An Attempt to Prepare Flexible–Strong Conductive Fiber with Bagworm Silk

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ABSTRACT

Bagworm silk is the strongest biofiber to date. In this research, we prepared bagworm silk/polypyrrole composite by oxidative polymerization as an attempt for preparation of flexible–strong textiles. Characters of the composite thus synthesized in this study were evaluated with infrared absorption (IR) spectroscopy, scanning electron microscopy (SEM), electron spin resonance (ESR) and conductivity measurement.

Keywords: Bagworm silk, biomaterial, composite, conductive polymer, fiber

Introduction

Bagworm silk is the strongest biofibers at the present stage. Bagworm silk is consisted of $\beta$ sheet crystal and amorphous structure for protein. The strength of the bagworm silk is derived from the long length amorphous parts\textsuperscript{1,2}.

In this research, we attempted to synthesis of flexible–strong conductive fiber with bagworm silk. Polymerization of pyrrole with FeCl\textsubscript{3} was carried out on the surface of the bagworm silk fiber.

Experimental

Materials

Bagworm silk fiber was collected from the nest of bagworm obtained in Shizuoka (Japan).

Synthesis

\begin{center}
\begin{tikzpicture}
\node (Py) at (0,0) {Py};
\node (FeCl3aq) at (2,0) {FeCl\textsubscript{3}aq Bagworm silk};
\node (n) at (4,0) {$n$};
\node (BS/PPy) at (6,0) {BS/PPy};
\draw[->] (Py) -- (FeCl3aq); \node at (3,0) {$\rightarrow$};
\end{tikzpicture}
\end{center}

Scheme 1. Synthesis of bagworm silk/polypyrrole composite (BS/PPy).

FeCl\textsubscript{3} (20 mg) was dissolved in the water (500 µL). Bagworm silk (0.35 mg) was immersed into the aqueous solution. After 17 h, the bagworm silk containing FeCl\textsubscript{3} was placed on a glass plate. Then, pyrrole (10 µL) was added to the bagworm silk. Oxidative polymerization of pyrrole on surface of the silk was carried out with FeCl\textsubscript{3}. The composite was washed by large volume of water and dried in the ambient atmosphere to obtain the product as a form of black fiber (0.47 mg).

Results and discussion

Molecular Structure

IR spectra for pyrrole (Py) as a monomer, bagworm silk (BS) and bagworm silk/polypyrrole (BS/PPy) were shown in Figure 1. Py shows N–H stretching vibration at 3403 and 3127 cm\textsuperscript{-1}. BS/PPy displays the N–H stretching vibration at 3175 cm\textsuperscript{-1}, indicating successful polymerization of pyrrole on the silk. Furthermore, absorptions derived from amide of protein are observed at ca. 1700 and 1500 cm\textsuperscript{-1}. These results indicate that the product has both characters of PPy and BS.
Figure 1. IR spectra for pyrrole (Py), bagworm silk (BS) and BS/PPy.

Surface images

Figure 2. Polarizing optical microscopy (POM) images of BS/PPy. (a): Low magnification. (b): High magnification.

Figure 3. Scanning electron microscopy (SEM) images of BS/PPy. (a): Low magnification. (b,c): High magnification. (d): Cross section.

Figure 4. ESR spectra of BS and BS/PPy.

Conclusions and future work

Synthesis of bagworm silk/polypyrrole composite with electrical conductivity was successfully carried out. In the present study, we could employ only small amount of the short length silk fiber for synthesis of the composite. Preparation of the natural/synthetic polymer composite thread with a long length silk fiber to examine mechanical strength is the next subject.

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References


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