

# Development of Bio-Based Plastics for Injection Molding

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## ABSTRACT

Technological development of materials derived from plants (e.g., polylactic acid (PLA), and the like) is required to break dependence on fossil fuels and reduce CO<sub>2</sub>. PLA has inferior hydrolysis resistance, impact resistance, and molding ability than polypropylene (PP), and in order to overcome these disadvantages, a novel PP/PLA alloy has been conceived where PLA is incorporated into a PP matrix. By optimizing compatibilizer and elastomer addition, PLA has been successfully dispersed into a PP matrix at a sub-micron order, and interior parts have been successfully developed that fulfill the performance, appearance, and mass-production capability requirements for practical application.

## 1. BACKGROUND

Since the Industrial Revolution in the 18th century, human society has become based on the mass-consumption of fossil resources. One of the consequences of this development is global scale environmental problems such as increases in atmospheric CO<sub>2</sub> and the depletion of oil reserves. As a result, the automotive industry is facing increasing demands to provide solutions. Plastics account for half the volume in a modern vehicle and will therefore play a critical role in meeting these demands. Reinforcing society's trust by developing environmentally friendly plastics is therefore an urgent task to ensure that the automobile can continue contributing to people's lives and society.

As part of this task, the development of plastics derived from plants (i.e., bioplastics) is progressing. The use of plants as raw materials enables the development of carbon neutral materials (Fig. 1), and also reduces oil consumption. The carbon neutral concept is based on the calculation that the combustion of materials derived from oil-based resources is a net cause of CO<sub>2</sub>; whereas the combustion of plastics derived from plants has no effect on overall CO<sub>2</sub> levels even if CO<sub>2</sub> is generated in the combustion process after manufacturing or use because of the amount of CO<sub>2</sub> absorbed by the plant during its lifecycle.

Films using bioplastics such as polylactic acid (PLA, see Fig. 2) have already been developed but have yet to enter mass production other than for vehicle parts that use natural fibers. Consequently, this research focused on the development of bioplastic injection molding materials that can be used for the main interior components.

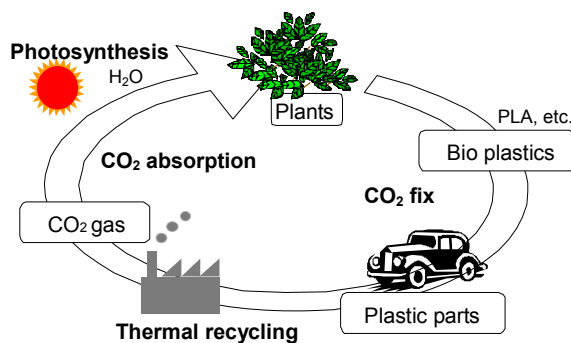


Fig. 1 Carbon Neutral Concept

2. ISSUES OF PLA

Examples of bioplastics compatible with injection molding that have been reported include PLA, polytrimethylene terephthalate (PTT), and polyhydroxy butyrate (PHB).<sup>(1)</sup> Of these, this research focused on PLA since it has already been commercialized and is comparatively cheaper. However, PLA has the following issues in comparison with polypropylene (PP), which is the main conventional injection molding material for automotive parts.

- 1. Low impact resistance (glass-like state at normal temperatures)
- 2. Susceptibility to hydrolysis and poor durability (ester bonds are dissolved in water: see Fig. 3)
- 3. Poor formability (long solidification process during injection molding)

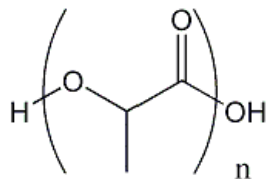


Fig. 2 Structure of PLA

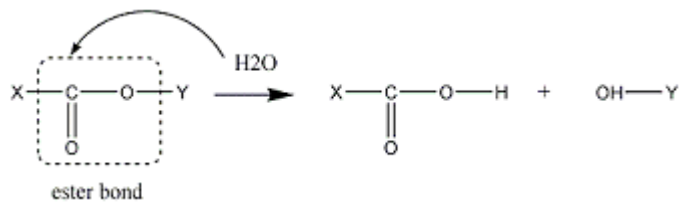


Fig. 3 Hydrolysis of Ester Bonds

3. DEVELOPMENT CONCEPT

As the most commonly used injection molding material for interior parts, PP is characterized by excellent productivity, durability, and formability (PP materials are compatible with thin parts, high-cycle molding, and style parts). PP materials are also highly suited to mass production from the standpoint of molding stability. In contrast, the demerits of PLA, such as its susceptibility to hydrolysis and its poor formability, are due to the intrinsic qualities of the material and make it very difficult to apply to parts by itself. As a result, the idea of polymer alloys has been proposed,<sup>(2)(3)</sup> in which PLA is incorporated in hydrolysis-resistant and highly formable PP (Fig. 4).

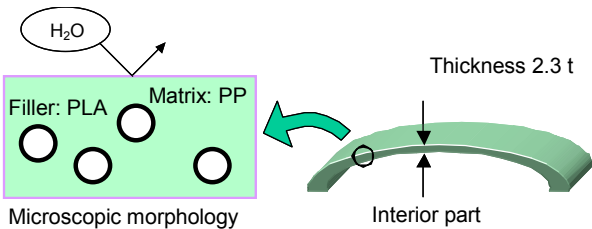


Fig. 4 Concept of PP/PLA Polymer Alloy

The concept of polymer alloys involves the use of PP to secure hydrolysis resistance and formability, with PLA as an organic filler that does not affect the characteristics of the material. This concept was used as the basis for developing a material with suitable impact resistance for interior parts that also satisfies certain targets for other physical properties. The amount of PLA to be incorporated into the PP was set to 25%, which has been determined to be suitable for alloy creation.<sup>(2)(3)</sup>

Table 1 Targets of PP/PLA Alloy

| Item                                   | Target    | Reason                               |
|----------------------------------------|-----------|--------------------------------------|
| Impact resistance (KJ/m <sup>2</sup> ) | Over 15   | PP level                             |
| Elastic modulus (MPa)                  | Over 1000 | PP level                             |
| HDT (°C)                               | Over 60   | Temperature of lower area in vehicle |
| MFR (g/10 min)                         | Over 15   | PP level                             |

4. MATERIAL DEVELOPMENT

4-1. TEST METHOD - The AZ864E material for interior parts was selected as the PP material, and the 3001 material manufactured by NatureWorks LLC was selected for the PLA material. The alloy was created using a twin-screw extruder. Physical properties were measured in accordance with ISO standards, and the states of the material were observed by TEM.

4-2. PRE-STUDY - The pre-study found that a simple blend of PP and PLA has poor compatibility and that PLA becomes dispersed in non-uniform clumps several tens of μm in diameter. The impact resistance of this simple blend is extremely poor. In general terms, the large dispersed clumps cause the concentration of excessive stress at the interfaces of the matrix, which form the origin of large faults that lead to the fracture of the material and prevent the formation of impact resistance (Fig. 5).<sup>(4)</sup>