

“eMosquitoTM”: An Actuated Microneedle for Automated Blood Sampling

Categories: BioMEMS, Actuators, Other Novel Designs

Introduction: Here proposed is an innovative design idea for a semi-invasive blood sampling, analysis and drug delivery device called “Electronic Mosquito” or “eMosquitoTM”. The device resembles the real mosquito in penetrating the skin to sample a very small blood droplet. The most intricate design problem is the automatic actuation and control of an individual microneedle. Hence, to demonstrate the feasibility of the project, three MEMS prototypes have been fabricated and are currently being tested. Even though Software tools are available, the accessibility to the CoventorWare Package would considerably accelerate the design and prototyping of the eMosquitoTM project.

Affiliations: Giorgio Gattiker did his undergraduate studies in mechanical engineering at the Swiss Federal Institute of Technology (ETHZ), and a specialization in electro-medical engineering at the University Latina of Costa Rica. He is currently working toward the Ph.D. degree in electrical engineering at the University of Calgary where he is supervised by Dr. Martin P. Mintchev and co-supervised by Dr. Karan V.I.S. Kaler. His research interests are in the areas of MEMS, VLSI and microfluidic design and system integration. During his graduate studies he received three MEMS-chip fabrication grants from CMC (Canadian Microelectronic Corporation); he coauthored four technical publications and one patent.

Proposal:

Background: The deficiency in automated, reliable, safe, and clinically acceptable blood sampling has been a major problem precluding the development of real-time systems for blood analysis and closed-loop physiological function control. The analysis of a static blood sample in laboratory conditions has been rapidly progressing in both reliability and blood volume reduction. However the progress in non-invasive real-time blood analysis performed in vivo has been subtle and unreliable.

Aim of the research: The study is exploring an innovative multidisciplinary idea for automated and minimally invasive blood sampling. This mechanism is imitating the skin penetration and blood retracting operation of a mosquito’s proboscis and is part of the ambitious eMosquitoTM project. The Electronic Mosquito, enclosed in a disposable patch and attachable to the skin, could be an avenue for real-time painless semi-invasive blood analysis and physiological cell interrogation with broad applicability in treating disorders like diabetes, or in blood monitoring for diagnostic and security-related purposes. The objective is to design a microactuator with an integrated microneedle, applying state-of-the-art MEMS technology. The implementation of the microsystem is realized within the framework of a complete MEMS design process (conceptualization, modeling, design, simulation, fabrication and testing).

Current status: An overall design concept of the e-MosquitoTM has been proposed and a provisional patent has been filed. Various microactuation principles have been analyzed in order to optimally integrate and effectively actuate the microneedle. Computer Aided Design (CAD) simulation and modeling of various microactuators have been made and three MEMS chips have been designed and sent for fabrication to CMC. These chips will

provide important information on the microactuator structure and its dynamic behaviour leading towards the next design iteration: the microneedle fully integrated on the microactuator.

Methods and hypothesis: Quantitative and qualitative analysis of existing microactuation mechanisms revealed that piezoelectric actuation techniques are beneficial in terms of high force delivery capabilities, large displacement, and power efficiency. A pyramidal out-of-plane hollow microneedle structure was found to be of adequate mechanical strength to reliably perform a single skin penetration, followed by a subsequent removal.

Anticipated results: Based on developed CAD and Finite Element Analysis models, and once obtained the testing results from the first MEMS chip, the next step towards realization of the Electronic Mosquito will be the fabrication of the piezoelectrically actuated microneedle. The manufacture of the proposed design will be done manually and in a highly specialized microfabrication facility (NanoFab, University of Alberta). Subsequently to fabrication, dynamic MEMS testing is foreseen (BioMEMS Lab, University of Calgary), as well as clinical testing.

Conclusion: This proposal involves two fields (MEMS and Biomedical Engineering) with extremely high economical impact factors. The outcome of the study is immediately applicable in the medical industry. Even though most of the tools to design MEMS are provided, the availability of the CoventorWare Software would significantly contribute to a faster design, prototyping, and implementation of the e-MosquitoTM.