

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

Composite processing is an efficient way of making materials with improved properties from a wide variety of materials. The advantages of this technique are simple, cost effective, and flexible. The keys to the success in the preparation of composites depend not only on the properties of the matrix and reinforcing materials, but also on the interaction between the matrix and reinforcing materials, morphology, size, amount, and distribution of the reinforcing materials. In this work, the composites are classified into three types which are macro-, micro-, and nano-composites. The difference between these various types is the size of the reinforcing materials. Typically, the macro-composites are used to prepare products with reduced costs. In this case, the important concern is on the cost of the reinforcing materials themselves. Though not of the main objective, incorporation of such reinforcing materials should, at best, not cause any deterioration in the properties of the resulting composites as compare with those of the virgin matrix. On the other hands, improvement in the properties is of prime concern for both the micro- and the nano-composites. Therefore, important issues for these types of composites are interaction between the matrix and the reinforcing materials as well as the state of mix of the fillers within the matrix.

In the macro-composite point of view, roselle fibers (*H. sabdariffa* L.) was successfully used to reinforce iPP matrix and their composites could be injection-molded into objects. At a fixed fiber loading of 30 wt %, an investigation on the effects of type and size of roselle fibers on the mechanical properties showed that the addition of pure roselle bast fibers resulted in the overall improvement in the tensile, flexural, and impact properties of the as-prepared composites, while incorporation of pure core fibers only improved the Young's and the flexural modulus of the composites. The property values were generally found to increase with increasing bast fiber content or with increasing lengths, hence the aspect ratios of the incorporated fibers. In addition, the composites became more rigid, as evidence by the loss in the elongation at yield. Microscopic observation of fractured surfaces of some selected impact specimens revealed that the surface of the fibers was smooth,

indicating poor interfacial bonding of the iPP molecules on the fiber surfaces. On the effects of roselle fiber content and the presence and content of maleic anhydride (MAPP) on mechanical properties of the resulting iPP composites, incorporation of the roselle fibers at about 40 wt % resulted in a much improvement in many categories of the mechanical properties investigated, without sacrificing much the processability of the resulting composites. Lastly, about 7 wt % of MAPP was required for the compatibilizing effect to become effective in improving some categories of the mechanical properties of the compatibilized composites.

In the micro-composite point of view, nylon 4, 6 as-spun fibers from the electrospinning process were selected as the reinforcing materials for polyvinyl alcohol. The average diameter of nylon 4, 6 as-spun fibers was about 116 nm. Incorporation of the nylon 4, 6 as-spun fibers was confirmed using scanning electron microscope. The tensile strength of films increased from that of the neat PVA film (i.e., 28.29 ± 4.06 MPa) with incorporation of the nylon 4,6 fiber mats to reach a maximum value (i.e., 32.05 ± 5.09 MPa) at the percent weight of nylon 4,6 fiber mats of about 10.40 wt.% and decreased with further increase in the nylon 4,6 fiber mats content. Interestingly, incorporation of the nylon 4,6 as-spun fiber increased in the Young's modulus of films from 54.31 MPa to 145.75 MPa at the percent fiber content about 13.43 wt.% and further increased with the increasing in the amount of nylon 4,6 content. Lastly, the Hapin-Tsai model was applied and compare with the experimental data. The fitting show that Haplin-Tsai model can be used for properties prediction for composite systems which used the as-spun nanofibers as the reinforcing materials.

In the nano-composite point of view, α -chitin whiskers from chitin flakes from shells of *Penaeus merguensis* shrimps were selected as reinforcing materials due to their unique properties. Chitin whisker-reinforced nanocomposite nanofibers were fabricated by electrospinning from a mixture between an aqueous solution of poly(vinyl alcohol) (PVA) and a suspension of chitin whiskers. The as-prepared α -chitin whiskers consisted of slender rods having a broad distribution in both of their length and width. The average length and width of these whiskers were about 549 and 31 nm, respectively, with the average aspect ratio between the length and the

width being about 18. Electrospinning of the PVA/chitin whiskers mixtures was straightforward. The average diameter of the as-spun nanocomposite nanofibers ranged between 185 and 218 nm, regardless of the whisker content. Incorporation of the chitin whiskers within the as-spun nanocomposite nanofibers was confirmed by infrared spectroscopic and thermogravimetric analyses. The tensile strength of the as-spun PVA/chitin whiskers nanocomposite fiber mats increased from that of the neat as-spun fiber mat (i.e., 4.3 ± 0.7 MPa) with initial addition of the chitin whiskers to reach a maximum value (i.e., 5.7 ± 0.6 MPa) at the chitin whiskers to PVA ratio of about 5.1% and decreased with further increasing the whisker content. Lastly, the presence of chitin whiskers within the as-spun nanocomposite fiber mats increased the Young's modulus by about 4 to 8 times over that of the neat as-spun fiber mat.

In another related work, the influence of the chitin whiskers on crystallization behavior, dynamic mechanical properties, and thermal properties was studied using the WAXD, DMA, and DSC. It is suggested that chitin whiskers could readily form strong hydrogen bonding interaction with the PVA chains in the amorphous region. This inhibited the crystallization of PVA in the composites leading to the decrease in the relative percent crystallinity when the amounts of added chitin whiskers were increased. The strong interaction by chitin whiskers also increased storage modulus and glass transition temperature of the composites. Moreover, the electrostatic force applied in the electrospinning process induced a stronger crystalline structure, as compared to the composites prepared from the solution casting process, causing a increase in the melting temperature of the PVA matrix. In addition, the water molecules that are present in the composites could have a plasticizing effect, rendering the PVA molecules to move more readily as indicated by the increase in the crystallinity content of the matrix.