

Reinforced polylactic acid for use in high strength biodegradable medical implants

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Melt compounding of polylactic acid and halloysite nanotubes gives a novel composite.

Traditional medical implants, such as orthopedic screws, pins, and coronary stents, are almost exclusively metallic due to high mechanical strength requirements. However, issues related to the use of permanent metallic implants are a cause of concern. These include immune rejection, consistent inflammation, removal surgery, stress shielding in orthopedic fixation devices, and restenosis in metallic coronary stents.^{1,2} Biodegradable polymeric implants that can degrade away after service life appear to be the solution to these issues. However, biodegradable polymers are much weaker compared to metal.

Ongoing research has been carried out to improve the mechanical strength of biodegradable polymers. Our research team is developing halloysite nanotube-reinforced polylactic acid (PLA), which can be used in biomedical applications that require high mechanical strength. The research involves compounding halloysite nanotubes with biodegradable polymers to produce high strength composites for use in the manufacture of biodegradable implants.

PLA is a type of biodegradable thermoplastic aliphatic polyester that is derived from renewable resources such as corn and rice. Following use, the polymer degrades, leaving only water and carbon dioxide as degradation products. PLA attracts research attention due to its renewability, biodegradability, biocompatibility, and good mechanical properties.³ PLA has a long safety history in the medical field, and has been involved in drug-delivery systems, surgical sutures, and tissue engineering.⁴ Halloysite nanotubes (HNTs) are a type of clay that is found Australia, the United States, China, New Zealand, Mexico, and Brazil. HNTs have been used in applications of controlled drug release and reinforcement of polymer matrices, and they also show good compatibility with a variety of cells both alone and in combination with polymer matrices.^{5,6} Their tubular structure and high aspect ratio helps to reinforce polymers in composites by optimizing the load transfer

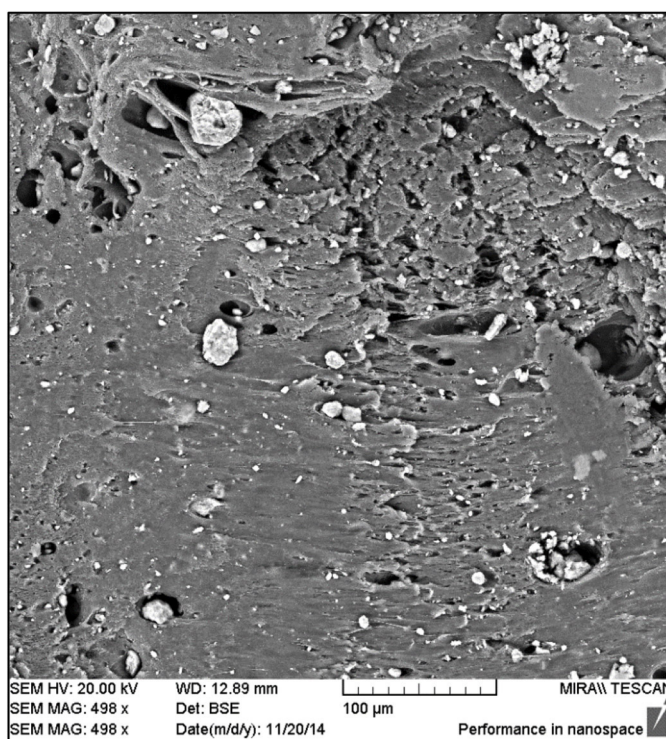


Figure 1. Good dispersion of halloysite nanotubes (HNTs) in poly(lactic acid) is seen. However, some aggregated HNTs were clearly visible as light spots. (Reproduced with permission from *Polymer Composites*.)

from the polymer matrix to the nanotubes.⁷

We melt-compounded PLA/HNT composites using a twin-screw compounder prior to molding thin polymer films for characterization. From thermal analysis of the composites, we found that the incorporation of HNT into the PLA matrix caused a slight, but noticeable, reduction in glass transition temperature (T_g) and degree of crystallinity.

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Fourier-transform infrared spectroscopy (FTIR) indicated that there were chemical reactions between PLA and HNT. Mechanical test results revealed that HNTs exhibited a reinforcing effect on PLA and resulted in a significant increase in stiffness and Young's modulus. However, scanning electron microscopy (SEM) indicated that complete intercalation did not occur as large micro-range particles are clearly visible in the photomicrograph (see Figure 1). This was illustrated using void content test measurements, and might be responsible for the reduction in thermal stability of PLA/HNT composites detected by thermogravimetric analysis.

Metallic implants are well-used in medicine. Despite this, there are several issues with metallic implants that can lead to severe clinical complications. As they can circumvent these issues, using fully biodegradable polymers for medical implants is a promising option. However, their lack of strength compared to metal is a stumbling block for their use in high-strength medical implants. Therefore, we are working to improve the mechanical strength of biodegradable polymers by incorporating reinforcing fillers, which have undergone surface treatment to improve the adhesion between the fillers and the polymer matrix. Our future work will focus on the use of these composites to fabricate prototype medical devices.

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Declan Devine is the director of the MRI at the Athlone Institute of Technology. He received a PhD in 2006 for his work in the field of controlled release of active pharmaceuticals from hydrogels. His current research focuses on the use of biodegradable composite materials for use in tissue engineering applications.

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