Tribological Properties of Quantum Dot/PMMA Nanocomposite Films

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Introduction

Poly(methyl methacrylate), also known as PMMA, is a very versatile substance. It's most common use is in a glass alternative known as Plexiglas. By itself, PMMA is used in a wide variety of other things such as automotive parts, filters, superglue and light-emitting diodes. When PMMA nanocomposites are formed by adding nanoparticles, interesting optical properties could be explored [1]. Even though PMMA is lighter than glass and it's easy to form, it is soft and wears easily. By adding nanoparticles, mechanical properties of PMMA can be improved for applications that require durability, such as optical filters and electronic devices [2]. In this study, we investigate the wear and scratch performance of quantum dot (QD)/PMMA polymeric nanocomposites films with different concentrations.

Experimental

Sample preparation and characterization
CdSe/ZnS QDs were synthesized by solution-based technique [3]. The QDs were then mixed with PMMA powder in chloroform solution at 0.1%, 1%, and 10% weight percent of QDs to PMMA ratio. The solution was stirred until the QDs and PMMA was completely mixed. The mixture was then spin coated over a flat glass substrate resulting in approximately 2 µm thick film on the glass substrate.

The surface topography of the samples was characterized using the scanning probe microscopy (SPM) of a TriboIndenter (Hysitron, Inc.). The scan area was 10 µm by 10 µm. The average surface roughness and the root mean square roughness were determined based on the SPM measurements.

Scanning wear and scratch testing
The wear performances of the samples were studied using the TriboIndenter with a conical diamond tip of 1 µm tip radius of curvature. The test procedure starts with scanning a 20 µm by 20 µm area under a normal load of 0.5 µN to serve as the pre-wear image, followed by scanning a 4 µm by 4 µm area one time in the center of the 20 µm by 20 µm area under a normal load of 80 µN to induce wear. Then the original 20 µm by 20 µm area was scanned again to serve as the post-wear image. This process was repeated 3 times on different areas of each sample. The wear depth is the difference in height of the unworn area and the worn area.

Scratch tests, conducted also using the TriboIndenter, were performed employing the same 1µm conical tip according to the following procedure. After the tip was brought to contact with the sample, it scratched 6 µm across the sample surface with a speed of 1 µm/s under a ramp load from 0 to 100 µN. Before and after the scratch tests, SPM images were taken over the same 10 µm by 10 µm scan area to reflect any topography change. The scratch tests were performed 3 times on different areas of each sample.

Results and Discussion

Surface topography
The SPM surface topography measurement results, shown in Table 1, indicate that the roughness is increased for QD nanocomposite films when the concentration of QD is larger than 0.1%. This increase in roughness can also be easily seen in the SPM topography images shown in Figure 1.

Table 1 SPM surface topography of the samples.

Sample Type	Average Surface Roughness (nm)	Root Mean Square Roughness (nm)
PMMA	0.23	0.29
0.1% QD/PMMA	0.16	0.21
1% QD/PMMA	0.36	0.45
10% QD/PMMA	3.91	5.32

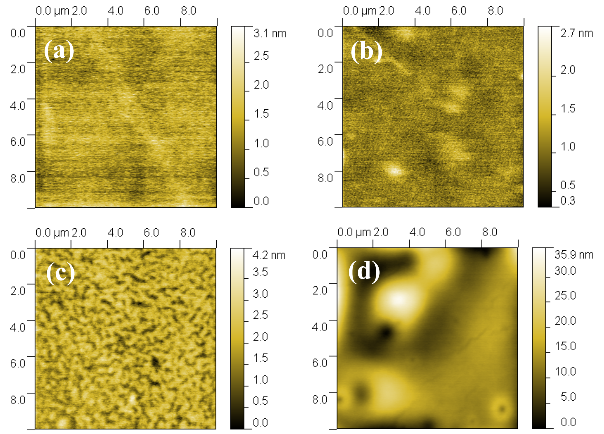

Figure 1. SPM surface topography of the samples. (a) PMMA, (b) 0.1%QDs, (c) 1%QDs, and (d) 10% QDs.

Wear and scratch resistance

Figure 2 shows the Comparisons of the scanning wear depths of the QD/PMMA nanocomposites films and the pure PMMA film. It can be seen that, as the nanoparticle concentration increases, the wear depth decreases. Adding 0.1% QD to PMMA reduced the wear depth slightly, but adding 1% QD reduced the wear depth significantly. However, adding 10% QD did not further decrease the wear depth much more than 1%.

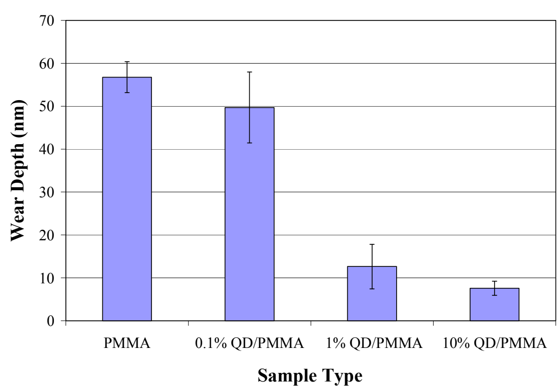

Figure 2. Comparisons of the wear depths of the samples.

Figure 3 shows the Comparisons of the scratch length and depths of the QD/PMMA nanocomposites films and the pure PMMA film. It can be seen that, as the nanoparticle concentration increases, both the scratch length and depth decrease. Adding just 0.1% QD to PMMA decreased the scratch length and depth significantly, but adding 10% QD did not further decrease the scratch length and depth much more than 1%.

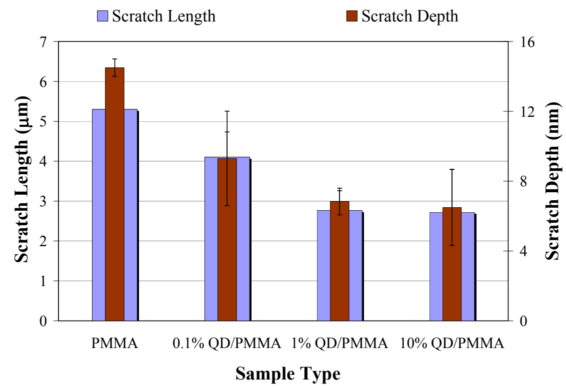

Figure 3. Comparisons of the scratch length and depths of the samples.

Conclusion

In this study, the wear and scratch resistance of the QD/PMMA nanocomposites were studied and compared to that of pure PMMA. The results show that the wear and scratch resistance of the nanocomposite films are all better than those of the pure PMMA film, and they increase with the QD concentration in PMMA. The results also show that only 1% of QD in PMMA is sufficient to improve the wear and scratch resistance. Adding higher percentage of QD in PMMA did not give much further improvement in wear and scratch resistance.

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