SPMC Technical Review

Development of Biodegradable Paper Coatings with High Biomass Content

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1. Introduction

The utilization of single-use or disposable plastic products has been a big issue leading to marine plastic pollution. The world is moving forward to reduce plastic garbage and reach de-plasticization society. Recently, single-use plastics such as plastic bags, plastic straws, and disposable plastic containers have been banned or will be banned globally. In 2019, Japanese government formulated "The Plastic Resource Circulation Act" to solve various problems caused by plastic products, aiming at 25% reduction of single-use plastics by 2030.

“Paperization” of packaging material has attracted much attention as one of the most prospective strategies described in the act. In fact, Japan Clean Ocean Material Alliance (CLOMA), which was established in 2019 for solving the problem of marine plastic pollution, sets "Developing and Disseminating Paper and Cellulose Materials” as one of its five key actions, pursuing to introduce 100 kilotons per year of paper and cellulose materials by 2030 and 1 million tons per year by 2050 as substitute materials for plastics.

Paper is a biomass material made from wood, biodegradable, and recyclable, which makes it a promising substitute material for plastics. However, paper shows poor resistance to liquid, inferior gas barrier performance, and poor processability compared to plastics, thus making it difficult to fulfil all requirements as packaging materials.

Polyethylene laminated paper products are widely used as packaging materials due to their superior water and oil resistance and heat-sealability, but there is a challenge in widespread use of it as a plastic substitute due to its difficulty in recycling. In recent years, easy recyclable paper products have been developed by coating with water-based resins to impart functionality, thus its application range is expanding.

2. "SEIKOAT™ series"

Utilizing our technologies cultivated in the development of paper chemicals and resins for printing inks, we have been developed functional coatings to facilitate de-plasticization and paperization from various viewpoints. The followings are representative water-based coatings.

The first coating example is (styrene) acrylic emulsions developed by focusing on paper recyclability[1)]. Paper coated with them is recyclable and shows the same properties as laminated paper.

Other examples are T-EF102 and T-EF103 characterized by "high biomass content and biodegradability" shown in Table 1 [2)] which are designed to maximize environmental friendliness. These coating emulsions provide biodegradable coated layer having high biomass content. Although these coatings are limited to use for imparting moisture resistance to paper, obtained coated paper is easy-recyclable and environmentally friendly. When discarded outside, it is expected to be decomposed smoothly due to its excellent biodegradability.

These “environmentally friendly packaging materials” are named as "SEIKOAT™" series. Through development of these functional coating emulsion, we are making efforts to contribute to a sustainable environment.

Table1. Physical properties, biomass content and biodegradability of T-EF102 and T-EF103

	T-EF102	T-EF103
Total Solids [wt%]	40	40
Viscosity [mPa・s]	150	150
pH	7.5	6.5
Biomass content (*1)	90% or more	85% or more
Degree of biodegradation (absolute value)	75% or more	60% or more

(*1) Percentage of biomass material in solids

In this report, we show the characteristics of SEIKOAT™ T-EF104, enabling to impart higher moisture barrier and water resistance to paper compared to T-EF102 and T-EF103. We are expecting that T-EF104 will help to replace plastics with paper materials having less environmental impact.

3. SEIKOAT™ T-EF104

3-1. Product design of T-EF104

In order to impart moisture barrier property to paper, it is necessary to form a hydrophobic coating film on paper surface. Therefore, we selected hydrophobic resins showing superior hydrophobicity and film formability among various biomass materials. Selected hydrophobic resin is used as a main component of coatings, and emulsified them by biomass emulsifier (Fig. 1). Both hydrophobic resins and emulsifiers used are complied with the composition requirements of Sec.176.170 and 176.180 of 21CFR FDA recognized worldwide.

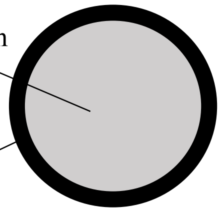


Figure 1. Image of particle structure of T-EF102 and T-EF103 emulsions

3-2. Physical properties and characteristics of T-EF104

Summary of physical properties and characteristics of SEIKOAT™ T-EF104 (abbreviated as T-EF104) are shown in Table 2. T-EF104 contains 80% or more biomass and show good biodegradability as well as T-EF102 and T-EF103.

Table 2. Physical properties and characteristics of T-EF104

	T-EF104
Total Solids [wt%]	40
Viscosity [mPa・s]	200
pH	6.5
Biomass content (*1)	80% or more
Degree of biodegradation (%)	72.6
Sec.176.170 of 21CFR FDA	Confirmed
Sec.176.180 of 21CFR FDA	Confirmed

(*1) Percentage of biomass material in solids

<Biodegradability test method>

In accordance with the method described in JIS K6950, biodegradability test was conducted in activated sludge at 25°C for 56 days.

3-3. Effect of drying temperature on moisture barrier

Moisture barrier performance of T-EF104 was evaluated by using paper coated with T-EF104 under the following conditions.

Coating conditions:

Base paper: Bleached craft paper (50 g/m^2)

Coating method: Wire bar, rod #10 to 20

Drying conditions: Hot air drying,

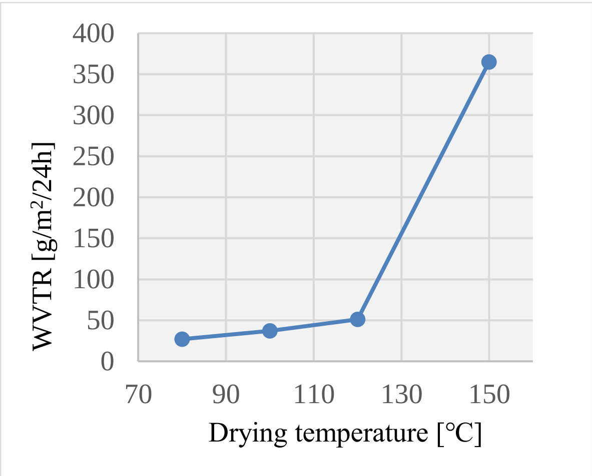
(80°C to 150°C/30 sec)

Measurement method of Water Vapor Transmission Rate (WVTR):

Cup Method (JIS Z0208)

Test conditions: 40°C, 90%RH, 24h

The formation of homogeneous coated layers on paper is important for the development of moisture resistance, which is highly affected by drying condition. Figure 2 shows the relationship between drying temperature and water vapor transmission rate (WVTR) of paper coated with T-EF104. Especially drastic rise of WVTR is observed over 120°C, indicating that excessive heating might prevent the formation of homogeneous coated layer on paper due to penetration of hydrophobic materials of T-EF104 in paper. Therefore, the optimization of drying condition is crucial to secure superior moisture resistance.



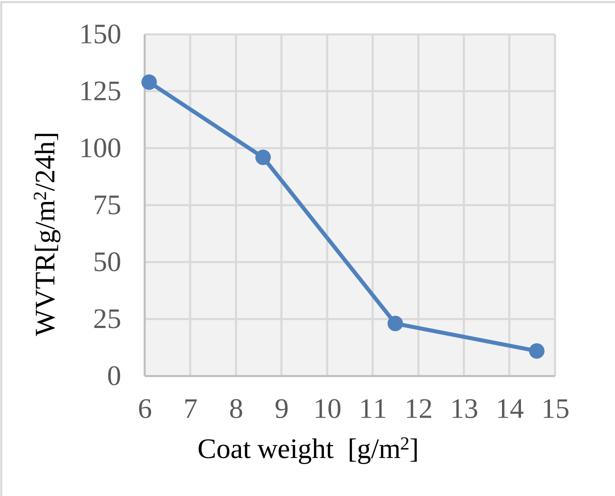
(Dry coat weight of T-EF104 is 11 g/m^2.)

Fig. 2. Relationship between drying temperature and water vaper transmission rate (WVTR) of T-EF104 coated paper

3-4. Relationship between coat weight and moisture resistance

Fig.3 shows the relationship between coat weight and WVTR of papers coated with T-EF104. Moisture resistance of coated papers improves as coat weight of T-EF104 increases.

Papers coated with 11 g/m2 or more of T-EF104 show WVPR of 30 g/m2 /24h or less which is roughly equivalent to that of polyethylene laminated paper. Furthermore, WVTR of coated paper reaches less than 15 g/m2/24h when more T-EF104 is applied to paper.



(Drying conditions 100°C-30 s)

Fig. 3. The relationship between coat weight and WVTR of papers coated with T-EF104.

Fig.4 shows the relationship between coat weight and the water resistance properties of paper coated with T-EF104. Water resistance performance was evaluated under the following conditions.

Water Resistance Measurement Method:

- Water repellency: JAPAN TAPPI No68
- Cobb Method: JIS P 8140: 1998 Paper and board−Determination of water absorptiveness−Cobb method (Base paper Cobb120 is 23 g/m2)

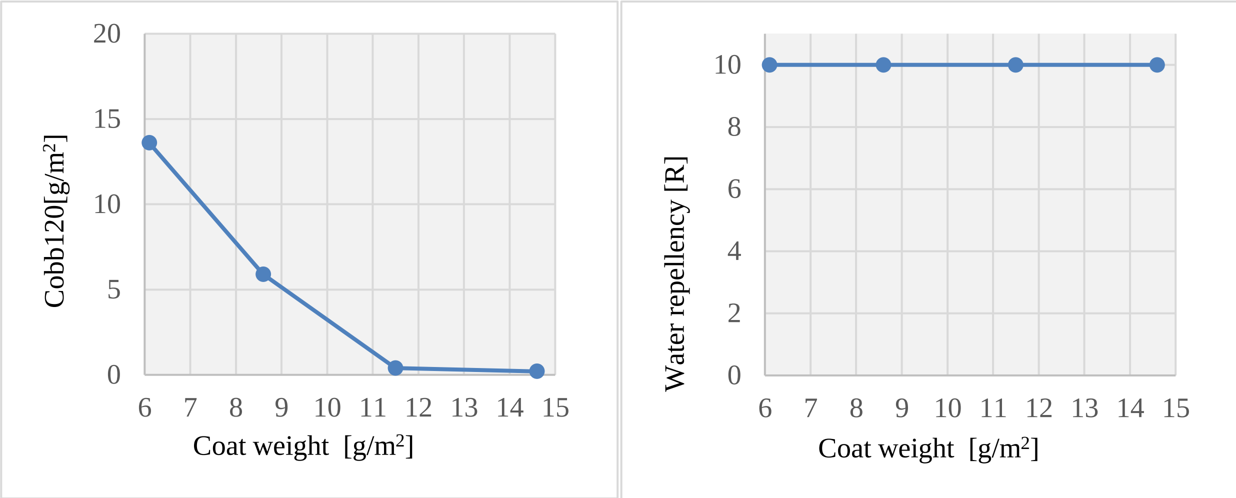


Fig. 4. Relationship between coat weight and water resistance of papers coated with T-EF104 (drying condition: 100°C-30 s)

Table 4. Characteristics of T-EF102, T-EF103, and T-EF104

	T-EF104	T-EF102	T-EF103
Biomass content	80% or more	90% or more	85% or more
Degree of biodegradation (absolute)	70% or more	75% or more	60% or more
WVTR [g/m^2/24h] (*1)	30	85	85(*2)
Cobb120	1.0	8.0	2.0(*2)
Water repellency	R10	R2	R7(*2)
FDA21CFR §176.170	Confirmed	Confirmed	Confirmed
FDA21CFR §176.180	Confirmed	Confirmed	Confirmed

(*1) WVTR at 11 g/m^2 of dry coat weight. Drying conditions: 100°C-30 s

(*2) T-EF103 could not show sufficient moisture resistance under these drying conditions. Therefore, 5% of a film-forming agent was added on the solid content of T-EF103

Application of T-EF104 with 6 g/m^2 or more on dry weight coat basis imparts high water repellency to paper and excellent water resistance is obtained when coat weight is 11 g/m^2 and more (Cobb value: less than 2 g/m^2).

4. Comparing with T-EF102, T-EF103

Table 4 summarizes characteristics of coating emulsions with higher biomass content and biodegradability. T-EF104 exhibits superior moisture and water-resistance compared with T-EF102 and T-EF103.

On the other hand, T-EF102 and T-EF103 impart better moisture resistance compared to T-EF104 in the case of lower cost formulations utilizing inexpensive pigments as shown in Figure 5.

T-EF104 is recommended when high moisture and water resistance are required. Meanwhile, T-EF102 and 103 are preferable coating emulsions in the case of lower cost formulations utilizing pigments such as Kaolin.

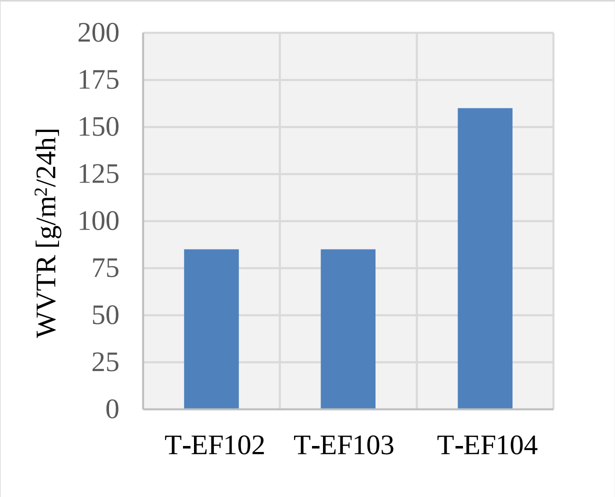


Figure 5. WVTR of paper coated with T-EF series and pigments.

<Evaluation conditions>

- T-EF series/pigment = 1/1 (solids ratio)
- Total dry coat weight 11 g/m^2
- Drying conditions 100℃-30 s
- 5% of a film-forming agent was added on the solid content of T-EF103

5. Conclusion

In this report, we discussed performances of "SEIKOTO series T-EF104", the coating emulsion with higher biomass content and superior biodegradability.

T-EF104 has five characteristics as below:

①Biomass content is more than 80% on dry weight basis.

②Degree of biodegradation (absolute value) is 70% or more.

③T-EF104 imparts superior moisture resistance to paper, which is equivalent to that of polyethylene laminated paper

④High water resistance.

⑤ In accordance with FDA21CFR § 176.170, § 176.180.

Currently, we are continuing our efforts to develop coatings with more superior moisture and water resistance.

Furthermore, we are focusing on the development of environmentally friendly coatings with other functions such as heat sealability and oil resistance.

In the global trend of trying to reduce plastic wastes, we will contribute to the future of global environment through the development of these functional agents.

<References >

1) Yasushi Fujiwara, *Japanese journal of paper technology*, **63** (7), 15 (2020)

2) Teruyuki Matsushima, *Japanese journal of paper technology*, **64** (7), 13 (2021)

Profile

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