

Novel Small Scale Carbon Dioxide Capture Polymer Membrane for Sudden Infant Death Syndrome Prevention

Das, Autri (School: Sunset High School)

Sudden Infant Death Syndrome (SIDS) is a leading cause of infant death, causing 41% of sudden unexpected infant death nationwide. SIDS is attributed to (i) rebreathing CO₂ and (ii) inorganic nanoparticle (INP) inhalation, as established by a recent physicochemical autopsy analysis by Gatti et al. (2022). This research developed the first ever technical solution to SIDS: a novel bifunctional polymer/graphene nanocomposite for pacifiers, uniquely designed for small scale CO₂ and INP capture. The design used one aldehyde site to form dense molecular pores via polycondensation, resulting in an optimized vanillin/melamine/polyurethane copolymer (VMP) material. VMP was most effective among five different polymer candidates prepared and tested. Acetone swelling experiments indicated VMP maintained structural integrity for ~56x longer than polyurethane, and Differential Scanning Calorimetry highlighted a sharp melting point showing semi-crystalline behavior - indicating VMP's stability. A custom-made setup for CO₂ capture through polymer films was retrofitted with a Residual Gas Analyzer, demonstrating maximum CO₂ capture/release efficiency with VMP material at 94.5% and 6.41x10⁻⁹ torr/sec, respectively. VMP was modified for INP capture via ultrasonication with graphene nanoribbons (GNRs) to form the novel bifunctional nanocomposite. Passive INP capture with GNR was monitored through a custom circuit and was consistent with chemisorption by modulation of GNR electrical activity with wet deposition of iron nanoparticles (FeNP) to ~0.6 V/cm, exceeding voltammetric thresholds for carbon oxidation/FeNP deposition. Thus, the proposed bifunctional polymer/graphene nanocomposite addresses SIDS by enabling CO₂ and INP capture in a widely disseminated consumer product: the pacifier.

Awards Won:

Missouri University of Science and Technology: \$1,250 tuition scholarship (renewable for up to 4 years)