pressure difference while allowing electron transmission. Here we examine how the membrane and supporting silicon chip influences the CMOS signal, aiming to isolate its contribution from effects caused by other factors, such as gas composition.

2. Experiment

To assess this, the CMOS signal intensity was mapped along a line scanning the membrane (Fig. 1). The CMOS matrix was mounted inside a JEOL JSM-100 SEM, which served as both the electron source and the vacuum chamber. The sample stage was moved along a predefined scanning path, directing the 10 keV electron beam at successive regions of the membrane window. Three regions are distinguished
(Fig. 1): A - full silicon substrate, ~350 µm thick; B - sloped pyramid wall formed during KOH etching; C - Si_3N_4 membrane, 100 nm thick. Signal intensities are reported relative to region C, taken as 100%. The recorded signal reflects the combined effect of electron scattering, energy loss, and Bremsstrahlung yield in the copper layer, rather than a simple beam transmission ratio.

3. Conclusion

The experiment quantified how the Si_3N_4 membrane and surrounding substrate geometry contribute to the CMOS signal. In region A no signal above the noise floor was detected (0%), confirming that the 350 µm silicon substrate fully absorbs the beam and X-rays that can be generated in it. In region B the signal increases as the silicon thickness decreases, indicating that the KOH-etched pyramid walls also contribute to the detected signal. In region C the signal reaches its maximum (100%). These results show that the etched window geometry significantly influences the signal and must be accounted for when separating membrane-related contributions from gas-related effects in future measurements at elevated pressure.

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