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A microfluidic chip for automated, parallel nucleic acid testing from raw samples

Stanford scientists have developed a microfluidic device that uses isotachophoresis to automate every step of nucleic acid testing, from raw sample to readout, and to run multiple reactions in parallel on a single chip with no moving parts.

Nucleic acid detection sits at the center of molecular diagnostics, a market valued at roughly $10 billion per year, yet the gold-standard methods that make it accurate remain difficult to deploy outside the clinical lab. Techniques such as PCR are sensitive and specific but depend on bulky instrumentation, trained technicians, and multiple manual sample-handling steps, which makes testing slow and expensive. Even the ready-to-use kits that proliferated after COVID-19 typically require separate extraction, amplification, and readout steps, each of which adds opportunities for error and limits usefulness in the field. The result is a persistent gap in accurate, affordable, field-deployable testing, especially in the low-resource settings where portable diagnostics are needed most.

This invention closes that gap using isotachophoresis, an electrokinetic technique that focuses target molecules into a sharp, self-steepening zone based on how they move through an electric field. ITP purifies DNA directly from complex raw samples such as saliva and blood, and a novel multifurcation design then splits the focused sample zone across a branching tree of channels, automatically aliquoting it into 4 to 16 parallel reactions. The process can also be used to mix ITP-focused reagents from two or more channels into a single channel, initiating reactions. In this way, the process offers a fairly general method to split or mix reagents. In one demonstrated assay, the purified DNA was mixed with amplification reagents and to drive loop-mediated isothermal amplification (LAMP), with detection read out in line on the same chip. Because all steps, including extraction, purification, preconcentration,

aliquoting, mixing, amplification, and readout, are controlled entirely by electric fields with no moving parts, the platform integrates a complete, multiplexed molecular assay onto a single inexpensive chip that is simple to fabricate and reconfigure for new targets.

Stage of Development
Proof of Concept

Applications

- Portable point-of-care nucleic acid testing for infectious diseases
- Diagnostics for low-resource and field settings where lab instrumentation is unavailable
- Multiplexed testing of several targets or pathogens simultaneously on a single chip
- Reconfigurable microfluidic platform for research and assay development
- Automated sample preparation and reaction control for broader on-chip biochemical workflows

Advantages

- Integrated workflow, from raw sample to readout, on one chip
- Runs 4 to 16 reactions in parallel through a novel ITP multifurcation design
- Purifies nucleic acids directly from complex raw samples such as saliva and blood
- Uses electric field control only, with no moving parts, lowering cost and complexity
- Simple to fabricate and readily reconfigurable for new pathogens or targets
- Enables rapid testing at a fraction of the cost of benchtop systems that can run tens of thousands of dollars

Publications

- https://www.pnas.org/doi/10.1073/pnas.2511724122

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