THE PRESENT STATUS OF COMMERCIAL PHOTODEGRADABLE PLASTICS

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I. *Introduction*

In Japan more than 5 million tons of plastics are being produced every year. More than 2 millions of this (or about 40 per cent) are discharged as waste plastics.

The enormous increase of plastic output naturally has brought about an increase in plastic wastes, which are presenting a serious problem in the industries concerned. The amount of waste plastics is tending to increase, making it urgently necessary to recover these wastes or expand disposal capacity.

At present, with more waste plastics being generated than can be disposed of, a major pollution problem is occurring. Naturally, solving this question——the recovery and disposal of waste plastics——is one of the essential requisites to the prevention of environmental pollution. The solution of pollution problems related to plastics is an essential precondition for the further development of the plastics industry.

Under such circumstances, the development of plastics that can be easily disposed of, and the expansion of demand for such plastics are some of the immediate aims of plastics producers.

Against this background, moves are being pushed vigorously to develop new types of plastics including plastics that can be decomposed by sunlight (ultraviolet rays) and those which can be broken down through bacterial action. Many studies of photodegradable plastics are now being undertaken, and some of the findings have lately been put to practical use.

In this paper I will describe the present status of commercial photodegradable plastics.

II. *The Product Developed by the Agency of Industrial Science & Technology*[1]

The Agency of Industrial Science & Technology has developed a process for producing stabilized photodegradable plastics which do not decompose during a certain period of use. Synthetic resins contain ultraviolet ray absorbents and antioxidants which prevent resin deterioration due to exposure to ultraviolet rays, and oxidation in the heating and molding stages. Polyolefins such as polyethylene and polypropylene are normally unstable when exposed to ultraviolet rays and are therefore liable to oxidize. Anti-deterio-

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[1] *Chem. Economy Eng. Rev.*, 5 No. 1, (1973) p. 58.

ration agents used to prevent this, however, melt at high temperatures or extinguish themselves over an extended period of use because they are not chemically bonded with the resin. Moreover, there are qualitative changes due to oil exuding on the surface of plastics, thus changing the contents of a packaged product. These additives also present pollution problems.

If these agents are copolymerized with the resin, they will disperse within the polymer uniformly. This will permanently preclude the possibility of such plastics additives melting out of the product. Esso Standard Oil, for example, recently developed a process for copolymerizing plastics anti-deterioration additives with olefin derivatives such as polypropylene. This process is practiced under reduced pressure in the presence of Ziegler-Natta catalysts.

The Agency, however, has discovered that the ordinary radical polymerization process also makes it possible to copolymerize additives in the presence of carbon-radical catalysts. It had been believed heretofore that the copolymerization of anti-deterioration additives with resins was impossible. The method developed by the Agency however, makes it possible to form strong polymeric bonds between resins and additives simply by mixing carbon-radical catalysts and polymerizable additives. The process can be applied also to the radical polymerization of butadiene and ethylene rubber, for example.

It is also possible to control the quantity of additives to be bonded with the resin. If a predetermined amount of such agents is copolymerized with a photodegradable polymer the copolymer will remain chemically stable for a certain period of use but after this period is over, it will rapidly decompose. Such a photodegradable copolymer can also be used for dental material. Some of the additives which retard the polymerization velosity at the time of molding are toxic. Their toxicity will become a real problem if such additives melt out. However, if these can be copolymerized with polymers, plastic teeth of great sanitary value will be developed.

III. *The Product Developed by Japan Synthetic Rubber (JSR)*[2]

JSR, which initiated development work in this field eight years ago, developed a new process for photodegradable polybutadiene using a Ziegler catalyst which it developed. The product developed by JSR easily decomposes on exposure to ultraviolet rays such as sunlight. Crosslinkage reaction occurs in the polybutadiene, causing cracks and disintegration of the material into fragments. The period of time needed to cause disintegration of the polymer can be controlled at from one week to one year by adjusting the amount of anti-oxidant and ultraviolet rays absorber added in the polymerization stage.

In general, polybutadiene is known as a polymer in which 1, 4-cis butadiene is linearly polymerized. Its main use is for automobile tires. The polymer developed by JSR however, is a synthetic polybutadiene which contains more than 90% 1, 2 links. It is a special thermoplastic resin. Polymer of this type has already been commercially produced in liquid form.

This is the first time, however, that solid polybutadiene has been developed of which the degree of crystallization can be freely changed above or below the 25 per cents level.

[2] *Chem. Economy Eng. Rev.*, 4 No. 1, (1972) p. 52; *ibid.* 4, No. 3, (1972) p. 37.

This degree can be controlled over a wide range, from 0 per cent to 50 per cent, according to applications. Among applications expected to be developed for this type of polybutadiene are shrinkable film, stretch film, masking film, packing film, one-way containers (blow bottles) and rubber products.

The polybutadiene developed by JSR also has the following features:

(i) It exhibits properties common to both rubber and plastics.

(ii) It is highly miscible with polyolefin resins.

(iii) It is suited to all molding methods (inflations, extrusion, blow, and injection).

In addition, the product showed different characteristics from conventional types of plastics. Specifically, it has excellent elasticity and transparency and a unique softness of feel. It also has light tear, ruptive strength and good gas permeability.

JSR has filed patent applications on total of 54 items covering the whole range of the new process from production to application.

IV. *The Product Developed by the Scott Process*[3]

Dr. G. Scott (Birmingham Univ.) discovered a polymer which can be decomposed by ultraviolet light, through addition of a metallic dithiocarbamate to the polymer. This additive is a nontoxic white powder, and can be mixed with polyolefin, polystyrene and polyvinylchloride by the Master-Buth Process.

The plastic containing Scott's additives is shown to decompose on exposure to the weather, with the result that cracks develop in the polymer, leading to disintegration of the whole polymer structure. These plastics do not contaminate through degradation. The rate of degradation can be controlled at from a few months to some years by adjusting the amount of additive and the exposure time of ultraviolet light.

The Amerplast Co. in Finland make shopping bag of polyethylene film under Scott's license. This bag is photodegradized in nine months. Recently a large scale practical test of low density polyethylene film which involves 0.01 per cent of ferric dibutyl and dithiocarbamate was carried out on a banana plantation in Israel. The measurement of tearing strength confirms that this film is completely degradable in six weeks. The film was used for fertilizer packaging, detergent packing and agricultural film.

V. *The Product Developed A.B. Akerland & Ransing Co.*[3,4]

The A.B. Akerland & Ransing Co. in Sweden has developed a new photodegradable plastic additive. This additive is photodegraded by ultraviolet light in from six to eight weeks, and is used in polyolefin and polystylene.

Once the degradation is started, the reaction progresses in whole parts of the plastic with no light. This process can be used not only for transparent film but also for colored film.

[3] *Modern Plastics International*, May (1972) p. 52; *Chemical Week* Dec. 12 (1973) p. 42.

[4] *Chemical Eng.* Oct. 15 (1973) p. 68.

VI. *ESLEN*[3,4]

In 1971, the Sekisui Plastic Co. began production of a new photodegradable polystylene using a technique developed by the Sekisui Chemical Co. This plastic is commercially called "ESLEN". At present the output of ESLEN is seven thousand tons per year, and product is used for agricultural film, throwaway lunch boxes, trays, egg cartons, etc.

VII. *The Product of the Biodegradable Plastic Co.*

The Biodegradable Plastic Co. of the U.S.A. (Boise, Idaho) sells a photodegradable plastic which is prepared with polystylene and additives. This plastic meets the FDA standard for food packing, and is used for portable disposable food containers by the Thompson International Corp. (Phoenix, Ariz.). It decomposes in from one to three months in the open air, and then secondary decomposition is carried out by living organisms in the soil or atmosphere.

VIII. *ECOLAN*[3,4]

A new photodegradable plastic called "ECOLAN" has been developed by the Princeton Chemical Research, Inc. (Princeton, N.J.). This plastic was prepared with polybutain-1 and photodegradable additives, and has photodegradable and biodegradable properties. ECOLAN is used for agricultural film.

IX. *ECOLYTE*[3]

Dr. James Guillet (Toronto Univ.) has developed a new photodegradable process by copolymerization of the photosensitive additive and polymer. This process has been put into commercial use by the Van Leer-Eco Plastics Ltd. which was established jointly by the Eco-Plastic Ltd. in Canada and the Royal Packaging Industries Van Leer in the Netherlands.

This plastic (ECOLYTE) is produced by polymerization of the monomer that contains the photosensitive keton radical, and is used as a photodegradable packing film. ECOLYTE was approved by the Canadian Health Center, because it presents no pollution problem. On the other hand, it is comparatively higher in cost than methods using an additive, because of the complex denaturation method which it uses.

X. *Summary*

In Japan, many techniques for the reuse of plastic wastes are already at a stage of practical use. Yet, a long time will be required before full industrialization of these techniques can be achieved because an economical and efficient resource recovery system has not yet been established.

Even if a plastics recovery system is established in the future, natural photodegradability would still be a valuable property for wastes that are left out of such a system.

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