Cell Phones Using Bioplastic

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Abstract

NTT DoCoMo is investigating bioplastic reinforced with kenaf fiber for the manufacture of cell phone cases as a means of reducing the environmental impact of cell phone bodies. We describe the background of this project and the process from prototype development to commercial product introduction. We also discuss some technical points and future problems.

1. NTT DoCoMo's efforts for the environment

The problems of the global environment are not limited to within any country: they must be tackled on a worldwide basis. Under the Kyoto Protocol, which went into effect in February 2005, Japan is obligated to reduce emissions of greenhouse gases by 6% relative to levels in 1990. NTT DoCoMo is faced with an increasing trend in greenhouse gas emissions driven by investments in new facilities such as the building of the FOMA network. It has set an emissions target of 11.7 million tons of CO_2 for 2010, a reduction of at least 15% compared with predicted emissions. The use of cell phones can reduce the load on the environment through more efficient social activities, energy conservation, and other such means. We are also promoting the use of natural energy, such as solar energy, in place of fossil fuels which are non-renewable resources.

At the same time, we are participating in the planning of a national campaign called "Team Minus 6%" led by the Ministry of the Environment to achieve the targets of the Kyoto Protocol and we are promoting activities to prevent global warming. In offices, we are introducing CoolBiz and WarmBiz (short for cool and warm business), concepts that have been discussed in the news media in recent years. Our efforts include turning off lights in offices during non-working hours and raising thermostat settings in summer and lowering them in winter while encouraging the wearing of more sensible business clothes such as open-neck shirts in summer and sweaters in winter.

Concerning the use of resources, we also set specific annual targets to promote efficient use. Obvious measures include increasing the recycling rate of communication facilities, increasing the reuse of office machines, and reducing the use of paper in offices. Beyond these, however, we are also moving towards electronic billing, which lets customers confirm monthly charges via the Web or email, the use of AC adapters for FOMA terminals and other equipment, and the offering of common product options to both reduce the use of resources and improve usability for customers.

Another measure we have implemented is the recovery of old cell phones. This effort has been in progress since 1998. In 2001, the Mobile Recycling Network was established to allow cooperation among cell phone manufacturers to take back any cell phone, regardless of which company made it. Between 1998 and 2005, a total of 58.35 million phones were taken back. On the other hand, as shown in **Fig. 1**, there has been a declining trend in recent years and only 4.14 million were recovered in 2005. The reason for this is believed to be that more people are keeping old cell phones even after getting new ones. In the future, we will continue to aggressively conduct well-publicized activities for recovering unwanted cell phones and

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develop various measures that allow phones to be taken back at the time they become unwanted by the customer while protecting private information contained on them.

NTT DoCoMo also collects disused cell phone bodies, batteries, and chargers, as well as other components at DoCoMo shops and other recycling places. Recovered cell phones are destroyed in front of the customer's eyes with a proprietary device called the Keitai Punch as a private information protection assurance measure. With the cooperation of consumers, who are more aware of recycling issues these days, we are achieving 100% recycling of recovered phones through appropriate processing. Recycled copper, gold, and silver become resources and the residual material from the remanufacturing process (slag) is used as raw material for concrete and cement.

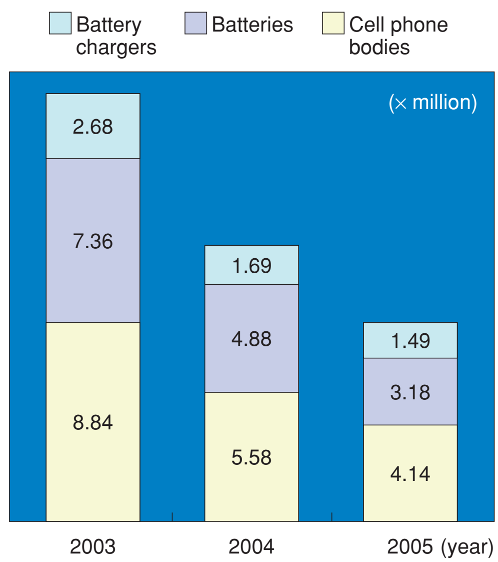

Fig. 1. Cell phones and accessories recovered by DoCoMo.

2. Study of cell phones from the environmental viewpoint

2.1 Project history

There are about 90 million cell phone subscribers in Japan. DoCoMo subscriptions reached 50 million in November 2005. Ten million new cell phones are manufactured each year, including model changes. Meanwhile, the world is being flooded with disused cell phones. Although DoCoMo has been recycling cell phones for some time, the number of returns is declining, as mentioned above. The main reason for this is thought to be that consumers are keeping old cell phones to use them for other purposes after getting new ones. Such secondary uses include using them for email and photograph storage, for data or address book backup, as a game machine, and as a digital camera (**Fig. 2**). The 3rd-generation FOMA phones can be used by inserting integrated circuit chips, so they can be reused within families and

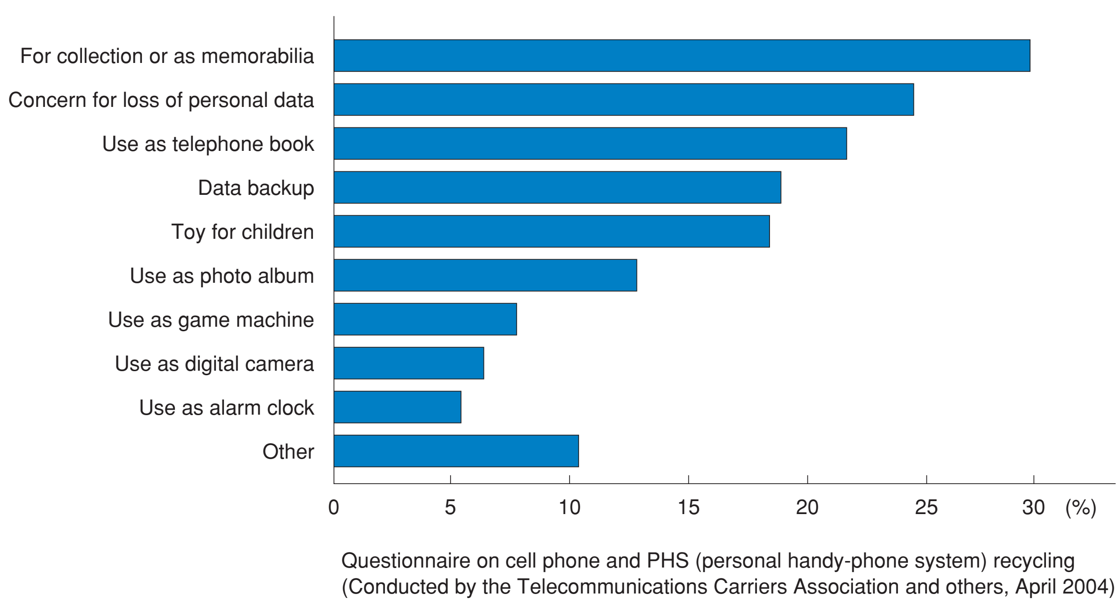

Fig. 2. Reasons for keeping cell phones rather than disposing of them (multiple replies allowed).

among friends and replaced only when they fail. Nevertheless, it remains a fact that some cell phones are just thrown away as garbage, which contributes to the load on the environment.

The "Contribute to Environmental Protection with Cell Phone Terminals" project began in July 2004. As a cell phone enterprise, we feel it is our duty to address this problem aggressively. Cell phone projects that have ecology as the theme have been studied from various aspects, but all of the proposals require time-consuming technological breakthroughs to implement. It is necessary to change such ways of thinking. One new focus of attention is the plastic case of the cell phone. We hit upon the idea that bioplastic, which is plastic derived from biological resources rather than fossil fuels, could be used in the cell phone manufacturing stage.

2.2 Development of a prototype and response to it

The environment was the theme of the Aichi World Expo 2005, so we produced prototype cell phones that use bioplastic for it. The first prototypes were based on the SO506iC, a model already available from Sony-Ericsson. Two eco-friendly models were made: a two-tone green model and a two-tone pink model (**Fig. 3**). Each case used about 22 grams of bioplastic to cover about 60% of the surface area. The media announcement was made on April 21, 2005, and the models were used as terminals for the Expo staff.

On June 9, 2005 an NEC test product that used kenaf fiber-reinforced bioplastic was announced (**Fig. 4**). It was also used at the Aichi Expo. That prototype is now being manufactured with about 26 grams of bioplastic covering about 70% of the surface area. The outside is brown and is finished so that the kenaf fibers can be seen, to suggest an association with ecology.

The reactions of the Expo staff and visitors were quite favorable. Support within DoCoMo also confirmed that taking the environment into account with cell phones is the right direction, so we have begun a full-scale investigation into bringing these products to market.

3. Toward commercialization

3.1 Advantages of kenaf-fiber-reinforced bioplastic

DoCoMo cell phones set high standards for robustness against impact in drop tests and resistance to heat. Polylactic acid, which is the raw material for bioplastic, is weak against thermal deformation and impact, so these characteristics must be improved

Based on the SO506iC terminal

Fig. 3. Prototype using bioplastic.

Based on the FOMA N900iS terminal

Fig. 4. FOMA prototype using kenaf-fiber-reinforced bioplastic.

Table 1. Comparison of physical properties [2].

Properties were measured after molding at 40°C for about 30 minutes (material has not crystallized), followed by four hours of annealing at 100°C to complete the crystallization

	Polylactic acid*3	Kenaf-reinforced polylactic acid for cell phones	Conventional petroleum plastic (PC+GF)	Conventional petroleum plastic (ABS)
Kenaf content (%)	0	>10	0	0
Plant-based content*1 (%)	100	90	0	0
Molding time*2 (s)	—	50–60	up to 30	up to 30
Impact strength (kJ/m^2)	4.4	9.6	10.5	20
Deflection temp. under load of 0.45 MPa (°C)	58	151	150	102
Bending modulus of elasticity (GPa)	4.5	4.9	3.1	2.45
Bending strength (MPa)	132	86	93	76
Tensile strength (MPa)	57	49	60	43
Total elongation (%)	4	6.4	22	29
Flammability*4	Equivalent to HB	Equivalent to HB	V2	HB
Specific weight (g/cm^2)	1.25	1.30	1.27	1.05

*1 The proportion of plant-based material content in the plastic, excluding inorganic components.
*2 The molding temperature for polylactic acid compounds for use in cell phones is 105°C (until crystallization of polylactic acid is completed). The molding temperature for petroleum plastics is 80°C.
*3 Unitika Telemark TE4000
*4 Flammability: HB and V2 are flame ratings specified by UL [3]

before the material can be used in commercial products. In the molding process, the molding of polylactic acid requires a high temperature and takes a long time to achieve crystallization. Therefore, for commercialization, the molding time must be greatly reduced to achieve efficient production. Furthermore, the material must conform to the UL specifications*1 concerning resistance to burning, release of halogens, and release of phosphorus. To achieve that conformity requires research on additives for improving the properties of bioplastic made from polylactic acid.

Throughout the world there is concern over the depletion of oil resources and global warming. Cell phone cases are usually made from plastic derived from petroleum, but we wondered whether bioplastic would work instead. In particular, the CO_2 emissions during case manufacture might be reduced by from two-thirds to one half compared with the petroleum plastics used in electronic devices. However, using petroleum products as additives to improve the properties of bioplastic would diminish the meaning of using plants as a resource, so there is a need to set standards regarding this.

*1 UL specifications: Specifications for resistance to burning as measured and specified by the Underwriters Laboratories [1].

To solve that problem by using materials derived from plant resources as additives, a group of researchers at NEC Fundamental and Environmental Research Laboratories led by Senior Researcher Iji, has turned its attention to the kenaf plant, which is a species of hibiscus. This group has developed a material whose characteristics are equal to or better than glass-fiber-reinforced ABS (acrylonitrile butadiene styrene), a common thermoplastic derived from petroleum (**Table 1**).

Kenaf fiber has long been used for making rope and paper, and more recently kenaf has begun to be used as animal feed. In kenaf, photosynthesis proceeds at least three times as fast as in other most other plants. In recent years, composites of polylactic acid and petroleum plastics have been studied, but application to electronic device cases made by injection molding has not been investigated. We have focused on this material and are developing it for use in cell phones (**Fig. 5**).

3.2 Commercial viability of the N701iECO

The cell phone with a kenaf-reinforced bioplastic case is being sold as the N701iECO. To avoid the extra cost involved in developing a new terminal, we decided to select a model that was already on sale, the N701i and simply replace the case. The N701iECO

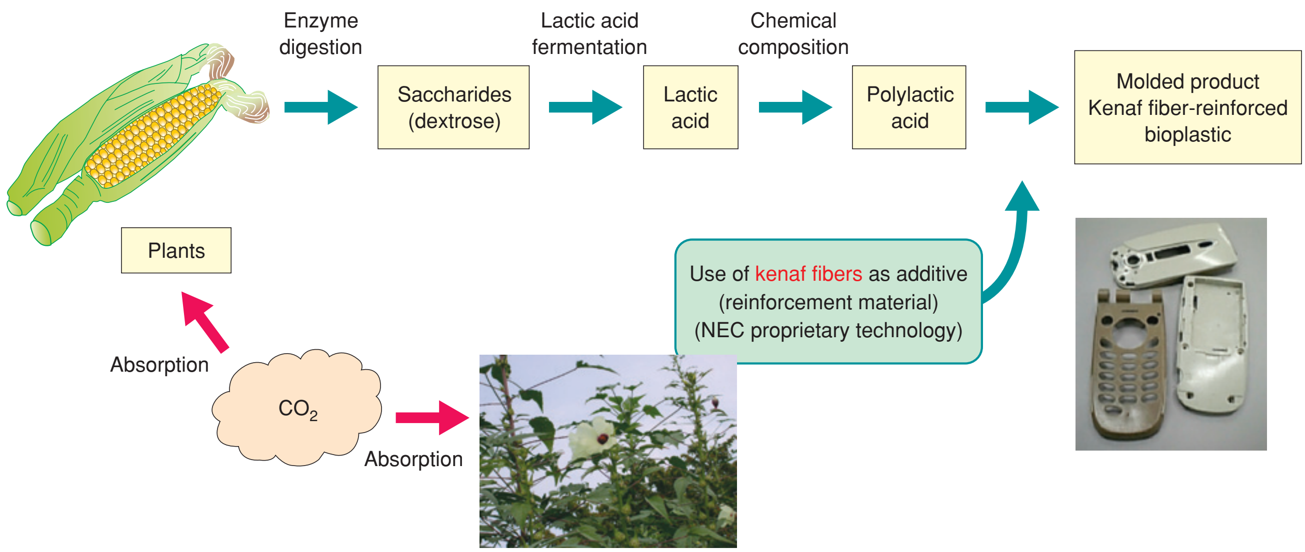

Fig. 5. Process of making kenaf-fiber-reinforced bioplastic.

Fig. 6. N701iECO.

has a rectangular form with rounded edges, making it both graceful and stylish (**Fig. 6**). This terminal comes with a Styleplus jacket, which can be used to replace the default removable front cover piece (around the liquid crystal display (LCD)). Sales to date have been good.

In the planning stage for the terminal, we decided that we wanted the customer to feel an awareness of ecology, so we also made some changes in the internal content, such as the menu screen for initial settings and received mail and stored images.

Particular aspects of interest to the user are the feel and color of the case. To give a true feeling of the fact that kenaf is used in the material, we blended the color into the material so that the fibers remain visible, rather than painting the entire case. Targeting women who are attuned to the LOHAS (lifestyles of health and sustainability) concept, we chose pink for the color. Breaking away from the stereotype that ecology is associated with green, we took the approach that ecology is something to be enjoyed. However, because this is a new material with which we had no expertise, we encountered many difficulties. We wanted it to be evident that the terminal made use of kenaf as a material, yet we wanted to avoid giving the product a cheap appearance. For that reason, only the sides were painted silver. Nevertheless, differences in molding characteristics from the conventional material created problems during painting.

3.3 Implementation of environmental policies

Considering the possible link between selling the N701iECO and dealing with social issues, we worked together with DoCoMo's Social Environment Promotion Department to carry out the plan. Specifically, we will apply 1% of the billing charges paid by customers who buy this eco-model terminal to fund environmental protection activities from January 2007 to March 2008. Specific descriptions of activities were not set in the planning stage, but they will reflect the social needs of the implementation period. These activities differ from the usual environmental activities of DoCoMo; they establish a new framework.

We would like to give persons who are considering purchasing this terminal a deeper understanding of ecology. Accordingly, we set up special sites called Eco-sites and an email magazine in conjunction with the selling of the terminals. The Eco-sites will publicize the progress of the 1% policy described above. The email magazine will present articles by various people who are putting ecological policy into practice and other articles that keep up with similar efforts outside Japan. Another activity is discovery tours of various natural areas all around Japan that give participants an ecological experience.

4. Future challenges

4.1 Increasing product viability

The main issue for future work is the problem of moldability. To reduce the development cost of the product itself, we chose to use terminals based on existing products initially, but there were significant differences in the molding of the eco-material, which created difficulties in using the same molds as for the conventional products. Because the base terminal supports Styleplus, the eco-model was also designed to support Styleplus jackets. However, the eco-model only accepts new jackets and the use of existing Styleplus jackets is not supported (the thickness is slightly different). Consequently, although it does have the same feature of interchangeable jackets, we chose not to sell it in the same way as existing Styleplus terminals (customers can buy extra jackets later), but to include an additional jacket in the box. In retrospect, we think that we should have made special molds from the beginning.

Price is also a problem. While there are a number of factors that increase the price, research on reducing the molding time to the level of conventional materials is particularly necessary.

4.2 Expansion to other types of devices

In future we will cooperate with other manufactures to extend this technique to other types of devices. Different manufacturers have different approaches to dealing with ecology, so we see a need to clarify standards for eco-terminals. We are following the progress of various companies, and other manufacturers may take up this challenge in the future. If high standards are set, those manufacturers will never be able to market products, so it is necessary to proceed flexibly with a cooperative system that takes into account the circumstances of all companies.

4.3 Other challenges

One example of the various approaches we are investigating is a cell phone equipped with a solar panel. These phones are being demonstrated at IT (information technology) exhibitions in Japan. At exhibitions in 2005, the charging rate was inadequate: a one-hour charge on a clear day enabled only one minute of talking time. However, improvements in panel efficiency and a larger panel area have led to the current rate of 30 minutes of charging time for five minutes of talking time. We think that this is acceptable for practical use. Although this is still the prototype stage, we believe that further improvements in battery charging efficiency and solutions to various problems in achieving commercialization will lead to a marketable product. We intend to continue making ecological contributions by developing cell phones with concern for the environment and by planning and developing a terminal that has an easy-to-use universal design and other features.

References

[1] http://www.ul.com/
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[3] http://www.ul.com/plastics/flame.html

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