Barrier Design for the future – two steps forward one step back.

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Abstract

Packaging regularly comes under the spotlight for both positive and negative reasons. I think that most people would agree that wasting less food because of being able to keep it longer is one of the positives. However there is a growing voice that argues that packaging should be minimised to reduce the carbon footprint as well as reducing the quantity of material ending up as landfill.

Packaging technology continues to develop and the number of different options in constructing the packaging continues to increase. This does not make the decisions for what packaging material to use any easier.

In this paper I will try to highlight some of the packaging problems that have been addressed in recent times and show how some of the changes have solved one problem but may have created another one.

Introduction

A core performance that is expected of many packaging materials is that of barrier. This can include a barrier performance for any or all of moisture, oxygen, light, micro-organisms, chemical taint, as well as odours. When this barrier performance is coupled to other attributes, such as being able to retort the product in the package, there is an opportunity to displace existing packaging such as tin cans by flexible pouches. In Europe this is one of the fastest growing market segments and the US shows signs of following this trend.

In existing packages there is often a requirement to save costs by reducing the material costs. Often the solution to this is simply to use a thinner gauge of polymer. If a significant part of the barrier performance comes from the polymer this is more of a problem but if the polymer has been coated such as by a vacuum metallized layer then most of the barrier performance comes from the coating. In the case of the coating providing the bulk of the barrier properties it becomes easier to use a thinner gauge of polymer and still maintain the same barrier performance. Where the polymer contributes a significant part of the barrier performance then it may require a change in the polymer to maintain the barrier performance but allow for a thinner gauge to be used. Depending on the composition of the package there could be several layers of laminate and each could end up as being a different polymer. In this way we solve one problem, which is that of cost, but we may have produced a new problem which is that of having a multi-polymer laminate that can no longer be re-cycled easily or even at all.

Technology is improving and this can also make the choice more difficult. We now have multi-layer, multi-polymer extruders that allow the production of 3, 5, 7,11,….. layer structures. The fact that this can be done at the point of extrusion makes it cheaper than by post lamination processes and allows for thinner individual layers. Investment into one of these systems is not cheap and so once it is running it needs to produce very large quantities of material to make the process cost effective. Thus owners of such systems may be tempted to transfer products, that otherwise would not use the multi-layer product, simply to maximise the productivity of the machine and in so doing minimise costs. This could mean that packages that previously might have been able to be re-cycled may be changed to a package that cannot be re-cycled.

One of the other benefits of co-extrusion is that the thicker centre layer may be of re-cycled polymer that has a thinner skin of virgin polymer to allow it to be in contact with food. Hence co-extrusion can be both the villain and the hero in responsible environmental packaging.

Materials choice.

Ideally we want a single material that provides us with all the attributes we require. In the real world this rarely if ever happens and so we have to look at using combinations of materials to deliver the attributes. Some of the simplest packaging materials are a single polymer substrate with a coating added. The coating may be another polymer, a lacquer or an ink and may do several things such as improve the surface durability, improve the barrier performance, block out the light, add product information or a combination of these. Already we have a variety of options both on the material type of the substrate but also for the material type for the coating and coating deposition technology type. The coating can be printed or coated and the coating can be by a variety of techniques ranging from atmospheric coatings to vacuum deposited coatings.

Once we get beyond this two layer system the options become greater still. For every additional layer there is the choice of material and process to add the material. Over and above the coating techniques we also have co-extrusion and lamination.

The materials range from organics to inorganics as well as mixtures of the two. Glass is a perfect gas and moisture barrier and so a glass coating on a polymer should give a perfect barrier. Unfortunately when glass is deposited in very thin layers there is not sufficient perfection in the coating and so there are diffusion routes through the glass and so the barrier is less good than often required. This same problem occurs with the opaque aluminium metallized coatings too. Hence neither is usually found as simple substrate plus glass or metal coating but have other materials added too. The additions may be in the form of a protective lacquer to prevent damage to the thin inorganic layer or it may be a laminate that provides both protection of the inorganic but also some other required attributes such as a heat sealing surface.

With the number of options available for the type of substrate which can be plain or filled and then the number of options for different layers and materials there very rapidly becomes hundreds of variants to the content of the final package. This is a cause for concern as in the future the legislation on packaging materials is likely to become more onerous with mixed polymer packages likely to become banned in some countries as they aim to maximise re-cycling.

Examples of package changes.

Aluminium foil was a material that was targeted in Germany as being a high energy consumption material that was not essential to most packaging and a problem material as it was being disposed of into landfill. There was a concern that all aluminium would be banned for packaging but vacuum metallized films were argued as being much more energy efficient and more easily degraded in landfill and became an accepted replacement material to foil.

It has been common that the simple comparison has been made between the aluminium thickness in highlighting the reduction in aluminium use and hence the energy saving. However now that energy in the form of the carbon footprint is being looked at more closely it becomes apparent that the energy savings are much less that everyone expects. The thick foil has a stiffness that a thin metallized polymer does not have. Therefore to directly replace the thick foil the thin metallized polymer has to be laminated to a thick polymer to bring the stiffness back to a similar level as the original foil. Thus for a deep foil tray that contains a frozen meal that can be transferred directly to the oven the replacement polymer construction comprises at least three layers and is more than double the thickness of the foil. When the carbon footprint calculations are done the energy saving is only of the order 12%-13% even though the aluminium thickness of the metallized layer is nearly 1000x thinner than the foil.

What may also get overlooked in the comparison is that foil is more readily recycled than some of the replacement multilayer polymer structures.

Coffee vacuum packs originally were quite thick laminates of PET/foil/PE that could exceed 100 microns. To save money this structure was reviewed and down gauged and the foil replaced by a metallized polymer film. Initially the structure thickness was reduced by 20% by using an OPA/metallized layer/PE or PET/metallized layer/PE. This was further refined and finally a 15 micron OPA/metallized layer/45 microns PE structure was used saving a further 20% on the original thickness. Further down gauging was tried but was not possible because, although the barrier performance was acceptable, the mechanical performance was unacceptable. The thinning of the polymer and removal of the stiff metal foil resulted in the bag becoming much more flexible. Below 60 microns the flexibility of the structure became more of a problem than a benefit as the pack would not remain upright during filling with coffee, leading to lost production. This is not the end of the development but any further reduction in material thickness will also require a change in material to make the resultant structure stiffer in order to meet the production machine requirements.

What is noticeable in the original structure as well as the cost saving reduced thickness structures is that all of them have mixed polymers. At the time of these developments the interest in re-cycling was not as great as it is now and it is unlikely that there was anything in the design requirements requiring the solution to be capable of re-cycling.

The PE layer is used as a heat sealing layer. It is possible to use an amorphous PET as a heat seal material and so, at least in theory, it would be possible to use a metallized PET laminated to a co-extruded crystalline/amorphous PET to make a single polymer type structure. This would potentially be a more easily re-cycled material.

Re-cycling.

Re-cycling is developing as an industry and materials are now graded in more detail than they used to be. Ideally a polymer package should be able to be re-cycled back into a similar quality product, true re-cycling. Often this cannot be achieved because of the inclusion of fillers or because of coatings, printing or a laminate but what may be achieved is to re-cycle the polymer structure into a lower grade of product. This is known as down-cycling and is preferable to sending the package to landfill but less desirable than true re-cycling. The next level of re-cycling is to recover some of the energy by incineration. Again this is less desirable to down-cycling or re-cycling but is still preferable to discarding to landfill.

A report on the production of carrier bags made from recycled rather than virgin polythene concluded that the use of recycled plastic resulted in the following environmental benefits:

reduction of energy consumption by two-thirds
production of only a third of the sulphur dioxide and half of the nitrous oxide
reduction of water usage by nearly 90%
reduction of carbon dioxide generation by two-and-a-half times

A different study concluded that 1.8 tonnes of oil are saved for every tonne of recycled polythene produced.

These benefits show why it will become increasingly important to design for recycling. However this process will be slow to implement and for some packages it may not be possible to design a suitable structure of a single polymer and so re-cycling technology also has to move forward and be more tolerant of mixed materials.

There is a relatively new process that takes flaked laminated material and separates out the component polymers. The process can do this in several ways. The process uses a centrifuge loaded with the flaked material that is purged of air to remove the oxygen and then uses hot nitrogen to raise the temperature to the softening point of the lowest temperature component of the laminate material. The polymer will soften and flow and the centrifuge will cause the material to be collected. If this material is the adhesive layer the two remaining layers will separate and if the polymers are different they will be of different densities and so can be transported using the hot nitrogen gas flow and separated using the density difference. The energy used in this type of process reduces the amount of saved energy compared to re-cycling a single polymer material but still beats incineration or disposal or producing virgin material. The materials can be separated to at least the 99% purity level by this process and it can be used to re-cycle metallized polymer too.

Currently there is often uncertainty about the best way forward. Governments, scientists and the packaging industry often appear to have either different solutions to the same problem or do not even agree what is the solution to a problem. This makes it difficult for consumers to make an educated choice on packaging and may also result in a slower uptake of consumers to actively participate in recycling. This is also not helped by companies not being honest about their packaging solutions. One company deliberately promoted their packaging as being greener that previous packaging and spent money raising their profile as being environmentally responsible. The reality was somewhat different in that the replacement material they chose was a paper / multilayer polymer laminate. The only possible way for the material to be recycled was for the consumer to delaminate the paper from the multilayer polymer and recycle the paper only. The multilayer polymer could not be recycled as it contained mixed polymer types and separating the polymers was difficult and costly so that there were no facilities capable of doing this. The company was fully cognisant of this information and were misleading the consumers, if only by omission. This type of behaviour tends to make the consumers very distrustful and sceptical of statements about packaging and environmental issues even from reputable companies.

Smart materials are being developed to monitor and control gas levels which use gas scavengers or freshness indicators. What does not appear to be part of the brief in developing these packages is to also make them capable of easy recycling. The gas scavengers started by being included as a separate pack but more recently the scavengers have been added into the polymer. This makes it easier and cheaper to make the package but stops the polymer from being fully recycled although it might still be used for down cycling. The indicators may be fluorescent or phosphorescent long decay dye polymers which are meant to be highly visible and so although only used on part of the package they can be a significant contaminant preventing full recycling.

The scavenging technology tends to improve the shelf life of the product, extending the sell by date. It could be argued that this results in less wastage of product due to passing the expiry date and hence is environmentally good. However if more of the good product ends up in landfill, incineration or having to be down cycled the package improvement could be called into question.

This could all sound as if I am a Luddite and do not want to see packaging progress. This is not so but what I find disappointing is that the development of smart materials appears to be being done without any regard to recycling. Sooner or later these products will either be discarded or have to be re-developed to include some method of recycling. There does not appear to be any consistent overview of the development targets that would make sure that any new development not only produced an improvement in some feature such as barrier but also at least matched, and preferably improved on, the existing material recycling performance too.

Conclusions.

There are many developments in packaging, some are individual package improvements others are generic technology applicable to many products. Whilst these improvements may achieve their immediate targets such as reducing cost with equivalent barrier or providing freshness indication or gettering of unwanted gases they all appear to lose performance with respect to environmental performance. The solutions reduce the possibility of recycling the packages and this aspect will eventually have to be returned to and improved.

The importance of environmental aspects of packaging tends to ebb and flow and it would be helpful for there to be clear messages to be given by governments, scientists and packaging industry groups about expectations of packaging. Whilst there are confusing messages being signalled there will continue to be the process of two steps forward and one step backwards as we improve the barrier and mechanical performance of packaging but are prepared to sacrifice the environmental performance in doing so.