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A highly-sensitive integrated capacitive sensor for contractile force measurement in an engineered heart tissue platform

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Introduction

Engineered heart tissues (EHTs) showed great potential in recapitulating tissue organization and function of the human heart *in vitro* [1]. Contractile kinetics is one key hallmark of cardiac tissue function and maturation level of cardiomyocytes, and a critical readout from EHT platforms. Typically-used optical methods to track elastic micropillar displacement upon tissue contraction are laborious and in most cases not conducted in real-time. This hampers automation and precise control of the EHT microenvironment. We address these unmet needs by developing a co-planar capacitive displacement sensor for tissue contraction force measurement integrated within an EHT platform.

Experimental procedure

The working principle of the displacement sensor relies on the deformation of the substrate wherein the sensors are integrated. Bending of each micropillar, caused by tissue contraction, results in local anti-symmetric out-of-plane deformation of the substrate. Two spiral capacitors are integrated below each micropillar of a previously developed EHT platform [2] to exploit the maximum substrate deformation. The capacitive sensors were fabricated using a combination of wafer-level micromachining and polymer processing. The mould for the micropillars and elliptic well was fabricated by deep reactive ion etching of a Si wafer. Another Si wafer was covered with an 80 µm-thick polydimethylsiloxane (PDMS) layer, whereupon sputtered Al was photolithographically patterned into sensor designs. De-moulded micropillars and wells were aligned and bonded to the wafer with sensors. Single 10x10 mm^2 PDMS chips with integrated sensors were wire-bonded to custom-designed printed circuit boards. Analog Device AD7746 was selected to readout the expected aF-range change in base capacitance.

Results

Static characterization of the sensors showed good agreement between measured and FEM-simulated values of base capacitance. The dynamic behavior was tested using a nanoindentation setup by applying specific force at different positions along the micropillars length while measuring the electrical response. Responsivity of 0.35 ±0.07 fF/µN was measured. Preliminary experiments with EHTs proved the biocompatibility of the new platform with integrated sensors, as tissues were functional and in culture for at least 14 days.

References

[1] Giacomelli, E. *et al.*, *Cell Stem Cell*, **26** (6), pp. 862-89 (2020)
[2] Dostanić, M. *et al.*, *Journal of MEMS*, **29** (5), pp. 881–887 (2020)