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A Superhydrophilic Biomimicked Ceramic-Reinforced-Polymer Nanocomposite for Enhanced Slip Resistance and Adhesion

R. Synthesis and characterization of functional nanocomposite materials

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Abstract

Slips and Falls (SFs) were not considered a major source of lethal injuries until recently. Two-third of SF accidents happen due to the presence of ice on the surface around countries with snowfall making it second prominent reason of fatal injuries. Nearly 70,000 serious SFs happen in Finland and Sweden every year, and about 17,000 people lose their lives in USA (annual 1 million cases). Approximately 83% of people in Russia and thousands of people fall during winter in the UK and die as per HSE-UK. WHO-2021 recorded 37.3 million SFs cases demanding medical attention including millions requiring intensive care which resulted into permanent injuries, trauma, loss of limbs, loss of jobs, and burden on insurance and healthcare. Huge monetary deficits were recorded in Finland as €2.4 billion, €280 million in Sweden, £42 million in the UK occurred due to SFs. USA and Canada spend more than $55 billions annually on healthcare due to SFs. An effective anti-slipping shoe-sole can prevent and avoid these mishaps. Shoe-sole design modifications like tread patterns, crampons, studs, spikes etc. or material variations to improve friction between the sole-ice interface have been utilised. Though crampons/spikes/studs are effective, they are unsuitable for indoor usages, physically challenged and children. Whereas material-based solutions lose their effectiveness due to quick wear or in the presence of wet ice with quasi-liquid layer.

We introduce nano-powder based ceramic reinforced composite patterned with Laser Surface Texturing (LST). Patterns are nature-inspired and are adapted from gecko/frog toepad structures that offer excellent friction on dry and wet surfaces. This innovation is a combination of material and design modifications and is not limited to anti-slipping shoe-soles. E-skin, drug delivery, wound healing, and electronic sensor patches face severed adhesion due to handling of body fluid

and perspiration at the interface. Silicone Rubber polymer and proven anti-bacterial nano powders of zirconia and/or titania were mixed, vulcanised and textured to produce microfibrillar structure. This composite is highly wettable, wear-resistant, and adhering to wet and dry surfaces by creating capillary bridges. The capillary bridges provide mechanical interlocking on icy surfaces and serve as suction locations for patches to absorb and evaporate the bodily exudations out.

We used five zirconia compositions (1, 3, 5, 7, and 9% by weight) producing composite with three sizes of capillary cavities to obtain best capillary effect. The findings of the study include average Shore-A hardness (32 to 40), morphology and topography, parametric optimisation of LST parameters, and wettability analysis. Obtained nano composite has excellent physicochemical superhydrophilicity (absorption of water droplet within 50 milliseconds after contact) with high static and kinetic friction coefficients of 2.5 and 1.62, respectively on wet ice suitable for mentioned applications.