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BIOPOLYMER NANOCOMPOSITES FOR THERMAL SHIELDS OF METEOROLOGICAL ROCKETS

As the density of the atmospheric layers increases consistently during entry, the nosecone is exposed to ever-increasing drag forces. The effect of these drag forces during supersonic entry leads to shock wave formation. These shock waves further lead to a phenomenon called aerodynamic heating and hence, the development of an elevated temperature profile over the surface of the nosecone stage. Whilst the exact temperature that can potentially develop is dependent on the tumbling motion of the nosecone, if no change in orientation is achieved for timescales below a hundred seconds, temperatures between 100 and 500 °C are to be expected. Whilst these temperatures can be sustained by the aramid lines of the drogue parachute, they cannot be sustained by the nylon lines of the main parachutes and hence, the heat shield that protects the outer surface of the recovery module before drogue deployment becomes a requirement [1].

Biopolymers are polymers obtained from certain living organisms, making them biocompatible and having various functional groups that allow controlling the interface with nanofillers. They are used in many fields due to their flexibility in processing conditions and competitive cost of final products. This work proposes the use of composites based on biopolymers with inorganic nanofillers such as metal, metal oxides, semiconductor nanoparticles, and carbon-based nanoparticles for application in creating thermal shields for meteorological rockets [1].

Unlike conventional polymer composites, the thermal and mechanical properties of nanoscale fillers, combined with other characteristics, have led to the development of macro-scale materials with highly desirable properties. By using the technique of affine deformation to obtain nanocomposite films from suspension, a composite can be obtained that will have resistance to transport phenomena, such as diffusion. This, combined with the low thermal conductivity of the polymer, demonstrates high fire resistance even for very thin thicknesses. Additionally, high alignment combined with the addition of a much stiffer filler, such as nanoclay, has led to the development of biopolymer nanocomposites with an elastic modulus ranging from 10 GPa to 30 GPa depending on the loading. It has also been observed that even at elevated temperatures, this modulus value remains above 10 GPa for a certain content of montmorillonite in sodium alginate. For example, the relationship between the elastic modulus and temperature depends on the concentration of nanoclay [1]. See Fig. 1.

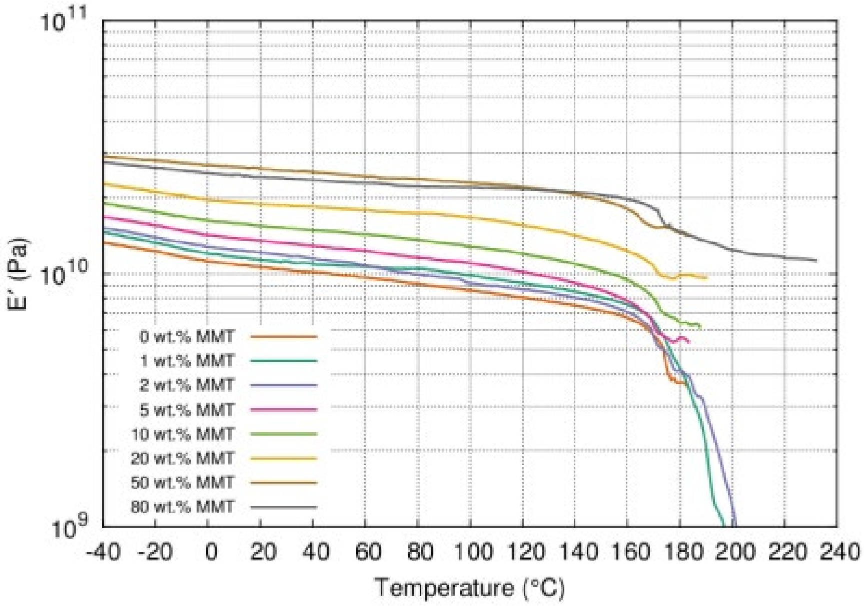

Fig. 1. Dependence of the elastic modulus on temperature

Despite these properties only meeting a portion of the requirements expected from a thermal shield, transforming the biopolymer nanocomposite into a solid substance, such as foam, can satisfy all criteria set for the thermal shield. Because foam is lighter than the original phase material, the density of the thermal shield is further reduced. Additionally, since the gas phase tends to occupy a larger volume fraction in low-density foams, further reduction in thermal conductivity can be expected. Thus, by deciding to develop a biopolymer nanocomposite foam, a durable product can be created that sets a new standard for insulation-related applications [2].

Simple production offer methods by which biopolymer nanocomposite foams of different relative densities can be produced. It was possible to use all three methods to produce foams with relative density values spanning from a minimum value of 0.017 to a maximum value of 0.891 [2].

Whilst it is easy to say that the preliminary thermal characteristics and the ease with which the foams can be produced guarantees their ability to work as hypersonic heat shields, it becomes important to assess the mechanical behaviour of these foams in order to guarantee their use as/within structural components. This was identified as being rather elusive due to the inconsistencies that were noticeable in existing analytical/numerical models to estimate the elastic modulus of foams [2].

The process of transforming nanocomposites into foam does not affect their ability to function as fire-resistant materials. These foams were able to provide a temperature gradient between 1.5x10^5 and 3.2x10^5 K/m under the influence of high-temperature propane-butane torch flame for 2 minutes. These values can be compared with the temperature gradient offered by high-temperature tile-based thermal protection systems on board the NASA Space Shuttle [2].

In this study, foam materials with single relative densities were considered of importance to understand the underlying properties. But since it is now understood that the production techniques offer great versatility when it comes to the properties of biopolymer nanocomposite foams themselves, a stacked structure using foams of different densities can also be trialed [2].

As the baked foams consistently provide the best results, there's enough reasons to suggest a more consistent grasp of their mechanical properties. Amongst the reasons listed for deviations in the baked foams' elastic modulus values, it is hard to gain consistent control over the amount of moisture present within the sample or the cracking within the foam. However, the level of exfoliation can be studied closely. To that effect, a detailed X-Ray Diffraction (XRD) study can be carried out to understand how changes brought about to the baking process can improve the exfoliation of the nanoclay. Although limited control can be expected over the cracking, tomography scans could also reveal an improved insight into the distribution of these cracks within the baked foams [2].

Only the thermal gradient that develops as a result of exposure to high temperatures was considered of importance in this study. This property was expected to critically define the dimensions and densities that become suitable for future considerations. However, understanding the heat capacity of these foams at different temperatures and different purge environments could also prove useful. This would help in assessing their thermal characteristics in different atmospheric conditions, by understanding their underlying chemical changes [2].

So far, only the static – elastic compressive modulus of the foams have been evaluated. However, for a system as dynamic as entry into the Earth's atmosphere, multiple load cases persist. It then becomes important to assess the behaviour of these foams when loaded flexural, or in shear, or using an oscillating load. These load cases serve to highlight the likelihood of failure of the foams when utilised structurally and address the limitations of the foam [2].

Finally, a detailed in-flight testing regime aboard a suitable sounding rocket would not just serve as a demonstration mission, but also provide suitable testing data under different flight conditions [2].

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APPLICATION OF VIRTUAL REALITY IN THE DEVELOPMENT OF FITNESS APPLICATIONS

The problems of not getting enough exercise, sedentary lifestyle, and dealing with excess weight have been around for a while. These issues weren't new even before the COVID-19 pandemic, but according to a publication in the "BMC Public Health" journal [1, p.3], things got worse when the pandemic hit. The number of factors contributing to these problems increased, making the situation even more challenging.

It is widely recognized that activities, be it educational processes or engaging in physical exercises, are more readily embraced when presented in a gamified format. Research findings [2, p.14] indicate that incorporating virtual reality into physical exercise regimens is not only effective but also holds promise in positively influencing both physical and psychological well-being. Consequently, the creation of fitness applications integrating virtual reality represents a notably beneficial, pertinent, and underexplored endeavor.