ABSTRACT

Two component composites comprising of polymer (polar/non-polar) and various conductors of varying particle sizes, prepared under different process conditions, were investigated as a function of volume fraction of the conductor (f_{con}) and frequency of applied signal. The polymer-conductor composites (PCC) exhibit an insulator-to-metal transition (IMT) at a critical concentration (f_c) where high values of effective dielectric constant (ε_{eff}) with low dielectric loss (Tan δ) have been observed. The electrical properties of these composites in the vicinity of f_c are explained on the basis of "boundary layer capacitor effect" and the conventional "percolation theory". The origin of extent of enhancement of ε_{eff} value for polymer-metal composites (PMC) at their respective f_c is attributed to spatial distribution, connectivity, inter-cluster distance and dc conductivity of the samples. The universal percolation behavior on approaching f_c is well satisfied under the inter-cluster polarization model. The critical exponents which characterize the divergence of ε_{eff} and effective ac conductivity (σ_{eff}) in the vicinity of f_c are found to be greater than their respective universal values and these variations are correlated to the extent of connectivity of the conducting filler particles in PMC. In polar PCC, dipolar relaxation (DR) plays a predominant role below f_c whereas anomalous low frequency dispersion (ALFD) becomes dominant above f_c. On the other hand, ALFD above f_c is the only likely possibility for non-polar PCC. The quantification of dielectric relaxation behavior in the PCC has been done in terms of the relaxation exponents of the Jonscher's universal dielectric response (JUDR) laws. The magnitude of relaxation exponents, evaluated from the experimental results using JUDR laws, falls within the universal limit ~[0, 1] with additional feature of strong dependence on f_{con} due to the prevalence of Maxwell-Wagner-Sillar (MWS) polarization contributed by uncorrelated electrons at f_c. The DR and MWS polarization relaxation have been analyzed in terms of various electrical parameters. Across f_c, Jonschers universal power law is well satisfied for both the regions of $f_{con} < f_c$ and $f_{con} \geq f_c$ in all PCC. The ferroelectric and ferromagnetic properties of polyvinylidene fluoride and nanocrystalline nickel composites have been investigated as a function of f_{con}.

Keywords: polymer composite, percolation, insulator-metal transition, critical exponent, phase transition, scaling, relaxation, dielectric constant, resistor-capacitor network, multiferroic.

Part of this thesis work is presented in journal articles, which are listed in the list of publications.