DEVELOPMENT OF A MICROFLUIDIC PLATFORM WITH INTEGRATED ELECTRONICS FOR A GUT-ON-A-CHIP SYSTEM

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Thesis submitted in order to obtain the academic degree of

International Master of Science in Sustainable Drug Discovery

Academic Year 2025–2026

Date 06/06/2026

ABSTRACT

The gastrointestinal epithelium is a critical interface whose dysfunction underlies inflammatory and infectious conditions. Gut-on-a-chip (GoC) platforms recapitulate key intestinal features that static models cannot; however, the absence of integrated, real-time barrier monitoring compatible with continuous culture has been a persistent challenge. Electric cell-substrate impedance sensing (ECIS) on membrane-based interdigitated electrodes (IDEs) offers a route to label-free monitoring, but existing microfabrication methods require cleanroom infrastructure.

This project developed and validated the epithelial barrier component of a GoC platform incorporating inkjet-printed gold nanoparticle (AuNP) membrane-based IDEs. Barrier formation was first characterized on Transwell® inserts using Caco-2 and MDCK-II cells, with transepithelial electrical resistance (TEER) and an EGTA calcium switch assay confirming tight junction-mediated paracellular barrier function. A microfluidic device was designed via computational fluid dynamics (CFD) and fabricated from laser-cut, pressure sensitive adhesive (PSA) tape around a porous polyester track-etched (PETE) membrane. AuNP IDEs were inkjet-printed onto PETE membranes and characterized for before integration into the full device.

MDCK-II cells were selected as the development model given their rapid barrier formation. Double-layer AuNP IDEs demonstrated reproducible electrical performance and acceptable dimensional accuracy. Seeding MDCK-II devices onto membrane-based IDEs showed that progressive barrier formation can be monitored over time, with impedance changes corroborated by brightfield imaging and ZO-1 immunofluorescence confirming tight junction formation. Integration of the IDEs into the microfluidic device produced a flow-stable electrical baseline with no significant impedance change between static and dynamic conditions.

Future work will focus on demonstrating barrier monitoring under flow, transitioning to intestinal epithelial cells, and integrating immune and neural components toward a gut-immune-brain axis (GIBA) model.