Life in the shock wave:
Controlling DNA reactions with electric fields

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We use on-chip isotachophoresis (ITP) to create electric-field-driven shock waves of ion concentration. These waves are formed at the interface between a high mobility leading electrolyte (LE) and a low mobility trailing electrolyte (TE). Ionic species with mobilities bracketed by these electrolyte species focus at the LE-to-TE interface. For trace sample concentrations, multiple species mix and co-focus inside a single, order 10 µm wide zone. Multiple reactants can be mixed and then pre-concentrated by more than 50,000x in a few minutes to accelerate chemical reactions. We apply this technique to extract and purify DNA or RNA targets from complex biological samples and to immediately co-focus these with synthetic DNA probes that we design. We can complete in 30 sec chemical reactions which would normally take 4 days. Presented will be recent work on applying this technique to homogenous reactions and heterogenous reactions (between macromolecule targets in solution and synthetic DNA probes immobilized on a surface). Quantitation of the reaction product provides a sequence-specific detection scheme, and so the technique has applications to medical diagnostics and basic biological studies. Current work also includes integrating ITP-based extraction and focusing to fractionate and analyze nuclear versus cytoplasmic RNA from single cells.

Biography: Juan Santiago received his MS and PhD in Mechanical Engineering from the University of Illinois at Urbana-Champaign in 1995. His research includes the development of microsystems for on-chip chemical and biochemical analysis, methods for sample preparation, miniature pumps, and electric-field based deionization methods. Applications of this work include molecular diagnostics, drug discovery, portable power generation, and the production of drinking water. Among other recognition, he was awarded a National Science Foundation Presidential Early Career Award for Scientists and Engineers (PECASE) ('04) and the Outstanding Achievement in Academia Award by the GEM Foundation ('06). He is a Fellow of the American Physical Society, a Fellow of the American Society of Mechanical Engineering, an Associate Editor of the journal Microfluidics and Nanofluidics, co-founder of several companies in the microfluidics area, co-inventor of micron-resolution particle image velocimetry (Micro-PIV), and director of the Stanford Microfluidics Laboratory. He has served as Associate Editor of the journal Lab on a Chip ('08-'13). Santiago has given 27 keynote and named lectures and more than 100 additional invited lectures. As a measure of impact, his work is cited about 1200 times per year (Google Scholar h index of 60). He has graduated 26 PhD students and advised eight postdoctoral researchers. 17 of his former advisees are now professors at major universities. He has authored and co-authored over 150 archival publications and 200 conference papers, and holds 42 patents (17 of which are currently licensed).