



Abstract

Using tungsten disulphide inorganic nanotubes (INT-WS₂) in organic-inorganic hybrid composite materials provide the potential for improving thermal, mechanical, and tribological properties of conventional composites [1]. Recent results have raised new expectations, since it has been observed that well-dispersed INT-WS₂ exhibit a much more prominent nucleation activity, improving the overall crystallization process of poly(L-lactic acid) (PLLA) and poly(3-hydroxybutyrate) (PHB) than specific nucleating agents or other reported nano-sized fillers, such as carbon nanotubes and graphene [2,3]. Similarly, good dispersion and interfacial adhesion of INT-WS₂ in a poly(hydroxybutyrate-co-hydroxyvalerate) (PHBV) matrix significantly influence the crystallizability of PHBV. These features may be advantageous for the enhancement of the mechanical properties and processability of this new class of WS₂-based composite materials.

Results and discussion

The major issue in expanding commercial opportunities for PLLA, PHB and related polymer materials (PHBV) is their crystallization behavior. Incorporating well-dispersed nanoparticles like INT-WS₂ into biopolymer can modify the crystallization behavior. Therefore, it is of great interest to investigate the nucleation, crystallization, and structural development of the matrix in INT-reinforced biopolymer materials. In this regard, the non-isothermal melt-crystallization of neat PHBV and its nanocomposites obtained with different INTs loadings, using a simple solution blending method, was investigated by DSC using a Perkin Elmer DSC7/Pyris differential scanning calorimeter. The results of revealed that the incorporation of INT-WS₂ in small weight percents (≤ 1.0 wt.%) dramatically accelerated the crystallization rate compared to the pure biopolymer (Figure 1). Nevertheless, for the same nanofiller loading, the improvements in crystallization temperature peak (T_p) for the PHBV(PLLA)-based samples are lower than those observed for the corresponding binary PHB-INT nanocomposites (Figure 2). In particular, incorporating 1.0 wt.% INT-WS₂ effectively increased the T_p of PHBV to a value comparable to that of BN, and greater than all other NAs. BN is currently estimated to be more expensive than INT-WS₂ and, like talc, is not a nanoparticle filler, also possibly leading to deficient mechanical reinforcement qualities that are observed with other nano-sized filler materials.

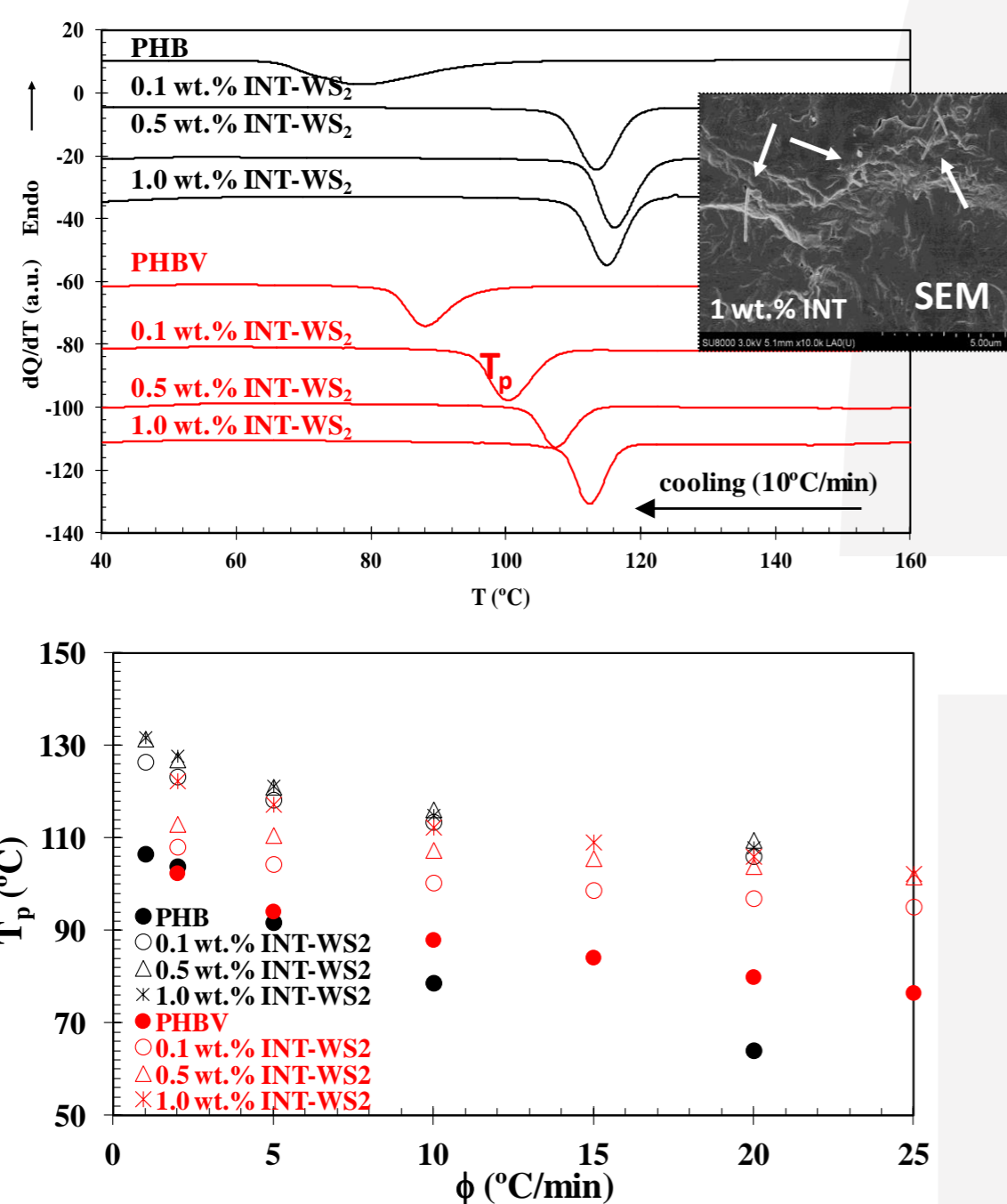


Figure 1. DSC data of the dynamic crystallization of biopolymer/INT-WS₂ nanocomposites.

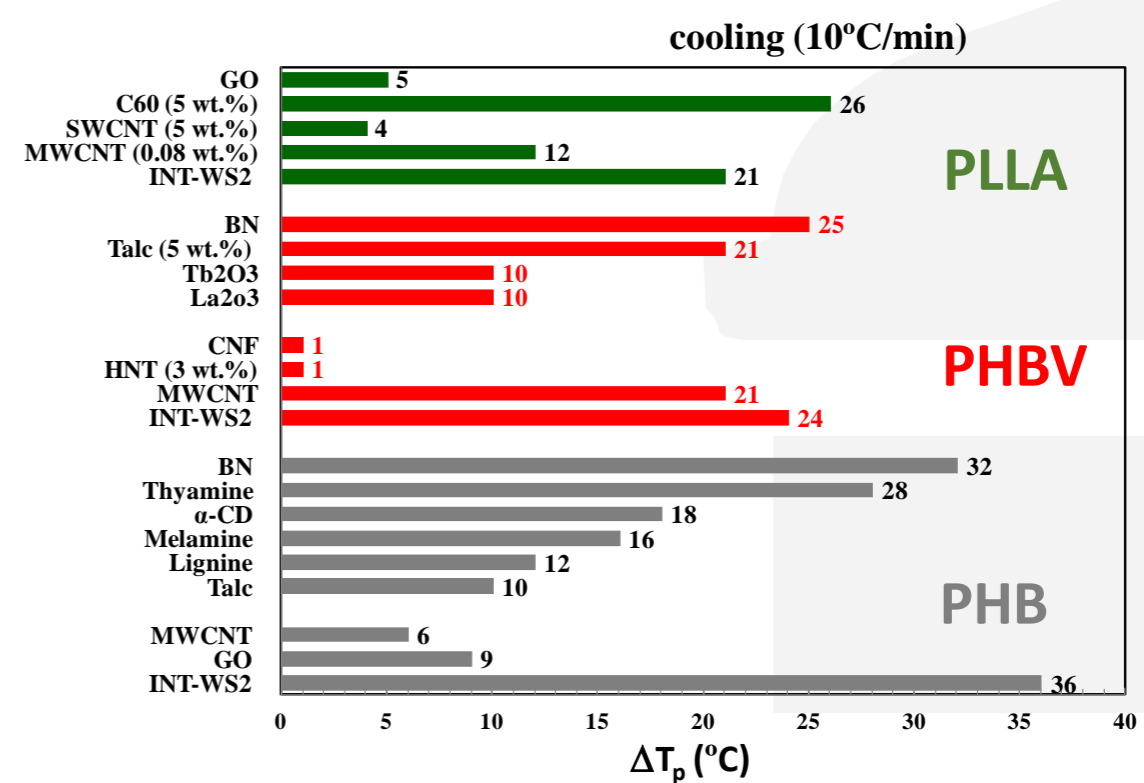


Figure 2. Increment in the ΔT_p of PHB and PHBV systems containing different kinds of fillers.

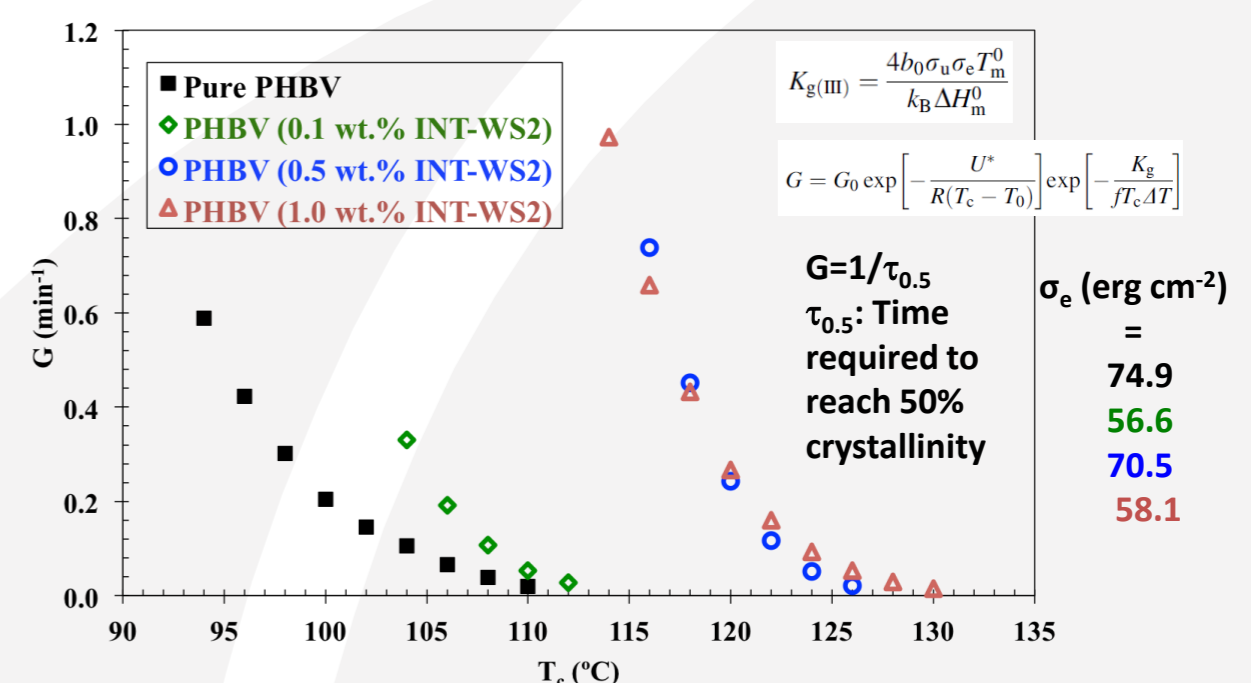


Figure 3. Variation of the rate of crystallization of PHBV/INT-WS₂ nanocomposites as a function of the crystallization temperature (T_c).

In the same way, the isothermal crystallization behaviours and kinetics of neat PHBV and its nanocomposites were intensively studied. It was found that the overall crystallization rates were reduced with an increase in the crystallization temperatures for both neat PHBV and PHBV/INT-WS₂ nanocomposites. Moreover, at a given crystallization temperature (T_c), the overall crystallization rates were faster in the nanocomposites than in neat PHBV and increased further with an increase in the INT-WS₂ loading (Figure 3). The addition of INT-WS₂ remarkably influences the energetics and kinetics of nucleation and growth of PHBV, reducing the fold surface free energy (σ_e) by up to 25.4 %.

Conclusions

The results obtained from the DSC crystallization experiments, along with the good materials processability, economic and sustainability benefits, encourage further investigations in order to evaluate the full potential of these new bionanocomposites for their potential use in eco-friendly and medical applications.

Acknowledgments

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References

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