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Fire Smoke Microphysics and Chemistry, and Predictive Exposure Models Through Materials Innovation

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ABSTRACT

Firefighters face increasing cancer risks due to complex and evolving fireground and post-fire exposures. Current monitoring and assessment methods are limited, hindering exposure documentation, health research, and compensation claims. This project addresses these gaps by developing a scalable, field-ready solution to quantify personal chemical exposures and support long-term health protection.

Representative wildland, Wildland-Urban Interface (WUI), and battery-involved fire smoke were simulated using a custom-developed ACCESS system. Smoke features were characterized based on soot formation, morphology, and particle size distribution. Specifically, ultrafine particles and their carried toxicants, including polycyclic aromatic hydrocarbons (PAHs) and heavy metals, were quantified. The uptake of these toxicants by silicone-based passive sampling materials was then compared against materials with highly porous structures. This comparative analysis determined chemical uptake performance for key fireground hazards—namely semi-volatile organic compounds (SVOCs), particle-bound PAHs, flame retardants (FRs), and heavy metals—under simulated structural, wildfire, and battery-involved fire conditions.

Guided by these findings, an advanced silicone-based Chemical and Aerosol Passive Toxicant Sampling (CAPTS) tool is being developed for personal exposure monitoring. This work will produce a validated passive sampling system and mobile interface that enable firefighters to monitor exposures, guide decontamination, and inform health interventions. Ultimately, these outcomes will support standard operating procedure improvements, toxicological and pathological studies, and cancer presumption policy efforts, enhancing overall firefighter health and safety.