STUDY REPORT

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Indicator Materials

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INDICATOR MATERIALS

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Abstract

There is potential for passive indicator, or "tell-tale", marking technologies that can be applied to building wrap materials during the manufacturing process. These marks would respond to environmental exposure in a way that would allow building inspectors and product manufacturers to determine if the building wrap had been covered by fitting of the cladding within a prescribed period. This project has explored the practicality of producing these markings, including an examination of existing technologies and potential barriers in regard to the pathway to use.

Keywords

Indicator, tell-tale, marking, printing, building wrap, exposure, degradation, colour change.

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1. SUMMARY

The objective of this study was to explore the possible use of indicator materials to show when building components have been exposed to too much potentially damaging UV radiation during the construction process.

Markings for synthetic building wrap materials, to indicate excessive exposure to solar radiation, were examined. Indication of UV exposure is believed to be the most critical requirement for synthetic wrap materials. A number of printing ink types were identified and tested by application to a representative synthetic building wrap product. The results obtained indicated that sensitive indications of solar exposures, in the time-frame required for building wrap materials, were possible.

2. BACKGROUND

The project focussed on examining the potential for development of passive UV indicator, or “tell-tale”, marking technologies that could be applied to building materials during the manufacturing process. The markings would respond to UV exposure in a way that would allow building inspectors and product manufacturers to determine if building wraps had been covered by fitting of cladding within the manufacturer’s prescribed period.

Synthetic building wraps, usually made from polyolefins, are known to undergo photochemical degradation during exposure to solar radiation. BRANZ research indicates that this results in an increase in permeability to water vapour. Results also show that synthetic wraps lose mechanical strength as a result of exposure.

A primary project focus was on understanding existing technologies, including the coverage of intellectual property in this area. A short experimental programme was planned to demonstrate that the potential seen was real.

3. LITERATURE REVIEW

3.1 Open literature searches

The search of the open literature focused on passive indicators and marking technologies that would respond to solar radiation exposure.

The items identified in the open literature fell into several generic categories including:

3.1.1 Time-Temperature Indicators (TTIs)

Markings or devices that gave an indication of time and temperature, for example packaging of temperature-sensitive drugs. These appear to be interesting for use in buildings, particular variants offering an integral of time and temperature (Pelbois 2006). However, they are not regarded as being of immediate help in indicating building products exposed to unacceptable conditions (Anon 2006, Anon 2006a, De Jong 2005, Goldsmith 2004, Lin 2003, Anon 2003).

3.1.2 Radio Frequency Identifiers (RFIDs)

RFIDs are finding many and varied applications, mainly as a result of the falling price of the technology and benefits in product traceability. For now the main applications remain high value, where protection against counterfeiting is desirable (Lister 2006, Williams 2005). Applications are broadening into performance critical products where the cost of the RFID is trivial in comparison to the cost of the item or the liability related to the good's condition (Anon 2005). The trend appears to be towards even cheaper RFIDs that will soon open up possible use with building components.

3.1.3 Tamper / leak evidence

Indicators employing gas-sensing dyes and optically variable films are finding uses in protecting products from tampering and in detecting packaging failures (Lister 2006, Jong 2005, Anon 2005a, Anon 2005b, Lee 2005, Mills 2004).

3.1.4 Humidity / moisture

Indicators employing humidity / moisture sensitive reactions that result in visible colour changes have also been developed (Smolander 2006).

3.1.5 Open time

The Timestrip product uses colour to monitor lapsed time after product opening (Isbitsky 2006, Anon 2006a, Anon 2006b). Products of this type would appear applicable to some building products.

3.2 Patent searches

The patent literature was also searched. Again, the searching encompassed passive indicators and marking technologies that would respond to UV exposure.

A number of filings were identified concerning TTIs. Some examples included US 6916116, US 6524000, US 6042264, US 5254473 and WO2006091466.

A number of patents related to the work reported here were found. These are discussed in detail below.

US 6652638 concerns a 'UV-Sensitive Marking Composition'. The first independent claim covers "placing a temporarily visible mark on a surface, comprising: a) a paint base; and b) a pigmented colorant, dispersed within the paint base". Another independent claim concerns a method for achieving this. The claims require that the mark substantially disappears, in a progressive manner, on exposure to UV.

US 6255659 discloses a "Method and apparatus for passive optical dosimeter comprising caged dye molecules". The independent claims regard "An ultraviolet dosimeter, comprising caged dye molecules which photolyze on exposure to ultraviolet radiation, thereby generating a density of free dye molecules", the incorporation of these into a material and an apparatus that utilises the generation of the dye. US 6054256 discloses a "Method and apparatus for indicating ultraviolet light exposure" comprising "a mutable colorant and an ultraviolet radiation transorber which, upon irradiation with ultraviolet radiation, interacts with the colorant to irreversibly mutate the colorant and thereby render the colorant substantially colorless".

US 5436115 discloses "a film that is substantially impermeable to oxygen and changes from one color to a different color in response to exposure to ultraviolet radiation".

US 5028792 concerns a "System for the visualization of exposure to ultraviolet radiation". The single claim is limited in scope to films comprising 50 to about 99% polyvinyl alcohol.

WO 2005016045 specification discloses "Indicator devices and articles comprising the indicator device". The independent claims currently concern a pigment "capable of being degraded by exposure to UV radiation" upon a carrier material that has a changing thickness so varying visible changes occur on exposure. A configuration where one pigment covers a second pigment, which becomes visible as the first pigment degrades, is also claimed.

3.3 Conclusion from the literature searches

The review of the literature showed that a lot of development work is currently underway in the area of passive indicating materials. Extensive technological understanding and intellectual property protection exists in the area.

4. EXPERIMENTAL PROGRAMME

The aim of the experimental programme was to produce building wrap samples printed with inks that would respond to solar exposure in a predictable way.

Building wrap samples were prepared using candidate printing inks in red and yellow. The inks were chosen to produce colour changes over an eight week solar exposure and were applied to a nominally 650 μm thick polypropylene non-woven wrap material. This base wrap was similar to building wrap products marketed in New Zealand.

The samples were placed on the BRANZ confidential exposure site on 4 December 2006. Samples of each wrap were removed from the exposure site as changes became evident to the naked eye, with the final samples being removed on 16 February 2007. NIWA's monthly climate summary sheets were also used to monitor the weather during the exposure (NIWA 2006, NIWA 2007a, NIWA 2007b).

After exposure the colours of the printed wrap materials were characterised using a Minolta Chroma Meter CR-200b colour meter. Values for the CIELab colour space parameters (L, a and b) were recorded for each specimen. Comparison to the unexposed control sample then allowed derivation of CIELab ΔE, the colour shift.

5. EXPERIMENTAL RESULTS

NIWA's monthly climate summaries for Wellington indicated that both December 2006 and January 2007 were cooler and markedly wetter than usual. February 2007 was cooler than normal, but very dry. Averaged over the exposure period for the development samples, the sunshine hours were near what was expected. The figures published by NIWA are shown in Table 1 and Table 2.

Table 1. Wellington climate summary for the time the development samples were exposed (NIWA 2006, NIWA 2007a, NIWA 2007b)

Month	Temperature				Rainfall	
	Mean	Departure from normal	Max	Min	Mean	% of normal
December 2006	12.7°C	-2.6°C	19.9°C	6.6°C	93 mm	109
January 2007	15.6°C	-1.3°C	24.3°C	6.3°C	102 mm	141
February 2007	16.5°C	-0.6°C	25.8°C	8.8°C	17 mm	27

Table 2. Wellington solar radiation summary for the time the development samples were exposed (NIWA 2006, NIWA 2007a, NIWA 2007b)

Month	Sunshine			
	Mean (hours)	% of normal	Mean daily solar irradiance (MJ/m^2)	% of normal
December 2006	241	106	23.0	102
January 2007	196	80	21.0	89
February 2007	239	114	21.6	109

The CIELab ΔE values obtained for the materials exposed from December 2006 to February 2007 are recorded in Table 3.

Table 3. ΔE values for exposed development samples (December 2006 to February 2007)

Exposure / days	Red / ΔE	Yellow / ΔE	Red+Yellow / ΔE
14	14.4	17.8	12.2
30	14.0	24.5	16.1
39	16.7	27.2	18.1
46	16.5	27.7	18.0
60	21.0	33.8	23.9
67	24.8	38.7	23.7

It is worth noting that on the CIELab ΔE scale a colour change of approximately 0.6 units is perceptible to most people.

It can be seen from Table 3 that the colour of all samples changed markedly during the exposure period. However, it is perhaps more difficult to visually discern the changes in the yellow samples than for the red sample. This is evident from images of the samples shown in Figure 1 to Figure 3.

Control 14 days 30 days 39 days 46 days 60 days 67 days

Figure 1. Exposed red development samples

Control 14 days 30 days 39 days 46 days 60 days 67 days

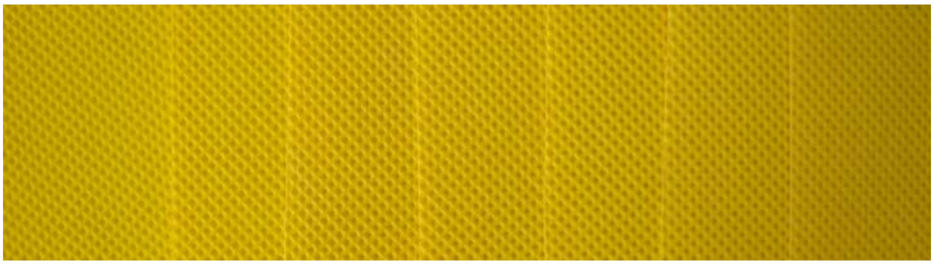

Figure 2. Exposed yellow development samples

Control 14 days 30 days 39 days 46 days 60 days 67 days

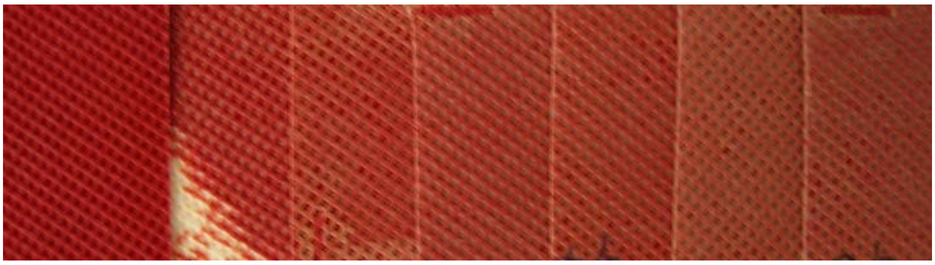

Figure 3. Exposed development samples printed with both red and yellow

The trends of ΔE changes with exposure time for the red and red / yellow mix samples are shown in Figure 4.

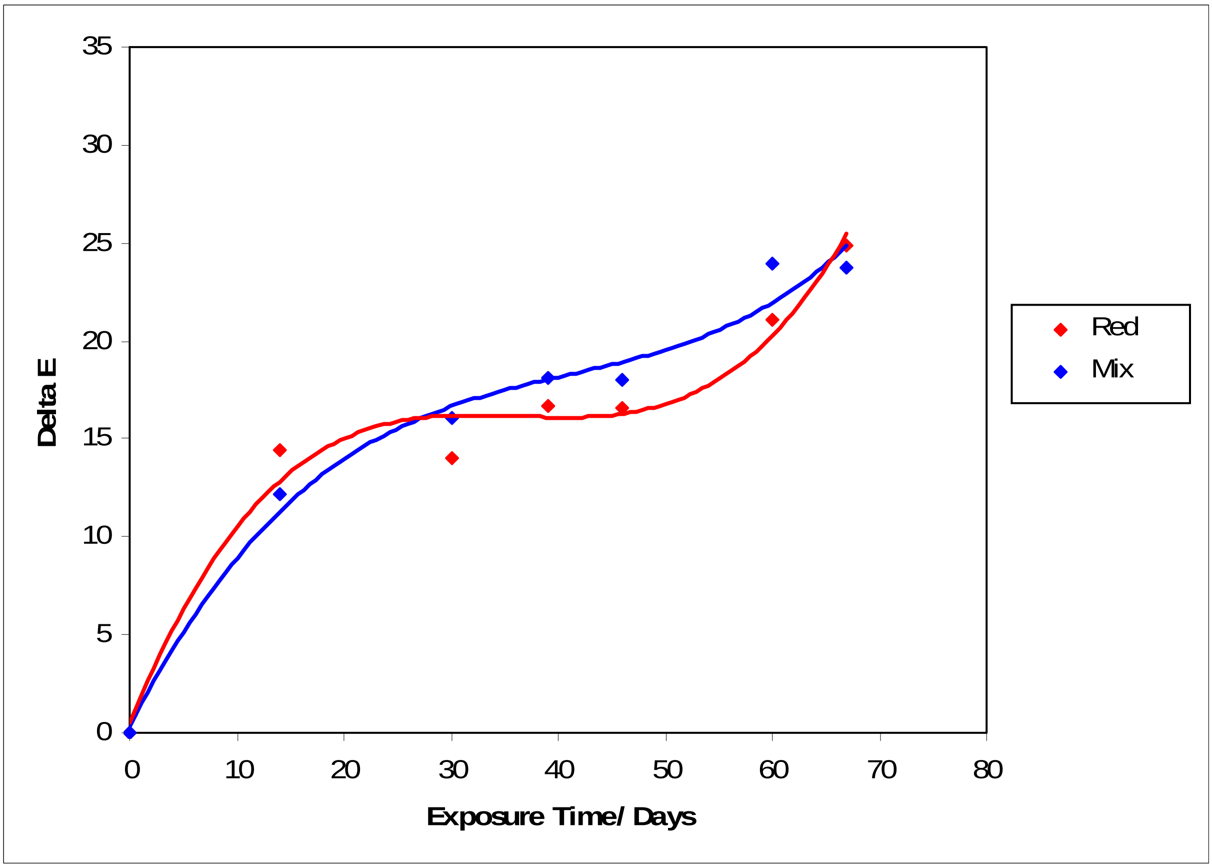

Figure 4. Colour shift trends for building wrap specimens

The trend in Figure 4 demonstrates that the colour shifts progress rapidly to a plateau and then change further when 50–60 days' exposure is reached. This implies the ability to indicate when a wrap material has been exposed for an excessive period, which is believed by BRANZ to be about 60 days' exposure.

6. CONCLUSIONS

The data from the printing ink materials clearly indicate a predictable and observable colour change as a result of solar radiation exposure. The time-frame for this change was commensurate with what might reasonably be considered an acceptable maximum exposure for some building wrap materials during the construction process.

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