CHAPTER 6
CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSIONS

In the present work, pure MWCNT, OH and COOH functionalized MWCNTs were characterized using XRD, FT-Raman, FT-IR, TEM, EDX and TGA-DTG/DSC studies to confirm its multiwall structure and oxidation behavior. MWCNTs nanofluids were prepared by dispersing carbon nanotubes in base fluids such as Silicone oil and Dowtherm A using ultrasonication technique. Molecular interaction studies and heat transfer studies were carried out for the prepared MWCNTs nanofluids by varying the MWCNTs concentrations at different temperatures.

The dependence of ultrasonic velocity and other derived parameters on the concentrations of the MWCNTs in the base fluids and temperature is an indicative of the presence of molecular interactions. Ultrasonic velocity values increased by adding the MWCNTs to the base fluids and it become higher compared to the base fluids, which confirms nanotube-nanotube interaction, and is dominant in the MWCNTs nanofluids. At higher concentrations as the inter nanotube distance decreases due to the presence of more number of nanotubes, the nanotube-nanotube interaction is strengthened. Refractive index values were also taken for the prepared nanofluids as a function of MWCNTs concentrations at different temperatures. Their value slightly decreases with both the concentration and temperature.

The dielectric parameters are computed for the base fluids and the prepared MWCNTs nanofluids at different temperatures for various concentrations. The decrease in the static dielectric constant ($\varepsilon_0$) values of
MWCNTs nanofluids with an increase in all the concentration of MWCNTs is mainly due to the arrangement of the carbon nanotubes in the base fluids and longer size of molecules. This trend could be attributed to the decrease in the number of dipoles in the MWCNTs nanofluids. The excess dielectric constant ($\varepsilon^E$) and the excess dipole moment ($\mu^E$) values for the pure and functionalized (OH & COOH)-MWCNT nanofluids are negative for all the concentrations and temperatures.

The negative values (-ve) of excess dielectric constant ($\varepsilon^E$) indicates that the molecules in the MWCNTs nanofluids may form multimers, in such a manner that the number of effective dipoles is reduced. This is due to the opposite alignment of the dipoles of the base fluids and MWCNTs molecules. The negative values (-ve) of excess dipole moment ($\mu^E$) indicates the absence of any contribution from the ionic structure of the MWCNTs nanofluids to the total dipole moment. From the ultrasonic and dielectric studies, the weak interactions present in the MWCNTs nanofluids are confirmed.

The heat transfer ability of the MWCNTs nanofluids is studied with the help of viscosity and thermal conductivity measurements. The thermal conductivity results show that the thermal conductivity of MWCNTs nanofluids increases with both increase in the MWCNTs concentrations and temperatures. The viscosity of nanofluids significantly increases with increasing MWCNTs concentration. Conversely, it decreases with increasing temperature. As the temperature increases the viscosity of the MWCNTs nanofluids decreases, which results in an increase in Brownian motion of nanotubes, this sets convection like effects resulting in enhanced thermal conductivity.

Noticeable thermal conductivity enhancements were observed in all types of MWCNTs nanofluids in this work and it has been confirmed that MWCNTs nanofluids have the potential to use it as heat transfer fluids. Moreover, the suspensions of different functionalized MWCNTs structures
were found to be stable. With all the nanofluids prepared for this study, OH-functionalized MWCNT suspensions showed the best result in the case of stability and thermal conductivity enhancement over the other MWCNTs nanofluids.

Hydroxyl (-OH) functionalized MWCNT + Dowtherm A nanofluid have highest thermal conductivity value (0.476 W/m.K) compared to other MWCNTs nanofluids taken for this work and prove its ability for heat transfer applications. The results show that the enhancement of thermal conductivity in MWCNTs based nanofluids are mainly due to percolation of heat through the nanotubes to form a tri-dimensional network because of the high aspect ratio of the carbon nanotubes in the base fluids (Silicone oil and Dowtherm A).

6.2 FUTURE WORK
6.2.1 Stability of nanofluids

Stability of the suspension is an important problem for both scientific research and practical applications. For the stability of nanofluids, especially the long term stability and the stability in the practical conditions should be of more concern. In this present work, stability of MWCNT nanofluids has been improved by carboxylic and hydroxyl functionalization of MWCNTs without adding surfactants. The methods used to improve the stability of nanofluids reported so far are stable only for several days or few months only.

In future work, an effective and simple method that can keep long-term stability of MWCNT nanofluids will be achieved by adding different surfactant types to modify the surface properties of suspended nanotubes and suppressing formation of nanotube cluster to obtain a stable and homogeneous suspension. Furthermore, the effect of surfactants on the thermal conductivity values of the MWCNT nanofluids can also be carried out.
6.2.2 Particle size and pH value

The particle size of the nanoparticles plays an essential role in the nanofluids to enhance the thermal conductivity and stability. Also, the stability of the nanofluids depends on the pH value of the nanofluids. In future, CNTs diameter and pH values can be varied to optimize the particle size and pH values for better efficiency of the prepared MWCNT nanofluids.

6.2.3 Cost effective CNT Synthesis

In order to employ CNT-nanofluids for heat transfer applications, stability and production cost are the major factors that obstruct the commercialization of CNT-nanofluids. By solving these challenges, it is expected that CNT-nanofluids can make a large impact as a coolant in heat transfer applications. In the future, efforts can be carried out to reduce the production cost of the CNTs and uniform size distribution of CNTs.