ABSTRACT

In search of smart and multifunctional materials many scientists took great interest in different nanostructures where nanoparticles or nanotubes were incorporated into several base matrices. Carbon nanotube (CNT) was found to be one of the promising materials when they are used in polymers, metals and ceramics as a reinforcing agent and also in heat transfer materials. However, few works have been reported regarding the mechanical and thermal properties of CNT-glass composites where the underlying mechanisms of strengthening and heat transport phenomenon was not yet been analyzed properly considering all the parameters. This thesis mainly deals with the mechanical and thermal properties of borosilicate and lead silicate glass composites containing single walled carbon nanotubes (SWCNTs) fabricated by melt-quench technique. The effects of the nanotubes were thoroughly discussed considering the reinforcing action and the thermal transport mechanism in these composites.

Reinforcement of SWCNTs into the base glasses shows significant increments in micro hardness, Young’s modulus, fracture toughness and recovery resistance of the glass composites compared to the base glasses. Enhanced hardness of the composites were discussed considering the cushioning property of the entangled SWCNT bundles Moreover the entanglement of the nanotube bundles was ascertained by the FESEM micrographs. In addition Reverse Indentation Size Effect (RISE) was observed both in the base glasses and the composites where hardness increases with load in the lower load region. Crack bridging and the crack arresting were another interesting observations which causes the incremented fracture toughness in the composites. One of the most amazing phenomenon was the dragging of some SWCNT bundles around the crack zone which was not hitherto been observed in any CNT composites. This observation was explained through the enhanced localized plastic flow in the composites which drags the SWCNT bundles near the crack zone. Here the energy released from the strained SWCNT bundles and the enhanced recovery resistances in the composites were discussed and further corroborated by the HRTEM micrographs. Moreover, the fatigue failure was investigated through the repeated indentation technique where the crack initiation, crack growth and eventual chipping were studied for the base glasses and the composites. For a certain load the number of cycles to
chipping was found to be higher in the composites than that of the base glasses. Consequently the fatigue resistance parameters were substantially increases in the composites. Considering the repeated damage in the specimens, the theory of residual stress was incorporated in the form of mathematical model to explain the failure behavior.

Lastly, the specific heats, thermal diffusivities and thermal conductivities were evaluated for the base glasses and the composites along with their temperature profiles. Significant increments of the diffusivities and the conductivities were observed at the higher temperatures in the composites compared to the base glasses. Correlating the FESEM and the HRTEM micrographs, the effective thermal conductivities of the composites were also estimated by using an advanced model based on the effective medium approach which shows a good agreement of the theoretical and the experimental values. In this context the effects of the thermal boundary resistance in tube-tube and tube-matrix interfaces was analyzed at different temperatures. Finally, the underlying physics behind heat absorption, thermal conduction, and the temperature profiles of the thermal parameters were explained with the help of Diffused Mismatch Model (DMM) and the inelastic scattering of phonons in the composites.

At the end one can conclude that the nanotubes inside the SWCNT-glass composites play the pivotal role in controlling different mechanical and thermal parameters. In view of those interesting mechanical and thermal properties of SWCNT incorporated glass composites it can be considered as the prospective materials in the field of aerospace, structural applications, heat sinking objects in electronics & motors and thermal interface device applications.