Lifting the barrier to new technologies

A review of packaging technologies and market trends revealed the need for functional systems that would overcome some of the existing drawbacks. This led to the development of new printable barrier coatings which are applied by the printer converter and now used in the packaging market on a commercial scale.

Functional printable coatings
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The packaging market today
Smart or active and intelligent packaging was identified as a significant trend in a recent packaging market analysis. Market reports give a good overall view of these potential technologies, which have a strong bearing on developments in inks and coatings for the packaging market. The largest market is active packaging, intelligent packaging includes 50 % RFID. PIRA estimated that the global active and intelligent technology market would be worth € 2.6 billion by 2010. Current packaging technologies are, in the main, not available in printable form. In addition to the active and intelligent market, there has been significant growth in the barrier and transparent barrier market, which has been identified as another area where printer-converter-applied coatings could resolve unmet market needs. This is not a new concept: polyvinylidene chloride (PVDC) barrier coatings, for example, have been used by many printer converters over the years, converting machinery having been modified to make this possible. The volume of various barrier materials produced indicates that there is a significant market for printable coatings, especially where printers do not have their own barrier technologies.

Focusing on barrier technologies
The portfolio of research projects (Figure 1) that passed the first stage gate into ideation was a mix of active, intelligent and barrier projects and classed as Functional Coatings. Trials were run, mock-ups prepared and price points met, but brand owners generally lost interest. However, formulation of a printable coating lowered the cost base and provided a product that could potentially be used. A valuable lesson was learned by all involved: if the market need is real, the brand owner will stay the course. The eventual value proposition was strongest for barrier technology, and also better aligned with Sun Chemical’s current businesses. As a result, the active and intelligent packaging projects were suspended, and to ensure that the resources were invested where the commercial opportunity was greatest, focus was placed on barrier technology. Within a relatively short time, UV light and oxygen barrier projects were moved through the feasibility gate.

The drawbacks of traditional barrier materials
The team was reorganised to invent and formulate products that could be suitable for specific segments of the barrier packaging market. In packaging, barrier systems prevent the penetration or loss of specific gases, light or odour that could compromise the integrity of the packaged product. Figure 2 shows that traditional materials such as glass, tin and foil all provide effective barriers in packaging. However, like all barrier technologies, they have some disadvantages, weight definitely being one. Plastics, although lighter in weight, provide poor barriers and PVDC-coated plastics are problematical, because they contain chlorine and have a high oxygen transmission rate (OTR). Some applications require no metal; extrusion lamination produces thick laminates; SiOx/AIOx coatings are fragile. All of these materials are used today, but there is still no one barrier technology that meets all requirements, including sustainability. As a result of all these drawbacks, new technologies such as nano-composites are now emerging.

PET packaging for perishables
A market assessment revealed PET to be the major base web for packaging barrier materials, so producing a barrier coating for PET that could compete with current technologies became part of the project.

A target market segment comprising food, flexible packaging and barrier technology in all its many formats and structures was developed. This was further broken down into chilled, dry and liquid foods. Technologies used for these applications include PVDC, EVOH, oxides, metallised systems and co-extrusions. Aluminium is also used, but there is a trend to avoid using it in packaging for various reasons, for example improvements in the supply chain regarding the shorter time from manufacturing to consumer sale, facilitate the removal of high barrier material such as aluminium. This means that shelf life can be reconsidered, changing twelve months to six months, for example, resulting in changes to barrier requirements.

Research was focused on these food sectors and barrier technologies, but to allow full definition of the coating requirements, packaging specifications also needed to be understood and taken into account.

Opportunities for functional printable coatings
It is difficult to determine a generic specification for a food group and packaging format, because requirements will depend on the history of the pack, geography, individual brand owner/packer, expected shelf life, and cost. Extrapolation from information accessed in the market was crucial to determine the required performance of the coating when applied to a base web, and more specifically within a laminate, where relative humidity gradients come into play. Supermarket surveys and analyses of the various food and packaging segments provided additional data, especially for oxygen barriers.

The focus was now on developing a printable oxygen barrier, specifically for PET webs, of below 10ccs oxygen per square metre, effective in chilled conditions and at ambient temperature, as well as on exposure to a relative humidity of up to 75 %. Identification of additional unmet market needs, which are discussed below, strengthened the value proposition still further.
Other trends in packaging include a move from rigid to flexible designs, growing demand for transparent packaging to make the contents visible, “light-weighting”, and finally increasing demand for single or smaller portions, resulting from the demography and today’s often smaller households. Aligning the program with these trends enabled development of a new, alternative solution to those in existence.

These trends suggest that there are opportunities for functional printable coatings, the benefits being lightweight, replacement of current technologies such as PVDC and enhancement of those with a weakness, such as AlOx or SiOx. Exploring the lightweighting option showed that if the technology can be applied successfully, it will add value throughout the supply chain and ultimately reduce costs.

**A typical application**

The model in Figure 3 is a lidding application but it could be any triplex (or more) laminated structure. The outer layer of the current commercial sample could be corona-discharge-treated PET. This would normally be either printed with ink or remain unprinted, a label then being attached on the packaging line. Behind the ink would be a layer of adhesive, then a barrier web, then another layer of adhesive laminated to a polyethylene (PE) or polypropylene (PP) sealing layer. A barrier coating applied to the inside of the outer web, printed and then laminated to the sealing web could provide a number of advantages the first being the elimination of a layer of barrier substrate and a layer of adhesive, which must mean a weight reduction. Flexible packaging is already lightweight, but with thousands of tonnes of laminate, a reduction of up to 30 % is significant and has an impact on a sustainability standpoint. All in all, the same performance could be achieved with fewer materials and at lower cost.

This type of coating is more resistant to flexing than metallised films. It could also help reduce material costs, depending on whether the printer converter manufactures barrier technology or has a very low cost base due to purchasing power. In addition, there is a potential for process savings, based on printer converter capabilities. Numerous three-ply laminates, for example, are processed twice through a duplex laminator: a barrier-coated two-ply laminate will result in a reduction of waste and of energy consumption as well as more efficient utilisation of conversion equipment. This will help to lower carbon footprint and promote sustainability. A further option is to produce PET/adhesive lamination/PET/heat seal (coating) heat seal laminates, which, when sealed to a rigid PET container, would yield a completely recyclable PET pack. Improved “SunBar” barrier technology also helps to prolong shelf life. Added to these advantages are the benefits of replacing materials such as PVDC and those resulting from improvement of current barrier technologies.

**Enhancing existing technologies**

Gas barrier systems can be significantly improved by dispersing or exfoliating mineral silicates in the organic polymers selected for the coatings. In this category, clays provide the greatest improvements as a result of their “platy” structure. The many different types of clay vary in crystal structure and “platiness”. When correctly exfoliated, these minerals are only 1-3 nanometres thick, and in a coating they align parallel to the substrate. Each plate is an absolute oxygen barrier in itself, so joining them all up would result in an excellent barrier. In reality, this is only partly achieved, but when optimised so that the platelets align correctly and close together, this system provides a very useful improvement in barrier performance. Since the platelets are absolute barriers themselves, the diffusing gas must find a pathway around them, which is described as “tortuous”, because the distance is many times the thickness of the coating. The transmission rate of the diffusing gas is therefore limited by the tortuous path it is forced to take.

The aspect ratio of a particle is the ratio of the shortest to the longest dimension. Although, as mentioned above, individual clay platelets are usually 1-3 nanometres thick, the most effective clays for barrier coatings are only 1-10 microns thick, i.e. they have aspect ratios of 1,000-10,000! In application, a compromise has to be made on aspect ratio to achieve other coating properties. The concentration of various particulates affects not only oxygen transmission but also aspect ratio.

**Printable coatings for PET application data**

Turning to the barrier performance of different technologies, Figure 4 shows the performance of the new oxygen-barrier printable coating versus that of other systems. The different materials are laminated to PE under the same conditions and compared on a MOCON at 23 °C and 50 % relative humidity. A printable coating applied to PET gives a very competitive result and is therefore a potential alternative to current technologies. Figure 5 shows flexibility, measured using a Gelbo Flex, in comparison with specific metallised barrier technologies: the printable coating is significantly more robust. The MOCON data was revealing but there was a need to investigate chilled packaging and formed pouches, including a food simulant in a modified atmosphere, and to monitor oxygen ingress over a 10-week period. The results are shown in Figure 6. A non-invasive technique ensured that the packs remained intact. The data obtained during week one showed all technologies to be performing as expected, but as the weeks went by, it became apparent that the SiOx PET laminated to PE allowed ingress first. This could be caused by handling during production. A repeat test revealed similar results. The PVDC laminate was the next to show ingress. The EVOH co-extrusion and the “SunBar” barrier coated laminate provided the best results. Figure 7 shows the results of a comparison between PVDC, EVOH and the new oxygen barrier printable coating in terms of increasing relative humidity. PVDC is not affected by relative humidity, whereas the coating and EVOH show similar results, reaching a limit at approximately 75 %. Performance at 90 % relative humidity will be poor unless the laminate layers provide some protection. At temperatures of up to 38 °C, simulating tropical conditions, the coating surprisingly performed better than both PVDC and EVOH.

The final application data relate to how a printer converter applies a coating. The film weight required for the appropriate barrier performance had to be adequate for application on conventional coating, flexo or gravure equipment. It was crucial to understand transfer rates and coating weights and their impact on oxygen barrier performance at different relative humidities. Figure 8 shows
that the coating weight can vary, depending on the requirement. At 50 % relative humidity, for example, as typically found in chilled food packaging, the coating weight window is perhaps between 2 and 4 g/m² wet. Dry food packaging exposed to 75 % relative humidity might need a coating weight of 4 to 6 g/m². Films of these weights can be applied on conventional printing coating equipment but the specifications will dictate the oxygen barrier and the drying capability of the process. Flexo is more difficult than gravure. All processes can run off line without the need to apply ink in line which can reduce press speed.

A new generation of packaging
The research program revealed a whole host of benefits: functional printable coatings, especially oxygen barriers, can satisfy market needs, including freedom from chlorine and metal, light-weighting, reduction of carbon footprint, and improved sustainability, transparency, and recycling potential, providing an alternative to other, perhaps more expensive barrier technologies.

Since the new printable coating technology provides excellent oxygen, aroma and odour barriers, improves flex crack resistance of oxide/metallised films and prolongs shelf life, it has the potential to replace PVDC and EVOH barriers and compete with current systems. The coatings can be applied at conventional film weights on existing equipment. They also eliminate the need for barrier film and adhesive in multi-ply laminates. In some instances, they allow duplex to compete with triplex laminates. They help to reduce processing waste, energy consumption and inventory working capital, and they can be applied when and where needed.

Functional printable coatings, it is believed, will enable the next generation of packaging design.

Results at a glance
A new printable coating technology provides excellent oxygen, aroma and odour barrier. The coating can improve the flex crack resistance of oxide/metallised films and prolong shelf life. The coating has the potential to replace PVDC and EVOH barriers and compete with current systems. It enables a reduced carbon footprint and higher sustainability thanks to fewer materials, less processing waste and lower energy consumption through the use of duplex instead of triplex (or more) laminates.
Figure 1: Market-identified feasibility projects. Coating programmes are aimed at unmet coating and printing solutions.
Figure 2: History/evolution of gas barriers in packaging. All these materials are in use today no one barrier technology meets all requirements.
Figure 3: Light weighting in coating applications. The 2-ply laminate with the printable barrier coating results in elimination of barrier film or foil and one layer of adhesive, lighter-weight packaging (up to 30% reduction), improved laminate integrity (post flexing O2 barrier improvement), lower material and/or operational costs, improved recycling and longer shelf life.
Figure 4: Oxygen transmission rate of "SunBar" coating versus PVDC, Met, EVOH, AlOx and SiOx. PVCD contains chlorine and has a higher OTR; AlOx and SiOx are brittle and also have a higher OTR; EVOH deteriorates over time in humid storage conditions.
Figure 5: Flexibility of barrier coatings. Oxide-coated and metallised films have poor flex resistance.
Figure 6: "SunBar" real-time packaging performance. The coating system maintains excellent barrier performance over an extended period, provides options for longer shelf life, is equivalent in performance to EVOH extrusion laminates and superior to PVDC and SiOx coated PET laminate structures.
Figure 7: Performance benchmark effect of humidity. "SunBar" performs well up to 75 % RH
Figure 8: Example of correlation between flexo anilox volume and wet coating weight of "SunBar" O2 barrier (above) and applied wet coating weight of "SunBar" O2 barrier and achieved barrier (below)