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)