

California Environmental Protection Agency

Air Resources Board

Rulemaking to Consider Adoption of Proposed Cool Car Standards
And Test Procedures – 2012 and Subsequent Model Year Passenger Cars,
Light-Duty Trucks and Medium Duty Vehicles

Public Hearing June 25-26, 2009

Comments of Bayer MaterialScience LLC and
Recommended Amendment to Permit Polymeric Glazing Materials
to Enhance Overall CO2 Emission Reductions

Introduction

Bayer MaterialScience LLC (BMS) believes the proposed standard as written would preclude the use of polycarbonate for automotive glazing. Polycarbonate is a high technology, clear lightweight material alternative to glass that offers, among other things, the ability to reduce the weight of a vehicle, resulting in enhanced fuel economy and subsequent reduction in greenhouse gas (GHG) emissions.

BMS makes the following recommendations regarding the proposed standards:

1. Change the proposed regulation to include polycarbonate as a material alternative to glass for glazing.
2. Specify independent energy transmission requirements for polycarbonate in addition to those for glass.

The basis for these recommendations:

1. Polycarbonate has a lower density than glass, resulting in lighter weight components which contribute to reduced fuel consumption and subsequent reduction in greenhouse gas emissions. This fact, in combination with acceptable energy transmission values, would allow the attainment of the desired reduction in greenhouse gas emissions.

2. Polycarbonate is fundamentally different from glass from a chemical standpoint and the same standard should not apply.
3. The technology does not exist today and we currently do not see a path forward that would allow polycarbonate to meet the standards being proposed for glass. Due to the fundamental differences between polycarbonate and glass, the energy transmission control techniques recommended for glass are not directly translatable to polycarbonate.
4. Lifecycle analysis suggests that polycarbonate is favorable to glass in terms of total life cycle carbon dioxide emissions for automotive glazing applications. Life cycle is defined as production, use and end of life.
5. Due to the free-formability of polycarbonate, high levels of part integration can be achieved with less manufacturing energy. This is not possible with traditional glazing materials and allows for enhanced “lightweighting” with fewer components, enhancing the energy efficiency of future automotive designs.

Polycarbonate as an Alternative Material

BMS recommends amendment of *Appendix A Proposed Regulation Order* to reflect polycarbonate explicitly as an alternative glazing material and agrees with the proposed language submitted by Exatec, LLC on June 12, 2009. This means the inclusion of the following additional definition under § 95602(a):

(#) “Alternative Glazing Material” means a transparent or translucent material, other than glass, that is used for glazing and provides equivalent green house gas reduction through reduced total solar transmittance and/or other means, such as reduced weight. Polycarbonate plastic, a synthetic thermoplastic resin, is an example of an “Alternative Glazing Material” where, when the effect of lower weight material is considered, the data demonstrate equivalent green house gas reduction.

Total Solar Energy Transmission Recommendations for Polycarbonate

BMS recommends amendment of *Appendix A Proposed Regulation Order* to reflect Total Solar Energy Transmission (Tts) values which take into account the carbon dioxide emissions reduction due to weight savings achievable with polycarbonate as well as the fundamental differences between polycarbonate and glass. BMS agrees with the levels submitted by Exatec, LLC on June 12, 2009. This means the inclusion of the following language below in § 95603, *Automotive Glazing Standards*.

The recommended text is underlined and italicized. Portions of the original text have been included for reference.

(a) Except as allowed in paragraph (c), the following glazing areas for new passenger cars, light-duty trucks, and medium duty vehicles less than or equal to 10,000 pounds GVW must not exceed the specified transmission of total solar energy (Tts) into the vehicle when the vehicle is parked:

(1) For 2012 model year vehicles, at least seventy-five percent of each manufacturer's total vehicle sales must use a windshield with a Tts less than or equal to fifty percent (50%). *For 2012 model year vehicles, Alternative Glazing Material windshields composed of polycarbonate must have a Tts less than or equal to seventy percent (70%). Alternative Glazing Material windshields composed of polycarbonate meeting this requirement, if employed, shall be included as part of each manufacturer's total vehicle sales for purposes of the seventy-five percent requirement.*

(2) For 2013 model year vehicles, the windshield must have a Tts less than or equal to fifty percent (50%). *For 2013 model year vehicles, Alternative Glazing Material windshields composed of polycarbonate must have a Tts less than or equal to seventy percent (70%).*

(3) For 2014 and subsequent model year vehicles, the windshield must have a Tts less than or equal to forty percent (40%). *For 2014 model year vehicles, Alternative Glazing Material windshields composed of polycarbonate must have a Tts less than or equal to sixty percent (60%).*

(4) For 2012 and subsequent model year vehicles, the rooflite(s), if any, must have a Tts less than or equal to thirty percent (30%), referenced to a glazing of 4 millimeter thickness. *For 2012 and subsequent model year vehicles, the Alternative Glazing Material rooflite(s), if any, composed of polycarbonate must have a Tts less than or equal to fifty percent (50%), referenced to a glazing of 4 millimeter thickness.*

(5) For 2012 and subsequent model year vehicles, sidelites and backlite(s) meeting 70 percent visible light transmittance requirements must have a Tts less than or equal to sixty percent (60%), referenced to a glazing of 4 millimeter thickness. *For 2012 and subsequent model year vehicles, Alternative Glazing Material sidelites and backlite(s) composed of polycarbonate meeting seventy percent (70%) visible light transmittance requirements must have a Tts less than or equal to eighty-five percent (85%), referenced to a glazing of 4 millimeter thickness.*

(6) For 2012 and subsequent model year vehicles, sidelites and backlite(s) not meeting 70 percent visible light transmittance requirements must have a Tts less than or equal to forty percent (40%), referenced to a glazing of 4 millimeter thickness. *For 2012 subsequent model year vehicles, Alternative Glazing Material*

sidelites and backlite(s) composed of polycarbonate not meeting 70 percent visible light transmittance requirements must have a Tts less than or equal to sixty-five percent (65%), referenced to a glazing of 4 millimeter thickness.

(b) Total solar transmittance shall be measured using International Standards Organization Standard 13837 Road Vehicles – Safety Glazing Materials – Method for the Determination of Solar Transmittance at 4 m/s, Convention A, dated April 15, 2008, which is incorporated by reference herein, or using an alternate test methodology that results in equivalent solar control, approved in advance by the Executive Officer.

Recommendations for Manufacturer Compliance Options

BMS recommends amendment of *Appendix A Proposed Regulation Order* to add more clarity and include polycarbonate as an alternative glazing material. BMS agrees with the recommended text submitted by Exatec, LLC on June 12, 2009. This means the inclusion of the following language in § 95604, *Manufacturing Compliance Options*. The recommended text is underlined and italicized. Portions of the original text have been included for reference.

§ 95604. Manufacturer Compliance Options. The vehicle manufacturer may choose to pursue alternative compliance options. Manufacturers doing so must notify the Executive Officer of the alternative being utilized for the specified vehicle model in the initial certification application. Improved performance of glazing in one position may offset lesser performance in another. When pursuing these options, glazing performance (Tts) shall be individually averaged on an area basis for the windshield, backlite(s), sidelites forward of the B-pillar, sidelites rear of the B-pillar, and rooflite(s), if any. Where appropriate, and with approval in advance by the Executive Officer, these options may be combined.

- (a) Improved solar management for the windshield. For each two (2) percentage points that the Tts of the windshield for a specified model is reduced beyond the *Tts* requirement *for glass or Alternative Glazing Material respectively*, one of the following options may be elected:
 - (1) The maximum Tts for the sidelites and backlite(s) for vision glass is increased by three percentage points; or
 - (2) The maximum Tts for sidelites and backlite(s) not meeting 70 percent visible light is increased by three percentage points; or
 - (3) The maximum Tts for the rooflite(s) is increased by two percentage points
- (b) Improved solar performance for the backlite(s) or sidelites.

- (1) For passenger cars, if the Tts of the backlite is reduced from sixty percent (60%) to fifty percent (50%), or in the case of a polycarbonate Alternative Glazing Material if the backlite is reduced from eighty five percent (85%) to seventy five percent (75%), the Tts for the windshield may be increased by up to four (4) percentage points; or
- (2) If the average Tts of the sidelites forward of the B-pillar is reduced from 60% to 50%, or in the case of polycarbonate Alternative Glazing Material if the sidelites is reduced from eighty five percent (85%) to seventy five percent (75%), the Tts for the windshield may be increased up to two (2) percentage points.
- (3) If the Tts of the sidelites and backlite(s) of passenger cars averages no more than 50%, the Tts for the windshield may be less than or equal to fifty percent (50%) or if the Tts of the sidelites and backlite(s) of passenger cars made of polycarbonate Alternative Glazing Material averages no more than 75%, the Tts for the windshield may be increased by up to ten (10) percentage points relative to the applicable requirement in Section 95603.

What does Polycarbonate offer Vehicle Manufacturers?

Two key developments in modern automotive engineering are the trend toward greater daylight opening surface area, including an increased number of large transparent car roofs, and the growing popularity of lightweight vehicle construction. According to Saint-Gobain Sekurit, in the early 1980s, the average glass surface area in a car was about 3 m². Today, this figure is about 4.5 m². (RESEARCH ANALYSIS: Review of roof systems 8 September 2008 | Source: just-auto.com editorial team <http://www.just-auto.com/article.aspx?id=95920>). While polycarbonate opens up a whole new range of design possibilities, a primary argument for its use is the fact that it is less dense than glass, which can deliver significant weight savings. In view of the current debate on climate change, this offers automobile manufacturers a crucial opportunity to reduce the fuel consumption and CO₂ emissions of their vehicles.

Polycarbonate and CO₂ Emission Reduction for the in-use Phase

Reliable sources have quantified the fuel savings that can be achieved through vehicle weight reduction. The Massachusetts Institute of Technology (MIT) states that for every 10% reduction in vehicle mass, an increase in fuel economy of 6-7%

may be achieved (MIT, Laboratory of Energy and Environment Report, “Factor of Two: Halving the Fuel Consumption of New U.S. Automobiles by 2035”; Cheah et al; October 2007.) The Fraunhofer Institut in Germany stated that a vehicle that weighs 100 kg less uses 0.8 liter less gasoline per 100 kilometers. (Birgit Niesing - Energie auf Sparflamme Fraunhofer Magazin May 2005, http://www.fraunhofer.de/fhg/Images/mag3-2005-20_tcm5-44610.pdf).

According the United States Environmental Protection Agency a gallon of gasoline is assumed to produce 8.8 kilograms (19.4 pounds) of CO₂. (<http://www.epa.gov/otaq/climate/420f05004.htm#step1>)

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Step 1: Determining the CO₂ produced per gallon of gasoline

A gallon of gasoline is assumed to produce 8.8 kilograms (or 19.4 pounds) of CO₂. This number is calculated from values in the Code of Federal Regulations at 40 CFR 600.113-78, which EPA uses to calculate the fuel economy of vehicles, and relies on assumptions consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines.

In particular, 40 CFR 600.113-78 gives a carbon content value of 2,421 grams (g) of carbon per gallon of gasoline, which produces 8,877 g of CO₂. (The carbon content is multiplied by the ratio of the molecular weight of CO₂ to the molecular weight of carbon: 44/12).

This number is then multiplied by an oxidation factor of 0.99, which assumes that 1 percent of the carbon remains un-oxidized.^[1] This produces a value of 8,788 g or 8.8 kg (19.4 lbs) of CO₂.

A primary goal of the proposed standard is to reduce greenhouse gas emissions. The calculations provided by Exatec, LLC on June 12, 2009 systematically highlight the fact that any increase in air conditioner usage and subsequent fuel consumption and CO₂ emissions due to higher energy transmission values for polycarbonate are offset by the CO₂ emission savings achieved through the weight savings. This allows CARB to achieve the desired result while not precluding the use of an innovative, future oriented material.

Life Cycle Analysis

BMS commissioned a study into the environmental credentials of various products including polycarbonate glazing. The study was carried out by the independent Vienna-based consulting firm Denkstatt GmbH, which has acquired an impressive reputation in Europe for its work in the areas of sustainable development and

environmental management. The calculations were based on a diesel-powered vehicle weighing 1,300 kilograms over a life defined as 150,000 kilometers. The study took into account the entire lifecycle of the glazing units, from the production and coating of the polycarbonate to its use in the vehicle and subsequent recycling (including thermal recycling).

The results show that the low weight of the glazing and the lower fuel consumption this delivers allow it to save approximately twice the amount of energy over the lifespan of the vehicle than is used in its manufacture and recycling. The use of polycarbonate in automotive glazing instead of glass results in an energy saving of 200 to 300 mega joules per kilogram of polycarbonate over the service life of the glazing component. Moreover, 14 to 22 kilograms less carbon dioxide are released into the atmosphere for each kilogram of polycarbonate (CO₂ equivalents as defined in the Kyoto Protocol). These calculations are based on an in-use fuel consumption reduction of nominally 0.35 liter per 100 km per 100kg saved, which is conservative in comparison to the figure stated by the Fraunhofer Institut.

The density of polycarbonate is 1.2 kg/dm³, which translates to 5 kg/m² for a 4 mm thick sheet. The density of glass is 2.5 kg/dm³ (St. Gobain Glazing Manual), which translates to 10 kg/m² for a 4 mm thick pane of glass.

In comparison to glass, 1 kilogram of polycarbonate used in automotive glazing saves in total life cycle (production/use/waste) nominally 20 kg CO₂. Life is defined as 150,000 kilometers.

The theoretical replacement of 4.5 m² of glass by polycarbonate could save approximately 50% of the weight. This equates to 22.5 kg x 20 kg CO₂ = 450 kg CO₂ savings in total life cycle savings.

According to a presentation provide by Hashem Akbari of the Lawrence Berkeley National Laboratory at a May 15, 2008 workshop:

- Average miles traveled per vehicle per year = 12,000 miles (19,300 km).
- Number of vehicles in California = 26 million.

Translating this into per year carbon dioxide emission reduction:

- 150,000 km lifetime with 19,300 km per year = 7.8 years lifetime.

- 450 kg CO₂ savings in 7.8 years results in 58 kg CO₂ reduction per car per year and 1.5 Mio tons carbon dioxide reduction per year in California with 26 million vehicles.

Polycarbonate fundamental comparison to Glass

Polycarbonate is an organic material created through a polymerization reaction. Granules of PC are supplied to injection molders who mold the material into a finished part, or to sheet manufacturers who thermoform finished sheet into the desired part shape.

Glass is an inorganic material, which is produced in flat sheet and subsequently high-temperature formed into finished parts.

Key differences relevant for automotive glazing:

- Processing temperatures for finished polycarbonate part production are extremely low in comparison to glass.
- Additive packages such as flow enhancers, IR modifiers and/or UV stabilizers are specifically designed for polycarbonate and are not applicable for glass.
- Energy transmission management methods that are in use or that are being considered for use in glass are not compatible with polycarbonate glazing.
- Polycarbonate is 50% less dense than glass, and the weight reductions achievable with polycarbonate are not possible with glass.
- The extreme toughness and impact properties of polycarbonate provide enhanced safety opportunities not possible with glass.

These fundamental differences between polycarbonate and glass make it inappropriate to apply the same standard for energy transmission to both materials. The recommended amendments to the language in the proposed standard take into account the material differences, while still allowing CARB to reach the intended targets.

Bayer MaterialScience LLC Credentials

BMS is one of the leading producers of polymers and high-performance plastics (such as polycarbonate) in North America and is part of the global BMS business with nearly 15,100 employees at 30 sites around the world. Business activities are focused on the manufacture of high-tech polymer materials and the development of innovative solutions for products used in many areas of daily life.

Bayer Corporation, headquartered in Pittsburgh, is a subsidiary of Bayer AG, an international health care, nutrition and high-tech materials group based in Leverkusen, Germany. In North America, Bayer had 2008 net sales of approximately 8 billion euros (about \$12 billion) and employed 17,000 at year end. Bayer's three subgroups, Bayer HealthCare, Bayer CropScience and Bayer MaterialScience, improve people's lives through a broad range of essential products that help diagnose, prevent and treat diseases; protect crops and enhance yields; and advance automobile safety and durability. For more information, go to www.bayerus.com.

The company recently bundled its know-how in automotive glazing under the BayVision™ competence brand, which symbolizes the comprehensive know-how, products and services it offers system suppliers and OEMs. BMS has extensive knowledge of polycarbonate automotive glazing applications and is a leading supplier of polycarbonate for current applications such as the lamella roofs of the Mercedes-Benz A-Class and B-Class, the roof module of the Mercedes-Benz GL and the large panoramic roof of the Smart fortwo. The BMS competence in automotive glazing extends beyond the clear polycarbonate and includes the selection of customized materials, the provision of plastic- and coating-compatible design and the delivery of suitable processing technologies such as injection-compression molding and subsequent coating.

Respectfully Submitted,

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