Antireflective Coating for Bus Windshields

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Transit buses operating at night are required to maintain interior illumination whenever passengers are onboard. This interior lighting reflects off the windshield and obscures the driver's vision. The problem of windshield reflection creates a hazardous situation that has not been adequately addressed by industry suppliers.

Figure 1 – Images of windshield reflection (Flannagan 2012).

The effect of windshield reflectance was recently quantified in research conducted at the University of Michigan Transportation Research[1]. In this experiment, interior illumination significantly reduced the distance from which driver's were able to detect a pedestrian approaching the vehicle. These experiments were done under controlled conditions from a parked vehicle on a secluded section of roadway. The measured results reported in [Flannagan 2012] are significant. Anecdotal evidence obtained from interviews with actual transit bus drivers operating under real world conditions on busy city streets indicates that the problem is even more significant than the empirical measurements show. We have identified no agency that keeps records of data to quantify the number and severity of accidents attributable to windshield glare but the hazards presented by reduced visibility are self-evident.

Heretofore, technical approaches to address the problem of windshield reflectance at night have focused almost exclusively on modifications to interior lighting. The color, intensity and direction of dashboard instrument lighting are modified to reduce glare and improve driver vision. While these approaches may be useful for commercial trucking and passenger vehicle applications, they do not apply to the unique circumstances present on transit buses. Regulations require that transit buses must maintain a significant level of interior illumination so that passengers are able to see. This situation does not allow for modifications to interior lighting; it can only be addressed by reducing the light reflectance properties of the windshield itself.

By using the newly developed diamond-like (DLC) materials, the Mackinac team has achieved unprecedented antireflection properties on windshield glass.

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[1] Flannagan, Michael P. and Joel M. Devonshire. "Effects of Automotive Interior Lighting on Driver Vision." *Leukos* 9(1) Jul 2012, pp. 9-23.

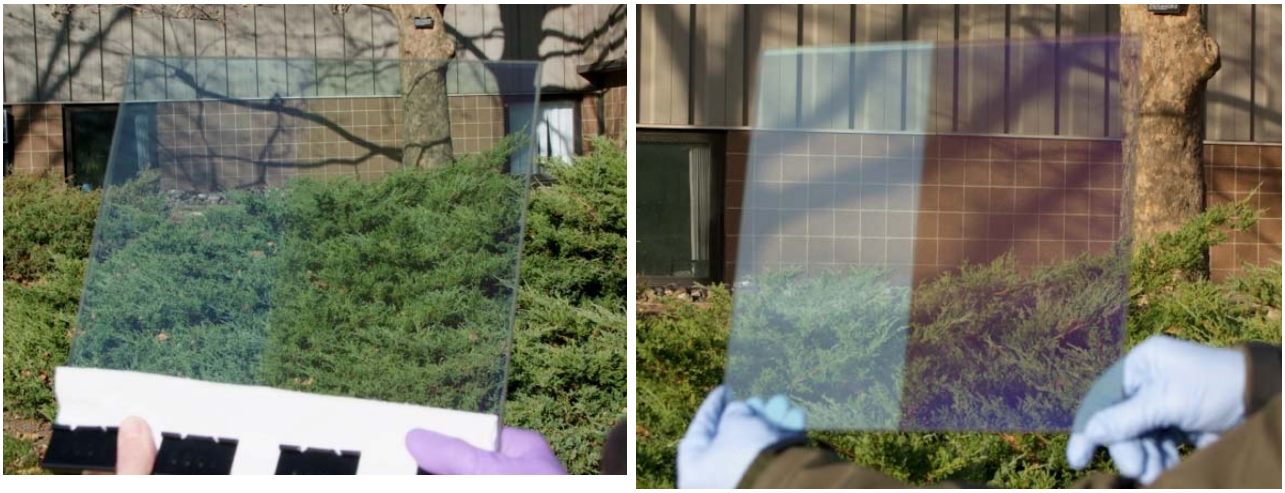

Figure 2. DLC layers applied directly to windshield glass show good antireflective properties. Left side is untreated. Right side is treated with AR materials.

Because of its relatively high hardness, DLC is commonly used to improve the durability of glass and other materials. Material hardness is often measured and reported as gigapascals (GPa). The hardness of DLC materials typically ranges from 15 to 50 GPa. For comparison, pure crystal diamond has a hardness of 100 GPa, glass is about 6 GPa and steel is 6 to 9 GPa.

Mackinac's DLC coating also has antifogging properties. The water contact angle of Mackinac's DLC is 148 **°**, which is even higher than Teflon at 110**°**. This feature is also an important safety factor for transit bus applications.

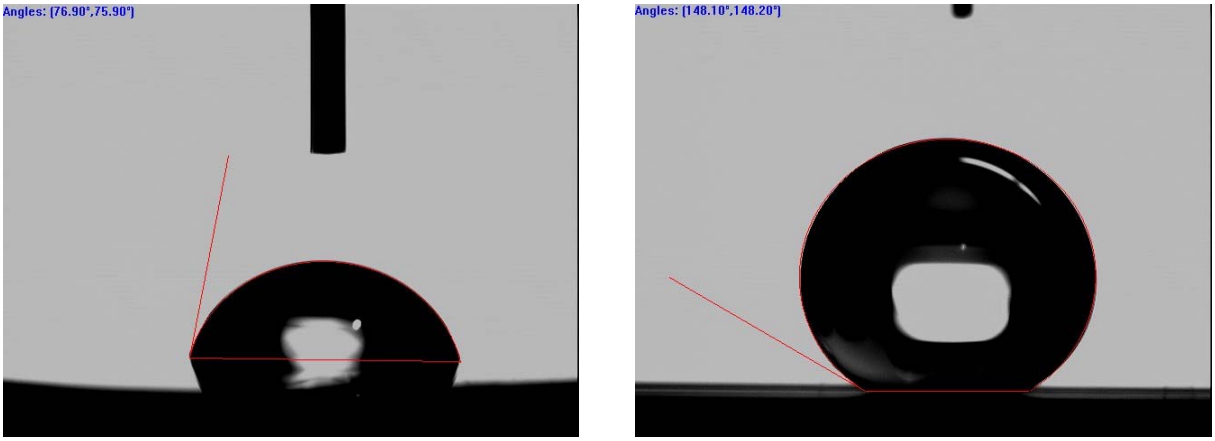

Figure 3. Left: untreated glass with a water contact angle of 76°, Right: Super hydrophobic DLC coating with a water contact angle of 148°.

There is precedent for applying DLC coatings to automotive windshield glass. The Southwest Research Institute (SwRI) has previously developed a DLC coating that is applied to the windshields of Humvee vehicles and deployed by the US Marine Corps in tactical applications. The SwRI DLC material does not have the antireflective and antifogging properties as the material recently developed by Mackinac. The SwRI material was developed exclusively for scratch resistance for vehicles deployed in desert type environments where the abrasive effects of blowing sand can cause premature deterioration of windshield glass.