Tribology of PTFE with Unusually Effective Nanofillers, including the Effect of Sliding Speed on Wear and Friction

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As opposed to microfillers, which have quite generally been shown to provide PTFE polymer with useful reductions of its high wear rate ~$0.4*10^{-3}$ mm^3/Nm typically by a couple orders-of-magnitude over a broad range of filler materials, when reduced to the nanoscale most such filler materials lose much of this wear reduction capability. One of the few notable exceptions to this trend is that of carbon, which has been shown in several forms to not only maintain useful levels of wear resistance but furthermore augment it to much higher levels of effectiveness. For example, at contents of 2%, mesoporous carbon and activated carbon nano-scale fillers have been shown to provide PTFE with rates of approximately 6.9 and 0.8 $*10^{-7}$ mm^3/Nm, while mixed micro/nano-scale multi-walled carbon nanotube filler at this content has been shown to comparably provide extreme wear rate reduction to PTFE down to $9.5*10^{-7}$ mm^3/Nm. Mixed micro/nano-scale graphene platelet filler has also been shown to provide PTFE with extreme wear resistance, especially at smaller platelet thicknesses which increase filler interfacial area for any given content, with a 1.25nm platelet thickness with $30*10^{-7}$ mm^3/Nm wear rate at 2% content reducing it much further to ~10^{-7} mm^3/Nm when increasing content to 10%. These several carbon nanofillers join the previously reported alpha-phase alumina among the very few exceptional filler materials whose ability to reduce PTFE wear rate increases markedly upon reducing particle dimensions from the micro- to the nano-scale. While from x-ray diffraction is appears that such nanofillers each stabilize a tougher Phase I of the PTFE matrix that is ordinarily only seen at higher temperatures, more importantly from FT-IR characterization it appears that these nanofillers also enable scission and chelation reactions that chemically bind thin PTFE transfer films to the metal of the mating countersurface. These studies have generally been done at a low sliding speed of 0.1m/s to prevent substantial frictional heating from confounding the effects of other variables (for example filler content, graphene platelet thickness) being investigated, and furthermore given the extremely long sliding durations required to achieve measurable mass losses from such wear-resistant materials at such modest sliding speeds, the wear tester with multi-station capability that has been employed to increase sample throughput has lacked the ability to measure friction at the individual stations. While some preliminary investigations on a single-station pin-on-disc tester have indicated that the friction coefficients of these nanocomposites do not differ greatly from the $\mu\approx0.2$ value typically measured for unfilled PTFE at 0.1m/s speed, this investigation further studies both the wear and the friction behavior of these unusually effective PTFE nanocomposites as a function of elevated sliding speeds.