

INTELLIGENT AND SMART PACKAGING WITH PLASTICS

The packaging scenario and requirement world over is changing fast. This is not only with regard to materials, forms, systems and machinery, but also legal aspects closely linked with environmental equilibrium and maintenance as well. Among these developments, the “Packaging of Future” is expected to do more than just contain and protect.

Imagine a packaged product which could interact with you, attracting your attention in a store by talking to you and letting you know if it is still fresh inside, allowing you to buy it without standing in the line for twenty minutes; ensuring you have cooked it to perfection!

Packages with moving colour advertisements and sound. Many new applications are already evident and are set to become increasingly common over next few years.

What is Intelligent Packaging?

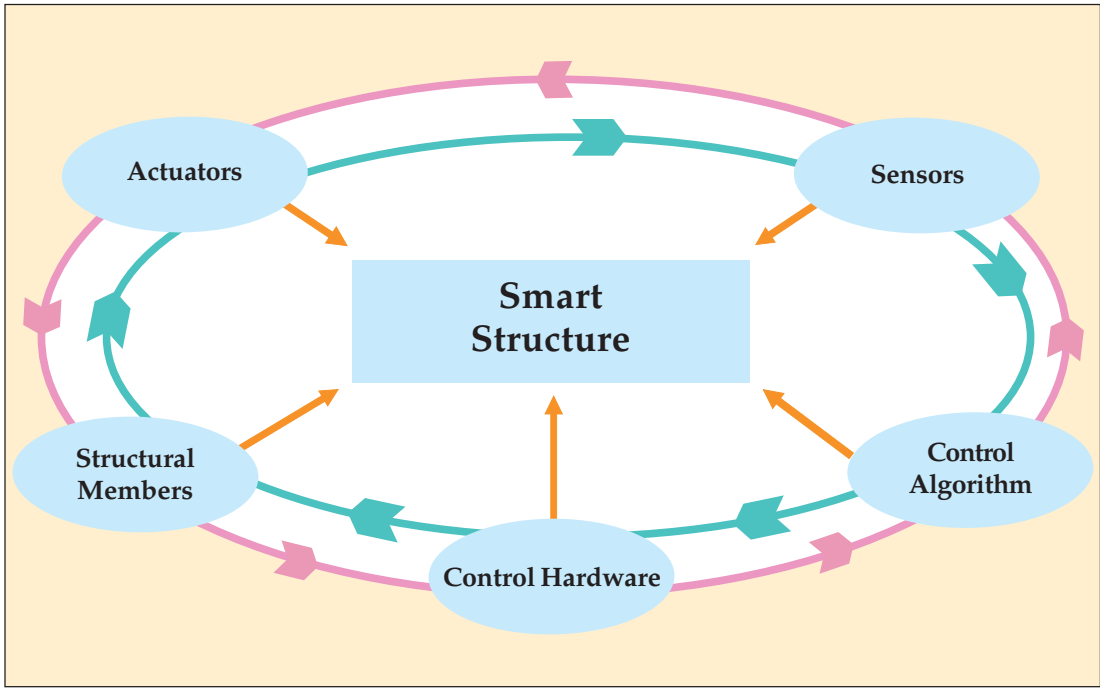
With the new role and the use of synonymous adjectives like ‘smart’, intelligent’, and ‘active’ to describe this role, it is worthwhile to trace the origin of smart technology.

Like all other great innovations, this technology also originated from the needs of the military. Around 1980, researchers mainly in US, began to examine the potential of combining advanced materials and sensors with powerful and compact computers to produce futuristic systems able to monitor their operating environment in real time and respond appropriately. For those of us who are aware of the use of ‘smart bombs’ during Gulf wars and now in Iraq, the word is not new. Infact, the technology in one form or the other is being used in transportation, building, civil infrastructure, biomedical, sports and leisure, power generation etc. and is slowly finding greater application in packaging. Intelligent and smart packaging covers a huge spectrum of radically fast developing technologies and applications.

Intelligent Features

An inherent ability to gather information on its operating environment or history, to process that information in order to draw intelligent inferences from it and to act on those inferences by changing its characteristics in an advantageous manner constitutes intelligent packaging. In doing so, five important elements are highlighted in Figure 1 with the relationship shown. The key aspect of a truly ‘smart’ system is that the response to any stimulus should be intelligent, as opposed to rigidly predetermined ‘dumb’ system.

Figure 1: Interacting Elements of Smart Technology



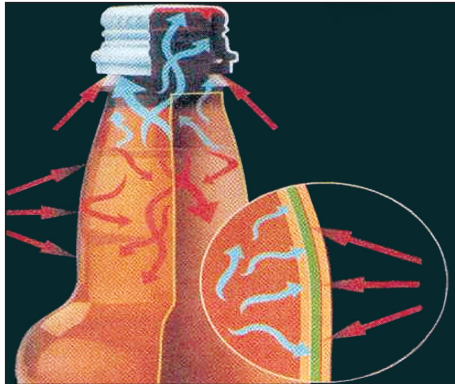
In a smart system, 'Sensors' collect the information on the changes in condition, history or the environment. The 'Control Algorithm' will define the way the sensed changed is to be corrected as desired and the 'hardware' will support the commands generated by the algorithm software. Finally, the 'actuators' will work in such a way so as to bring in the desired correction. The 'structure' incorporates arrays of sensors and actuators in it and together with control hardware allows it to perform the primary function.

A truly 'intelligent package' is likely to be produced in a way that it monitors the consumption of the contents packed within and orders just in time with the best buy, and ensures the disposal in the most optimum way. It also offers the consumer, convenience by way of information on the quality of contents, its use etc. While doing all this, through the package structures it also ensures optimum performance of the contents as designed. However, with the availability of Plastics and their 'tailor making properties' many exciting possibilities have emerged.

Plastics – Active Packaging Opportunities for Food Applications

Thanks to the latest developments in plastic-chemistry, by binding oxygen, condensation of carbon dioxide, or by incorporating anti-microbial substances via 'smart foils', packaged foodstuffs are able to retain a maximum level of quality and freshness. With respect to food, primarily active features refer to a method of slowing down quality-impairing process within

the package and these have been commercially employed as:



Oxygen Scavenger/EVOH

Oxygen Scavenging

The best known and most widely used active packaging technologies for food today are those engineered to remove oxygen from the interior package-environment. Oxygen scavengers reduce oxidative effects in the contained product. **The incorporation of non-iron based oxygen removers directly into plastic package materials has propelled the notion of controlling food deteriorative vectors through packaging as the food preservation medium.** As a matter of fact, the last decade's co-injection stretch blow moulding of polyester and nylon MXD6 has now been overtaken (perhaps by reverting to original "elementary" 1980's

CMB Oxbar-type technology) by monolayer plastic structures from Amcor Polyester, Mississauga, Ontario, Canada.

Diene Types: Amosorb DFC (Direct Food Contact, formerly Amoco Amosorb 3000) from BP Chemical is a polybutadiene/polyester oxygen scavenger engineered to blend with bottle-grade polyester to produce a monolayer, with a virtually zero-oxygen-permeation plastic. If applied in small but still effective concentrations, the blend remains transparent. Because the oxygen scavenging is initiated immediately after fabrication, logistics for empty bottles will be challenging. Such bottles, made by Amcor, have little carbon dioxide barrier and so are not (yet) suitable for carbonated beverages. Amcor has commercialised the structure for 16-oz plastic bottles for fruit beverages in the United States. StarShield is a 3-layer construction of PET/scavenger-passive barrier/PET. The middle layer features the firm's Oxbar O₂ scavenger, which relies on a cobalt salt to catalyze the reaction of O₂ with the barrier resin, MXD6 grade nylon. This layer typically accounts for 5% of the bottle's thickness.

The bottles are recyclable, as the Oxbar layer readily separates during hot caustic washing.

Moisture Control

In a package, moisture control is usually targeted at either very dry food or at respiring, wet, and consequently high relative humidity, fresh/minimally processed produce. To-date, silica gel has been the moisture absorbent of choice for dry food, but incorporated into sachets or other forms placed within the package. **Perhaps, the most intriguing moisture controllers are those in which the desiccants are incorporated into the plastic package itself.** Blending the desiccant into the plastic structure separates the drying agent by the polymer that is usually a moisture barrier, thus restricting the passage of free moisture to the absorber. These engineering technologies have a potential application to maintain dry conditions



Monolayer Bottles

within packages of very low water activity food, i.e. dry food with water activity of 0.7 and below. CSP Technologies, Auburn, Ala., has commercialised package structures capable of removing moisture from both closed and opened/re-closed packages. Microscopic inter-connected transmitting channels are generated throughout the solid polymer structure of the package wall, especially at the inner surfaces. The channels provide pathways to permit diffusion of water molecules through the plastic structure so that they may be captured by the desiccant particles within the matrix. **The plastic material with the active component can be physically bonded or co-injected, co-extruded or co-extrusion blow moulded with other materials into multi-phase plastic package structures.**

Ethylene Removal

Ethylene is a growth hormone that facilitates in sprouting and faster ripening. Some of the PE/LDPE plastic films with finely ground calcium carbonate or crysburite ceramic have been tried by Japanese companies, for ethylene removal from fresh food packaging.

Antimicrobial Agents

When antimicrobial agents are incorporated into a polymer, the material limits or prevents microbial growth. This application could be used for food effectively not only in the form of films but also containers and utensils. The mathematical model for the diffusion has to be established to explain the release profile of an active substance from an antimicrobial packaging material into a food product. This will permit the estimation of accurate concentration patterns, provide the diffusion profile of real food packaging systems, and predict the period in which the antimicrobial concentration will be maintained above the critical inhibitory concentration in the packaged food.

Inherently Antimicrobial Plastics

Some polymers display inherent antimicrobial properties, such as chitosans and nylons whose surface amine concentration is increased by ultraviolet radiation activation.

Aroma Emission

Controlled release of desirable aromas from plastic package materials has been suggested as a means to enhance the flavour perception of contained food on opening and closing shortly thereafter. **Flavours diffuse into or permeate through plastic by virtue of the free volume and porosity of the polymer.** Plastic materials contain unoccupied space or free volume within their polymer matrix. As the free volume increases, the mobility of the polymer chain segments increases, and the diffusion of small volatile molecules increases. **Some aromas are available for direct use in PE, PP, EVA, Nylon, Ionomer, PET and PVC. The processes in which these can be inducted are injection moulding, film blowing and casting, sheet extrusion, foaming etc.**

Other active packaging systems using plastic that might become available commercially are:

- Antioxidant-releasing films
- Flavour-absorbing and flavour-emitting systems
- Anti-fogging films
- Oxygen emitters
- Light-blocking/regulating compounds

Other Smart Packaging Solutions Using Plastics

Currently, a few commercial packaging systems are available which are based on Active Packaging. Availability of plastic package borne sensors to sense temperature, gas phase, liquid and solute etc. and the new polymer (plastic) materials with modern printing technologies have opened the door to low cost electronics thereby resulting in some commercial applications.

- Plastic containers for pouring syrup for pancakes can be purchased in the US that are labeled with a thermochromic ink dot to indicate that the syrup is at the right temperature following microwave heating.
- In the US, breathable polymer films are already in commercial use for fresh cut vegetables and fruits. These are acrylic side-chain crystallisable polymers tailored to change phase reversibly at various temperatures from 0-68°C. As the side chain components melt, gas permeation increases dramatically, and by further tailoring the package and materials of construction, it is possible to fine tune the carbon dioxide to oxygen permeation ratios for particular products. The final package is smart because it automatically regulates oxygen ingress and carbon dioxide egress by transpiration according to the prevailing temperature. In this way, an optimum atmosphere is maintained around the product during storage and distribution, extending freshness and allowing shipping of higher quality products to the consumer.
- A colour indicating tag that is attached as a small adhesive label to the outside of the packaging film, which monitors the freshness of seafood products. A barb on the backside of the tag penetrates the packaging film and allows the passage of volatile amines, generated by spoilage of the seafood.
- Sorbate-releasing LDPE film for cheese has the potential to extend the shelf-life of perishable food while at the same time improving their quality by reducing the need for additives and preservatives.
- Data logging during transit is something similar to black box in an aircraft. This is already in use for monitoring the travel and temperature history of frozen food in refrigerated container over its travel distance through the use of accelerometers and temperature sensors. This is necessary in communicating product information, product history or condition to the consumer.
- Bacteria detecting and time-temperature indicators for demonstrating the freshness, product integrity, quality and safety etc.
- Fun and information features such as sound and image interactivity to enhance brand packaging.
- Consumer interactivity and error prevention-dosage devices, refrigerator recording, auto cooking in the microwave, disposable timers on the hair-dye etc.
- Anti-theft and stock control benefits within the supply chain through EAS and low cost RFID.
- Interactive security such as electronic patients compliance monitoring and assistance, and anti-counterfeiting devices.

- Plastic electronics, the next generation new polymer (plastic) materials and printing technologies open the door to new technologies. A new paradigm well matched to the requirements of electronic labels and packaging.

Case Study

In a recent study conducted at Indian Institute of Packaging on packaging of Mawa(Khoa), it was deduced that the shelf-life can be increased from 15 days to 21 days (when stored under refrigeration) by adopting Active Packaging (For example, the use of oxygen scavengers and desiccant inside the package). In the above experiment, the product was vacuum packed in the following flexible packaging materials:

- Polyester / met. Polyester / Polyethylene laminate
- Polyester / 5 layer Nylon based co-extruded film
- Polyester / Al foil / Polyethylene laminate
- Polyester / 5 layered co-extruded film having EVOH

Conclusion

Smart packaging-in some aspects-will totally transform the retail environment and the products we purchase as consumers in the future. Several companies in Japan have set up smart packaging divisions. However, there are many barriers to full-scale implementation of intelligent technologies-namely-high cost, tentative consumer acceptance, getting supply chain partners to work together harmoniously, as well as some complex legislative and standard issues. To this, another question which is raised often is, can package materials and structures be truly active-sensing and reacting in a positive manner while remaining benign to other properties? Active packaging is still in the elementary stage. It is a challenge to plastic scientists and technologists is to present the materials so that the packaging professionals give the shape to their future dreams. One can, however, say that plastics till date have been of able to offer more “Smart Packaging” solutions as compared to other packaging materials.