Nanoparticle Enabled, Rapid Detection of Infectious Diseases at Femtomolar Sensitivity

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Major challenges exist in detecting infectious diseases early on as biomarker concentrations are often below the limit of detection (LoD) of conventional assays. This detection failure leads to further transmission. Although sensitive tools exist, they are highly inaccessible, being costly and slow. Using the inexpensive nanoparticle-supported rapid electronic detection platform, this project engineers hydrodynamic forces to optimize detection sensitivity while reducing assay time. Antigen-functionalized gold nanoparticles (AuNPs) act as multivalent probes to bind with the target mAb-SARS-38, a SARS-CoV-2 antibody, forming aggregation and precipitation. The remaining free-floating AuNPs are quantified by optical transmission, reflecting the concentration of the target. However, relying on diffusion in the assay is time-consuming. To accelerate detection, hydrodynamic-driven drift is investigated. An optimal centrifugation force localizes antigen-antibody interactions to the bottom of the tube, accelerating detection and increasing sensitivity when antibody concentrations are low. An optimized vortex rate subsequently generates lift forces to disperse unbounded AuNPs from aggregates. This forms a vertical AuNP concentration gradient, by the Mason-Weaver theory, for signal readout. Compared to 60 nm, 80 nm AuNPs demonstrated greater concentration-dependent signals, corresponding to the Stokes-Einstein relation. The assay maintained a 400 fM LoD and limit of quantification even in human serum. By optimizing drift-dominated transport, rather than diffusion, detection of SARS-CoV-2 is achieved in under 30 minutes, using only 6 μL of biological fluid. This optimized assay has the potential to detect other infectious diseases rapidly, inexpensively, and ultra sensitively.

Awards Won:
Third Award of $1,200