Dispersion Control of Nano-Carbon Fibers Utilizing Selective Adsorption of Component Polymer Chains in Polymer Blends: Viscoelasticity, Electrical Conductivity and Electromagnetic-Wave Absorption

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Introduction
When nano-carbon particles are dispersed in a polymer blend, the particles show a marked trend to localize in one phase selectively. This selective localization is governed by flexibility of polymer chain (or adsorption of polymer chain) as well as interface energy between the polymer and carbon particle. In this study, vapor grown carbon fibers (VGCFs) are dispersed in a PMMA/HDPE (97/3) blend, and the effects of HDPE-chain adsorption on structure, viscoelasticity and electrical properties of the composites are examined.

Experiments
PMMA (Mw=60k, Mw/Mn=2.3) and HDPE (Mw=230k, Mw/Mn=4.5) with the weight ratio of 97/3 were melt blended with Vapor Grown Carbon Fibers (Diameter=150nm, Length=10-20μm) and pressed at 200°C. After etching of PMMA phase by acetone, SEM observation was made using VE-7800 (Keyence). Electrical conductivity was measured using Hiresta-UP (circular twin probe) and Loresta-GP (4 pin probe) of Mitsubishi Chemical. A vector network analyzer 37247D (Anritsu) was used to measure both complex permittivity (group-delay cutback-type stripline method, KEYCOM) and electromagnetic-wave absorbance (microstrip method) in GHz band.

Results and Discussion
By subtracting the matrix contributions from the dynamic moduli G’, G” of the composites, the filler contributions Gf’, Gf” are obtained. From the frequency dependence (power law) Gf’ ~ Gf” ~ ω^n with the exponent n, the percolation threshold of the PMMA/HDPE/VGCF composite (after 4h annealing) was determined as 1.15vol% of VGCF. This threshold is much lower than that of PMMA/VGCF, as also observed by conductivity measurement (Fig.1).

The lower threshold is due to selective adsorption of HDPE chains at the ends of VGCF (rough surface), acting as a bonding agent for VGCF as shown in Fig.2, where HDPE spheres are seen at VGCF ends. The fractal dimension D at the threshold obtained from the relation n = 3/(D+2) is D ≒ 2.0, suggesting a very effective formation of a fractal path (almost linear array).

Dielectric and electromagnetic-wave absorbing properties of the PMMA/HDPE/VGCF composites were studied in GHz band. As VGCF content increases, relative permittivities ε_r’, ε_r” of the PMMA/HDPE/VGCF increase, and significant enhancement is seen near the percolation threshold. Due to this increase in ε_r”, the composites with VGCF fraction higher than the threshold, show very high electromagnetic-wave absorbance (95–98%) in 2–20GHz band (Fig.3).