CHAPTER VII
CONCLUSIONS AND RECOMMENDATIONS

In the present study, inorganic–organic hybrid material of magnetic particles, silver particles, magnetic/silver particles, zinc oxide particles and bacterial cellulose were successfully prepared by using template-directed synthesis method. Firstly, the precursors of metal or metal oxide particle which were in the form of cations (Fe^{3+}/Fe^{2+}, Ag^{2+}, Zn^{2+}) were incorporated into bacterial cellulose by immersing bacterial cellulose pellicles into the precursor solution. The cation precursors were readily penetrated into the hydrogel structure of bacterial cellulose. Then, the penetrated-cation precursors were trapped inside bacterial cellulose matrix by electrostatic interaction with the high polar groups at the surface of bacterial cellulose. Finally, the crystallization process of the penetrated-cation precursors were generated inside the matrix of bacterial cellulose. By using template-directed synthesis method, the lack of unique properties of the as-synthesized particles due to particle agglomeration was eliminated. The homogeneously distribution with optimizing particle size of the as-synthesized metal or metal oxide particles inside the matrix of bacterial cellulose was directly resulted in the overall properties of the as-prepared inorganic–organic hybrid material in that the overall properties were represented the unique properties of the incorporated-metal or metal oxide particles and bacterial cellulose matrix. The magnetic particle incorporated-bacterial cellulose samples were exhibited the strength and flexibility of bacterial cellulose matrix and also showed the magnetic properties of the incorporated-magnetic particles. The as-prepared magnetic particle incorporated-bacterial cellulose samples were exhibited the superparamagnetic behavior with the saturation magnetization in the range of 1.92-26.20 emu/g. The silver particle incorporated-bacterial cellulose samples were exhibited the strength and flexibility of bacterial cellulose matrix and also showed the electrical properties of the incorporated-silver particles. The as-prepared silver particle incorporated-bacterial cellulose samples were showed the electrical conductivity in the range between $2.60\times10^{-4} \pm 5.31\times10^{-5}$ to $2{,}188.32 \pm 120.82$ S/cm with the percolation threshold at 25.09 ± 0.46 wt% of silver particles. Whereas, the magnetic and silver particle incorporated-bacterial cellulose samples were exhibited the strength and flexibility of bacterial cellulose matrix and also showed both magnetic and electric properties of the incorporated-magnetic and silver particles. The as-prepared magnetic and silver particle incorporated-bacterial cellulose samples were exhibited the superparamagnetic behavior with the saturation magnetization in the range of 25.53-45.85 emu/g and also showed the electrical conductivity in the range between 0.0022 ±0.00012 to 2009.55 ±105.75 S/cm with the percolation threshold at only 4.70 ±2.20 wt% of silver particles. Finally, the zinc oxide particle incorporated-bacterial cellulose samples were exhibited the strength and flexibility of bacterial cellulose matrix and also showed the photacatalytic activity of the incorporated-zinc oxide particles. The as-prepared zinc oxide particle incorporated-bacterial cellulose samples were showed the high photacatalytic activity with strong antibacterial activity against *E. coli* (Gram-negative) and *S. aureus* (Gram-positive). These results were firmly supported the successfully preparing of the novel inorganic–organic hybrid material of magnetic particles, silver particles, magnetic/silver particles, zinc oxide particles and bacterial cellulose with the combing properties between the incorporated-metal or metal oxide particles and bacterial cellulose matrix. Moreover, the preparation method is simple and cost-effective, which may lead to the more development for new applications, such as electromagnetic absorption devices and enzyme immobilization for biosensor applications. Not only for bacterial cellulose but this preparation method may be used to achieve magnetic properties, electric properties, photocatalytic activity and antibacterial property in other materials such as electro-spun nanofiber mat and other porous materials.