

# „Polyethylene Nanocomposites with Carbon Nanofillers: Similarities and Differences”

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## Abstract

Polyethylene nanocomposites with most of known carbon nanoparticles: carbon black, nanodiamonds, carbon nanotubes, fullerene, graphene and reduced graphene oxide, were prepared by melt blending. The samples were studied employing various experimental techniques and analyzed. Only carbon nanotubes and graphene platelets nucleated polyethylene crystallization and elevated its crystallization temperature by 3-4°C. Single grains of the other carbon nanofillers did not show nucleation ability in contrast to their agglomerates. Hence, the number of nucleated polyethylene structural elements was less than the number of the introduced nanoparticles by few orders of magnitude. The impact strength of nanocomposites increased by 30-40% for carbon black, nanodiamonds, fullerene, and carbon nanotubes, while it decreased by 25-30% for both plate-like nanofillers. In tensile stretching, polyethylene and its nanocomposites cavitated around the yield stress as shown by volume strain measurements. It appeared that the cavities of both origins: from HDPE alone and by detachment from the nanofillers are larger than 10-15 nm. Surprisingly, small angle x-ray data did not evidence voids smaller than approximately 10-15 nm in diameter. The absence of small voids was noticed for plain polyethylene and all cavitating nanocomposites, for all local strains with fixed sample length and for all nanofiller concentrations. This observation opposes the common belief that the cavities are first initiated and subsequently slowly grow during further deformation. Apparently, the cavitation pores having 10-15 nm in diameter are formed suddenly in a single step. This value is surprisingly close to the thickness of the amorphous layer. It is suggested that, similar to ordinary liquids, the surface tension of amorphous phase of polyethylene collapses small caverns. For strained amorphous polyethylene with the surface tension of 35.7 mJ/m<sup>2</sup>, the collapsing pressure for 20 nm cavern would be 7 MPa. During stretching, the uniaxial stress of 21 MPa would counterbalance the 7 MPa closing pressure. Such stress is generated close to the yield point. Any smaller cavities would require larger stress and would collapse under the action of surface tension. This shows that the cavitation behavior of the amorphous phase of polyethylene at nanometer scale bears similarity to an ordinary liquid.

