Abstract

In today's context of alarming pollution and serious environmental concerns, sustainable development, lower carbon footprint, greener technologies, and the practice of 3R (Reduce-Reuse-Recycle) is of prime concern. Moreover, there have been increasing demands for developing multi-functional and smart materials.

A smart stimuli-responsive composite was developed utilizing white cement (WC) and slag (SG) in the Hydrogenated Nitrile Rubber (HNBR) matrix. The calcium-rich phases in slag enticed the post-polymerization modification of the rubber matrix in conjunction with cement, reporting ~50 MPa and ~8% changes in modulus and volume, respectively, upon repeated wet-dry cycles. The addition of only 10 phr of conducting carbon black (CCB) into such composites reported a DC conductivity to the tune of 10^{-5} *S/cm. Even the gamma radiation shielding (Half Value Length, HVL) values were found to be ~49 mm and ~60 mm from Ba-133 and Cs-137 isotopes, respectively, which is half of that of concrete. Also, the electromagnetic interference (EMI) radiation shielding values (for X and extended* K_u*-band) of these samples were increased two folds (~17 dB and ~28 dB, respectively) compared with high CCB-loaded samples. Engineering of thermal and electrical conductivities of flexible composite materials has become very important, particularly for applications in e-vehicles which have recently gained a tremendous impetus in the market. Therefore, the addition of SiC filler in pristine form in conjunction with silica in the ratio of 1:1 exhibited improved mechanical properties and enhanced thermal conductivity (0.8 W/mK), almost double with respect to conventional carbon black-filled samples (0.43 W/mK). The addition of such hybrid fillers helped in the in-situ modification of the filler network by infringement of the silica network. Furthermore, magnetically active composites and fluids are considered one of the smartest ways to maneuver various techno-rheological properties. Therefore, the incorporation of a magnetic filler of ceramic origin, like, ferrosilicon nitride (FSN), into the rubber matrix yielded significant improvement in mechanical, rheological, magnetic, and thermal properties. For a better understanding from the point of magnetorheological aspects, liquid silicone rubber was also employed along with HNBR-based ones. Indeed, the silicone-based system exhibited ±3 emu/gm more saturation magnetization and better rheological properties than HNBR. Today, it is crucial to concentrate on renewable energy sources and energy storage. A variety of human motions can be employed to generate energy. Piezoelectric, pyroelectric, thermoelectric, and triboelectric methods have all been created to gather these various forms of energy. Therefore, the optimized samples from the preceding chapters and a new generation 2D nano material MXene were employed as a proof of concept for using ceramic waste for triboelectric generation and studies. Amidst those, the triboelectric generator made by the combination of white cement, slag, and MXene yielded maximum efficacy in generating electricity (~20 V, ~2 A) through friction.*

These developed wasted ceramic-based materials may be potentially applicable for low-cost, lightweight, flexible shielding materials, microfluidic valves, printed circuit boards, mounts, isolators for e-automotive, magnetorheological, magnetostrictive, and triboelectric applications, to mention a few.

Keywords: Elastomer, Ceramic wastes, Carbon footprint, Green and sustainable, MXene, Smart materials, Stimuli-responsive, EMI shielding, Gamma radiation shielding, Electrical conductivity, Thermal conductivity, Magnetorheology, Triboelectricity