Transactions of the Materials Research Society of Japan 25 [3] 697-700 (2000)

Characterization of New Composite made from *Chlorella* sp. and Polyethylene

Toshi Otsuki*, Masatada Yamashita*,
Zhang Farao**, Yuji Ikegami**, Masami Yoshitake**, Hiroshi Tsutao**,
Hiroshi Kabeya***, Ryoichi Kitagawa*** and Takahiro Hirotsu***

*Ishikawajima-Harima Heavy Industries Co., Ltd.
1, Shin-Nakahara-cho, Isogo-ku, Yokohama 235-8501, Japan
Tel 81-45-759-2162, Fax 81-45-759-2149
** Research Institute of Innovative Technology for the Earth (RITE)
2-8-11, Nishi-shinbashi, Minato-ku, Tokyo 105-0003, Japan
Tel 81-3-3503-5666, Fax 81-3-3503-4533
*** Shikoku National Industrial Research Institute, Agency of Industrial Science and Technology, MITI
2217-14, Hayashi-cho, Takamatsu 761-0395, Japan
Tel 81-878-69-3511, Fax 81-878-69-3550

The purpose of this study is to make ecofriendly building materials such as floor tiles using micro-algae and high density polyethylene (HDPE). *Chlorella* sp. (hereafter *chlorella*), a kind of green micro-algae, is being studied for fixing CO_2 because of its high growth rate compared with common plants. After *chlorella* has been grown in the photobioreactor to fix CO_2 emitted from the power plant etc., carbon should keep in *chlorella* bodies for a long period. While *chlorella* has been in the materials such as floor tiles and laminated plastic boards, CO_2 could not appear in the atmosphere again.

The mixture of *chlorella* powder and powdered HDPE was set in the mold frame and then pressed, heated simultaneously for a certain period to make rigid form using the thermocompressor. After being cooled down, the sample was removed from the frame, and its physical properties were examined.

Chlorella-HDPE composites showed the strength as same as commercial plasticized PVC compounds and it suggested to be applicable to the building materials.

Keywords: *Chlorella* sp., Polyethylene, Composite, Floor tile, CO_2 fixation

1. INTRODUCTION

Increasing of CO_2 in the atmosphere is so serious problem for mankind that many studies are implemented to reduce CO_2 emission. One is a biological CO_2 fixation using the photosynthetic function of micro-algae (*chlorella* in this case).

After CO_2 fixation a great amount of *chlorella* is produced. In order to utilize *chlorella* effectively, we made some plastic compounds with a thermoplastics such as polyethylene aiming at developing ecofriendly materials. Figure 1 showed our concept in the biological CO_2 fixation and utilization system.

2. EXPERIMENTAL

2.1 Materials

Dried *chlorella* powder (Yaeyama Ltd.) as the alternative of real photobioreactor products and HDPE pellet (7000F, MW$\fallingdotseq 2\times10^5$, Mitsui Chemicals, Inc.) were used in this study. The grain of *chlorella* which was constituted of cells (about 5×10^{-6}m in diameter) was a nearly spherical aggregate (about 5×10^{-5} m in average size) as SEM photograph showed its shape in Figure 2. HDPE had a density of 0.92 g/cm^3, it was used as pellet in the early stage and then used after shivered mechanically into spherical powder with a size of about 1 mm.

2.2 Molding methods

In case of using HDPE pellet, it needed to take a complicated method as shown in Figure 3(a), but after we succeeded in shivering the pellet to powder under the low temperature condition, the method was simplified as shown in Figure 3(b).

Basically the aluminum mold frame with inner size of 120x20x7mm was used for making samples which could be measured tensile strength. Thermocompressor (NSF-37, Shinto Metal Industries Ltd.) for molding was used with oil pressure apparatus and heating device.

The sample of mixture filled in the frame and molded under selected condition. When molding was finished, the frame was cooled to the room temperature and the sample was peeled off from the frame.

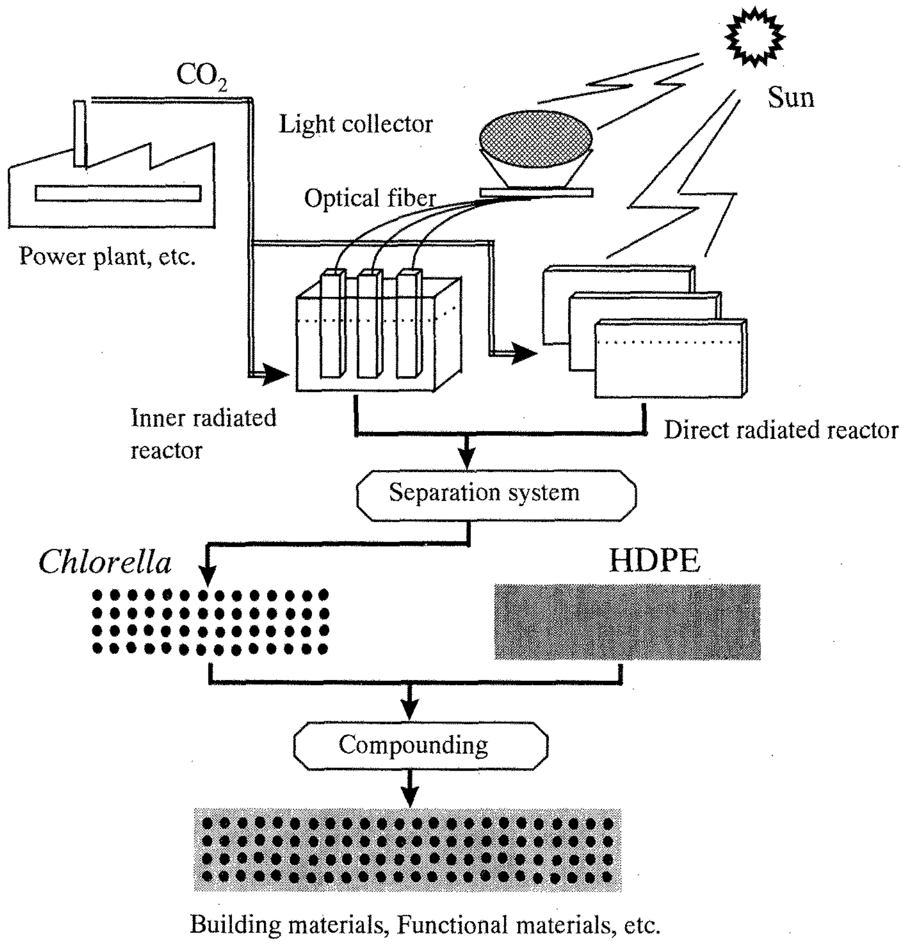

Fig.1 Concept of the biological CO_2 fixation and utilization system for ecofriendly materials

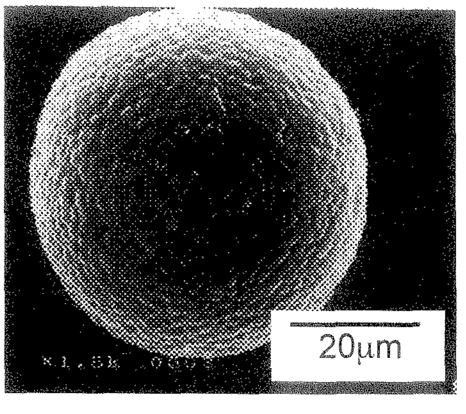

Fig.2 SEM photograph of *chlorella* aggregate grain

2.3 Measurement

The test piece (sheet sample) was conditioned at 20℃ and 65% relative humidity in the room for 24Hr before measuring tensile strength and elongation. Test piece for the measurement was made according to JIS method [1].

The tensile tester (AG-100A, Shimadzu Ltd.) was used to measure tensile strength and elongation at break in accordance with testing method for tensile properties of plastics (cross-head speed of 5 mm/min.).

Microstructure of the materials was observed by a Scanning Electron Microscope (S-2460N, Hitachi Ltd.).

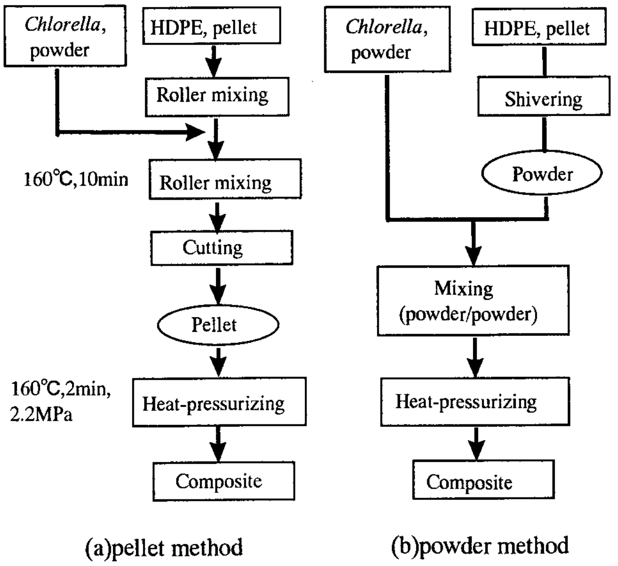

Fig.3 Chlorella-HDPE composite molding method, (a)pellet of HDPE, (b)powder of HDPE

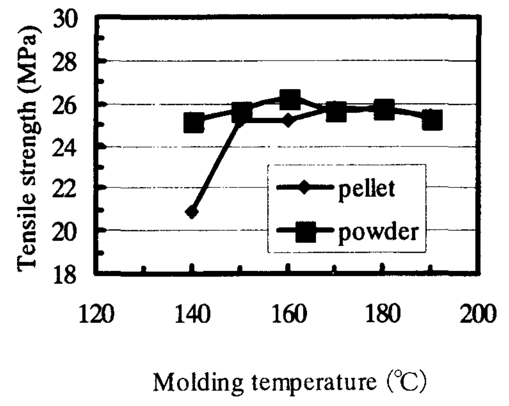

Fig.4 Effect of molding temperature on tensile strength
chlorella /HDPE=20/80, Pressure:2.2MPa, Time:2min.

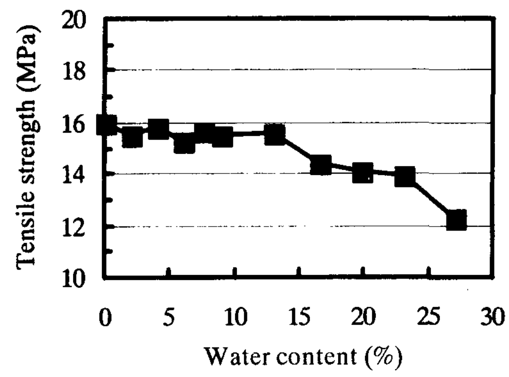

Fig.5 Effect of water content of *chlorella* on tensile strength
chlorella/HDPE=20/80, Pressure:2.2MPa, Temp.:160℃, Time:2min.

3. RESULTS AND DISCUSSION

3.1 Optimum molding condition of *chlorella*-HDPE composite

Effect of molding temperature, pressure, time, water content of *chlorella*, and *chlorella* /HDPE ratio in the mixture on the tensile strength were examined respectively.

Figure 4 showed the relation between molding temperature and tensile strength at the ratio of *chlorella*/HDPE=20/80 in weight, pressure of 2.2MPa, time of 2min in which both pellet and powder were tested. It was decided the suitable molding temperature was 160℃ and the powdered HDPE was preferable to the following works.

The effect of pressure on the strength was examined at *chlorella*/HDPE=20/80, 160℃, and 2min. The tensile strength decreased gradually with pressure increased, and the best pressure was 2.2MPa.

The effect of molding time on the strength was also examined at *chlorella*/HDPE=20/80, 160 ℃ , and 2.2MPa. The tensile strength did not change from 2min to 30 min. So it was decided the best molding time was 2min.

Figure 5 showed the effect of water content of *chlorella* on the strength at *chlorella*/HDPE=20/80, 160℃, 2.2MPa and 2min. It is important how content of water could be contained because the drying of wet *chlorella* take much energy. It is supposed to be water content of *chlorella* from the dewatering process could be 10~15 % in the system. As the tensile strength did not change up to 13 % of water content, it seemed that the permissible water content was 13%.

Figure 6 showed the effect of *chlorella*/HDPE ratio in the mixture on the strength at 160℃, 2.2MPa and 2min. The tensile strength decreased with the ratio of *chlorella* increased, and it crossed the line of the JIS standard [2] (15MPa of strength) at 20% of *chlorella*.

3.2 Evaluation for floor tile

The *chlorella*-HDPE composite as a floor tile was evaluated as shown in Table I.

The *chlorella*-HDPE composite can be good floor tile because the characteristics of the sample almost came up to the JIS standard [3].

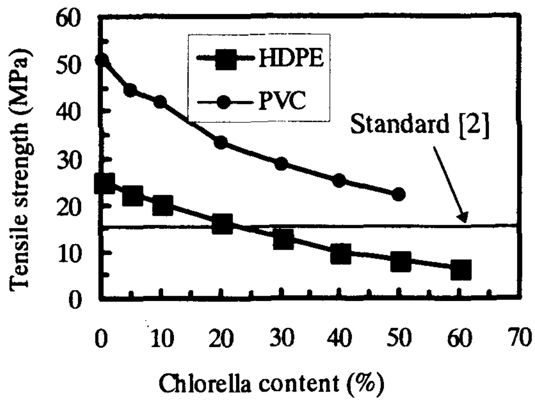

Fig.6 Effect of *chlorella* content in the mixture on tensile strength
HDPE Pressure:2.2MPa, Temp:160℃, Time:2min.
PVC Pressure:4.4MPa, Temp:180℃, Time:5min.

3.3 Improvement of tensile strength of the composite - chemical modification of HDPE

Figure 6 showed that the tensile strength of *chlorella*-HDPE was lower than that of *chlorella*-PVC. It seems that the adhesion between *chlorella* and HDPE is so weak because of the air gap around the *chlorella* grain which prevent the reaction of *chlorella* and HDPE.

As shown in Figure 2, the rough surface of the grain suggested the existence of many air gaps. So we modified HDPE with Maleic anhydride and Benzoyl peroxide to make its surface from hydrophobic to hydrophilic. *Chlorella* can be strongly combined with HDPE after chemical mondification and be filled up to 40% without a sharp drop of tensile strength [4].

4. CONCLUSION

We succeeded in making practicable sample of floor tile using *chlorella*-HDPE composite and suggested the tensile strength after HDPE chemical modification could be much higher. The effective process to treat a great amount of *chlorella* could be developed.

5. ACKNOWLEDGMENT

This work was performed under the management of Research Institute of Innovative Technology for the Earth (RITE) as a part of the Biological Fixation and Utilization Project supported by New Energy and Industrial Technology Development Organization (NEDO).

REFERENCES

[1] JIS K7113-1995, Testing method for tensile properties of plastics, Japan Standard Society
[2] JIS K6723-1995, Plasticized polyvinyl chloride compounds, Japan Standard Society
[3] JIS A5705-1992, Floorcovering-PVC, Japan Standard Society
[4] Farao Zhang, Hiroshi Kabeya, Ryouich Kitagawa, Takahiro Hirotsu, Masatada Yamashita, and Toshi Otsuki, Chem. Mater. 1999, 11, 1952-1956

Table I . Evaluation of the *chlorella*-HDPE composite as a floor tile described in JIS standard.

Items	Unit	Standard [3]	Sample
Rate of length change after heating	%	<0.2	0.09
Rate of length change after dipping water	%	<0.2	0.04
Rate of weight decrease after heating	%	<0.5	0.23
Dent at 20℃	mm	>0.25	0.19
Dent at 45℃	mm	<0.8	0.29
Rate of dent residual	%	<8.0	0.31

Molding condition : *chlorella*/HDPE=20/80, 160℃, 2.2Mpa, 2min,
Sample : 150×150×3mm

(Received December 16, 1999; Accepted March 30, 2000)