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# Scratch-Induced Deformation of Poly(methyl methacrylate) under Dry and Wet Conditions

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**ABSTRACT**

Poly(methyl methacrylate) (PMMA), transparent thermoplastic materials similar to glass, was applied in several wide-ranging applications such as cell phone display screens, transparent windows and signboards. However, they are soft and easily appeared poorly transparent properties when getting scratches on their surfaces of applications under dry and wet conditions. Therefore, in this research, the features of PMMA materials after scratch damage was studied by diamond scratch tester under various loads at different environments. The optical microscope was thus applied to investigate the morphology of scratch track on the materials. In addition, the scratch resistance was analyzed by the scratch tester. From the results, the scratch depth was increased with an increasing load in both conditions as well as with the higher stress concentration. The scratch hardness, specific scratch wear rate and scratch coefficient of friction related with the applied load that it affected elastic and plastic deformation state.

*Key words:* PMMA, Scratch resistance, Deformation, Wet and dry environment, Load

## INTRODUCTION

The Scratch performance test for PMMA is greatly important in the applications of electronic, optical and automotive materials [1] because the scratch induces the feature damages, such as more propagation cracks and wear deformation [2-4] and causes high friction coefficient, poorly transparent properties and decreasing lifetime. Moreover the effects of load conditions and type of materials, during the scratch, are also induced as well. Due to few studies on the scratch deformation and transmission properties under wet and dry conditions, the objective of this work was to understand the effect of load and environments on scratch behavior of PMMA.

*Experimental:*

Poly(methyl methacrylate) (PMMA) sheet was supplied with Pan Asia Industrial Co., Ltd, Thailand. It was fabricated to a disc at diameter of 25.4 mm by laser cutting machine. After that, the PMMA disc was examined with scratch tester under 1 mm/s scratch speed test and various loads at 50, 100, 150, 200 and 250 N in the dry and wet conditions. The indenter tip was the apex angle of 120$^{o}$ diamond conical indenter. From the result of test, scratch hardness, scratch depth, specific scratch wear rate and scratch coefficient of friction were analyzed [5-7].

## Result And Discussion

Figure 1 described the scratch depth of PMMA with apply load from 50 to 250 N under dry and wet conditions. Taking into account of this case, under dry condition, the scratch depth was transferred into two ranges. At this state, the scratch depth was slightly increased with an increasing load applied from 50 to 100 N due to increasing stress concentration in the elastic deformation. Next step, when the load was applied from 150 to 250 N, the scratch depth was sharply increased. This was because the high stress affected crack on the scratch track. The trend result of scratch depth under wet condition was shown similarly under dry condition, but more extended elastic deformation was observed when load in a range from 100 to 150 N was applied. Figure 2 indicated the scratch hardness, the resistance movement strength of counterpart that was related to cohesive properties and shear stress. The scratch hardness was increased due to an increasing load applied in the elastic deformation state from 50 to 100 N under dry condition and also at the load applied from 50 to 150 N under wet condition.

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These situations were caused by increasing stress concentration. When more force was applied, molecular chains of the polymer were more stretched. After that, the plastic deformation was decreased because the applied force was used for breaking of chemical bonding in the molecular chain. Hence, the observed results were more crack appeared on the PMMA surface groove.

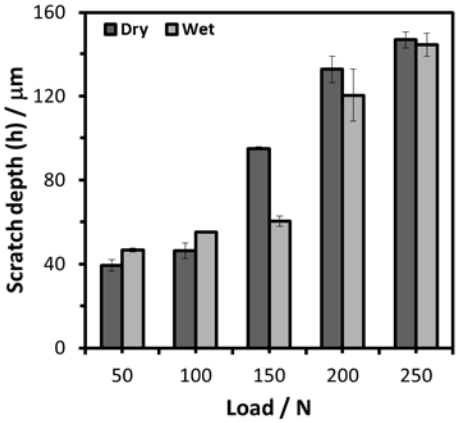


**Fig. 1:** Scratch depth at different loads (50 N, 100 N, 150 N, 200 N, and 250 N) under dry and wet condition test.

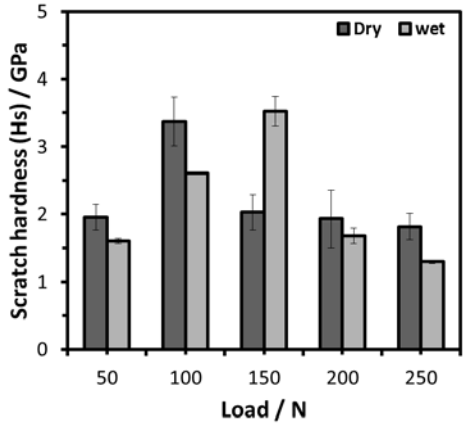


**Fig. 2:** Scratch hardness at different loads (50 N, 100 N, 150 N, 200 N, and 250 N) under dry and wet condition test.

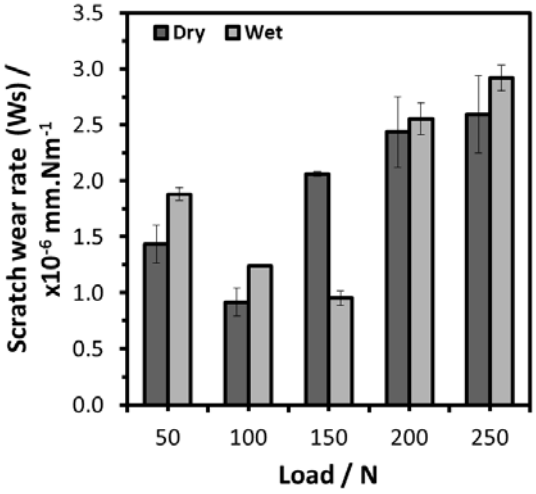


**Fig. 3:** Scratch wear rate at different loads (50 N, 100 N, 150 N, 200 N, and 250 N) under dry and wet condition test.

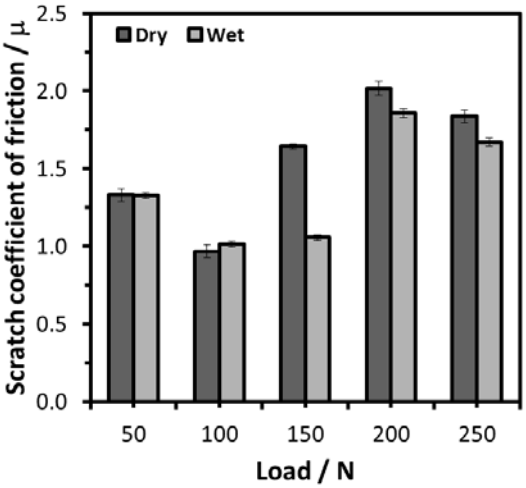


**Fig. 4:** Scratch coefficient of friction at different loads (50 N, 100 N, 150 N, 200 N, and 250 N) under dry and wet condition test.

The reductions of specific scratch wear rate and scratch coefficient of friction (**Figure 3 and 4**) were observed in the elastic deformation state due to stretching of molecular chains of the polymer. In the plastic deformation state, these circumstances were increased with an increasing applied load due to severe wear from cracking on the groove surface as shown at the **Figure 5 and 6**.

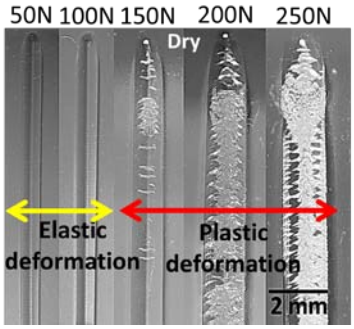


**Fig. 5:** Scratch damage at different loads (50 N, 100 N, 150 N, 200 N, and 250 N) under dry condition test.

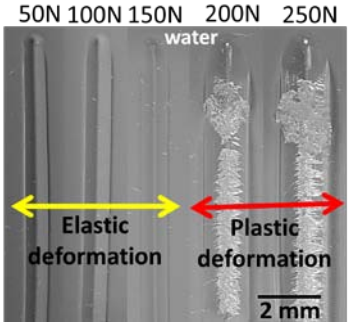


**Fig. 6:** Scratch damage at different loads (50 N, 100 N, 150 N, 200 N, and 250 N) under wet condition test.

*Conclusion:*

The Scratch deformation was more noticeable with an increasing applied load. This characteristic could be seen into two ranges from elasticity to plasticity when increasing stress concentration. Under dry condition test, the elastic deformation state could be occurred during the load applied from 50 to 100N whereas the plastic deformation could be shown for the load applied from 150 to 250N. Under wet condition, the elastic deformation range was further extended from 100 to 150N. The scratch hardness was observed increasingly in the elastic deformation state but decreasingly in the plastic deformation. These were because of molecule chain of the polymer broken. The specific scratch wear rate

and scratch coefficient of friction was also decreased in the elastic deformation stat but increased in the plastic deformation state due to crack damages. Therefore, from overall, wet condition could help expand the plastic durability in the elastic deformation state.

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