Nanotechnologies for Detecting and Mitigating Antimicrobial Resistant Bacteria

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Antimicrobial resistance is a growing global threat across bacterial and fungal pathogens. Effective treatment depends on rapid infection screening and antimicrobial susceptibility testing (AST), yet current methods are slow, delaying therapy. At the same time, conventional antibiotics act indiscriminately, disrupting the microbiome and accelerating resistance. These limitations highlight the urgent need for new technologies that accelerate diagnostics and allow for targeted antimicrobial action.

To address the diagnostic bottleneck, we developed the Phase-Shift Reflectometric Interference Measurements (PRISM) assay [1], a label-free phenotypic platform based on photonic porous silicon microstructures. In our recent work, we extend the PRISM technique to integrate both infection screening and AST within a disposable microfluidic chip: microbial attachment enables rapid detection, while growth under antibiotic exposure informs resistance profiles. Applied to urinary tract infections, PRISM delivered susceptibility results for *Escherichia coli* isolates and processed urine samples with >90% accuracy. In a prospective double-blind clinical study (>150 specimens), PRISM showed high concordance with standard methods while reducing time-to-result by ~30-fold.

Extending from detection to therapy, we have developed the Halloysite Nanotubes Targeting (HaNTr) system, schematically illustrated in Figure 1, a therapeutic nanoplatform for precision antimicrobial delivery [2]. HaNTr employs naturally occurring porous nanoclays functionalized with antibodies for selective pathogen capture. When loaded with ciprofloxacin, HaNTr particles achieve localized, sustained antibiotic release directly at the bacterial surface, yielding up to a ten-fold increase in selectivity compared to free drug. Importantly, *ex vivo* microbiome studies reveal that HaNTr treatment preserves commensal bacterial populations, thus reducing antibiotic-associated dysbiosis. Biocompatibility studies further confirm their safety with intestinal epithelial cells, underscoring translational potential.

Together, biosensing for rapid infection screening and AST, and nanocarrier-based targeted therapy represent complementary approaches to precision antimicrobial interventions. Addressing different stages of the clinical workflow, these technologies have the potential to improve both detection and treatment, supporting more accurate and sustainable management of bacterial and fungal infections.

References

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[2] Printz Setter O., Gliboa A., Shalash G., Refael G., Tarazi Riess H., Levi C.S., Lesmes U., Segal E., Advanced Functional Materials, 34, 2315923 (2024).

Figures

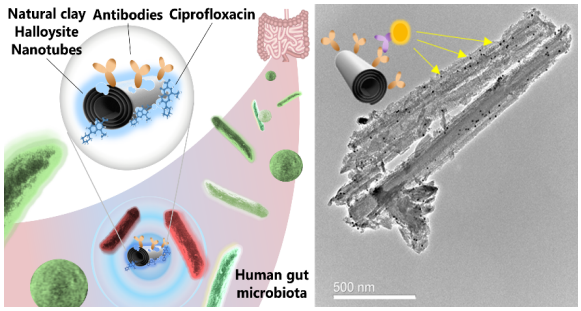

Figure 1: Natural Halloysite nanotubes are utilized to alleviate the inadvertent collateral damage of antibiotics to vital gut bacteria. Antibodies, conjugated onto the silica surface of the nanoclay, endow it with targeting capabilities, while the intrinsic mesoporosity enables the sustained release of an antibiotic payload near the bound bacteria, demonstrating enhanced selectivity in an *ex vivo* model of the human microbiome.