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Biomechanosensors for Cardiomechanical Studies Using MEMS/NEMS Technologies

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Mechanical force has provided invaluable information in the study of cardiomechanics. The force abnormality of single cardiac myocytes often reflects various levels of heart diseases because the contractile performance of the heart pump heavily depends on the cellular forces. The local and precise detection of cellular force is therefore expected to assist in the study of various conditions, including heart failure, acute myocardial infarction, and stroke. In the present work, the design, fabrication and testing of miniaturized biomechanosensors are demonstrated using MEMS/NEMS technologies. These biomechanosensors have been used to resemble the in vivo like cell morphology and to measure cellular forces with subcellular spatial resolution.

Two types of polymer fabrication technologies are developed: 1) pressure-assisted micromolding and 2) pressure-assisted micropatterning. The former enables fabrication of polymer structures with various aspect ratios from a single master template; and the latter enables patterning of non-photo-definable polymer on top of rigid templates. Using such technologies, cellular force measurement with subcellular resolution is enabled in isolated cardiac myocytes. Moreover, cell alignment in vitro and cellular force measurement are performed concurrently with three-dimensional polymer structures. The results conform to previous reports and validate polymer microstructures as a viable tool for cardiomechanical studies. The nanoscale biomechnosensors have also been presented for better probing resolution and enhanced spatial resolution. Since direct optical microscopy is no longer appropriate at nanoscale, scanning moiré technology is proposed and validated. In addition, reactive ion etching and fluorine enhanced oxidation are utilized to fabricate silicon-based nanostructures with flexible geometric profiles, opening a door for electrical measurements of the cellular forces in the future. These microscale and nanoscale structures are expected provide a full set of functional biomechanosensors for investigation of cardiomechanical studies at small scale.

Dr. Yi Zhao holds a B.S. and M.S. degree in Mechanical Engineering from Tsinghua University, China, and a Ph.D. degree in Manufacturing Engineering, Boston University. During his Ph.D. study he has been working as a lead member in a NSF funded project to develop a nanoscale sensing component to determine the mechanical forces developed by living cells. Zhao's research interests lie in investigation of material behavior and processing at small scales, non-conventional micro/nano fabrication technologies, and development of functional Micro-electro-mechanical Systems (MEMS) for biomedical application. He has 7 journal publications and over 15 peer-reviewed conference proceedings since 2004. His work has been presented in the major conference and workshops in the MEMS field. Zhao is a member of IEEE, ASME, AVS and MRS.