US 2005/0109984 discloses a method for authenticating that a test polymer is an authenticatable polymer using a thermochromic compound.

WO 2005/086099 discloses a currency genuineness detection system using a plurality of opto-electronic sensors with both transmission and reflectance properties.

In accordance with one aspect of the present disclosure, there is provided a method of identifying a counterfeit item comprising a polymer film multilayer substrate, the method comprising: measuring the thickness of a layer of the multilayer substrate by white light interferometry; comparing a thickness measurement value obtained in said measurement step with a predefined thickness value indicative of a designated non-counterfeit film; and determining if said item comprising said polymer film multilayer substrate is counterfeit or otherwise based upon said comparison.

In accordance with another aspect, there is provided a detection unit adapted to carry out the method of the above aspect.

~~From a first aspect~~In an exemplary embodiment, the present ~~invention~~ disclosure provides a method of authenticating a polymer film comprising measuring the thickness of a layer therein by white light interferometry.

Preferably the measurement is made on a core layer of the film.

Transparent thin film materials reflect from both forward and rear surfaces; light reflected from both of these surfaces will differ in path lengths by a distance determined by the thickness of the transparent layer and the angle of incidence of the light. The reflected light waves will therefore undergo phase changes related to the path length differences. A path length difference equal to $[(2n+1)*\lambda/2$ of a beam of light (where n=0,1,2,3... and λ=wavelength) will cause the returning waves to be completely out of phase and will therefore result in destructive interference, cancelling out any reflected light. A path length difference equal to $n\lambda$ will

cause the returning light waves to be completely in phase with one another in a state known as constructive interference, whereby the returning light is twice as intense as before. Path lengths between these two conditions will cause intermediate degrees of intensification or cancelling out of returning light. Interferometry is a series of techniques which utilise the above phenomena to measure distances and thicknesses of materials.

Monochromatic Interferometry uses a single wavelength source to measure a single interfering response. This technique works well in

applications such as surface profilometry or in the measurement of thin optical films where the thickness of the substrate is reasonably well known. However, its use as a method of security verification is limited by the small amount of data returned (a single interference pattern) and the possibility that the resulting patterns could be generated by quite different thicknesses (the above formulae illustrate that the same interference can be generated by path lengths of $\widetilde{\lambda}2$, $3\lambda/2$, $5\lambda/2$, $7\lambda/2$...).

In contrast to monochromatic interferometry, white light interferometry is used in the present ~~invention~~disclosure. The applicant has found that it is most suitable for measuring multiple layered polymer films in security applications. White light interferometry measures the interference pattern generated by a material across a wavelength range defined by the range and resolution of the spectrometer used. A film with an interference path length of any given size will generate interference across the spectral range under analysis; however, the degree of interference will be determined by how in or out of phase the reflected waves of a particular wavelength become. Therefore, the spectrum obtained in a white light interferometer will be composed of a number of fringes of differing sizes, the largest of which will be for those values of n that are simplest to resolve. The thickness of a layer can be reliably determined via a Fourier transform of the data to give the frequency of the fringes. A further advantage of white light interferometry is that the data collected is sufficient to allow for the measurement of multiple interfering layers and the resolution of the individual thickness of those layers with a single measurement.

~~From a second aspect~~In another exemplary embodiment, the present ~~invention~~ disclosure provides a method of authenticating a polymer film comprising measuring the birefringence of a core layer therein.

Birefringence, or double refraction, is a property of materials caused by differences in the refractive indices of the material for the two different polarisations, s- and p-. The resulting effect manifests itself as a rotation of the polarisation angle of light being transmitted through the material; the effect is initiated via an interfacial interaction and propagated through the birefringent material; the degree of birefringence observed is a product of the initial interfacial interaction (i.e. the angle of incidence) and the subsequent path length through the material. The birefringence can be observed in a number of ways, as exemplified below.

The present ~~invention~~ disclosure allows a film to be securitized as is. The particular inherent characteristics of the film are observed in the present ~~invention~~disclosure, and there is no need to add any further security or identifying features. This identification allows authentication for security purposes and also allows the film's origin to be determined.

The films referred to herein are generally sheet-form materials, and may be provided as individual sheets, or as a web material which may subsequently be processed (by die cutting for example) to provide sheet or article form materials. When referring to "film" in this specification it is intended, unless expressly provided otherwise, to include films in sheet, article or in web form.

The film may comprise a polyolefin film, for example polyethylene, polypropylene, mixtures thereof, and/or other known polyolefins. The polymeric film can be made by any process known in the art, including, but not limited to, cast sheet, cast film, or blown film. The film or sheet may be of mono layer or of multi-layer construction. Preferably the film or sheet is of multi-layer construction with at least one core layer therein. In the case of a mono layer construction the mono-layer is the core layer. In the event that multiple core layers are provided, the measurement of the thickness of a core layer by white light interferometry, or the measurement of the

birefringence of a core layer, may be made on just one and/or on more than one of the core layers. The film may be optionally coated, e.g. with opacifer(s). This ~~invention~~ disclosure may be particularly applicable to films comprising cavitated or non-cavitated polypropylene films, with a polypropylene core and skin layers with a thickness substantially below that of the core layer and formed for example from co-polymers of ethylene and propylene or terpolymers of propylene, ethylene and butylene. The film may comprise a biaxially orientated polypropylene (BOPP) film, which may be prepared as balanced films using substantially equal machine direction and transverse direction stretch ratios, or can be unbalanced, where the film is significantly more orientated in one direction (MD or TD). Sequential stretching can be used, in which heated rollers effect stretching of the film in the machine direction and a stenter oven is thereafter used to effect stretching in the transverse direction. Alternatively, simultaneous stretching, for example, using the so-called bubble process, or simultaneous draw stenter stretching may be used.

The films used in accordance with the present ~~invention~~ disclosure can be of a variety of thicknesses according to the application requirements. For example they can be from about 5 to about 240µm thick, preferably from about 10 to about 120µm thick, more preferably from about 12 to about 100µm thick, and most preferably from about 14 to about 80µm thick. Plural layers of films in accordance with the ~~invention~~ disclosure may be laminated together to form relatively thick substrates for use as, for example, security cards and the like. The thickness of such laminated structures may be considerably higher than the preferred maximum thickness of the unlaminated film, for example 250µm or even more.

The film may comprise one or more additive materials. Additives may comprise: dyes; pigments, colorants; metallised and/or pseudo metallised coatings (e.g. aluminium); lubricants, anti-oxidants, surface-active agents, stiffening aids, gloss-improvers, prodegradants, UV attenuating materials

strength of the film when subjected to white light interferometry, for example. Low haze films may allow the possibility of using detuned white light interferometers to produce a measurable signal with smaller light sources, narrower wavelength ranges (such as emitted by white light LEDs for example) shorter integration times and/or less demanding optical components and sensors.

Accordingly, the ~~invention~~ disclosure specifically contemplates the use of a detuned light emitting device and/or a white light LED source in interferometry measurement of a film comprising one or more clarifying agents..

Suitable clarifying agents may include diesteric salts of phosphoric acid, such as sodium 2,2'-methylenebis(4,6,-di-tert- butylphenyl)phosphate; salts of mono- or poly-carboxylic acids, such as sodium benzoate and aluminum t-butylbenzoate; sorbitol derivatives such as dibenzylidenesorbitol or its C_1-C_8-alkyl-substituted derivatives, such as methyl-, ethyl- or dimethyl-dibenzylidenesorbitol; inorganic additives such as silica, kaolin or talc; or mixtures of two or more thereof. Other suitable clarifying agents, or combinations thereof will be known to the skilled addressee, or with reference to for example the Plastic Additives Handbook, 5th ed.; Zweifel, H., Ed.; Hanser Publ: Munich, 2001.

Some or all of the desired additives listed above may be added together as a composition to coat the sheet of the present ~~invention~~ disclosure and/or form a new layer which may itself be coated (i.e. form one of the inner layers of a final multi-layered sheet) and/or may form the outer or surface layer of the sheet. Alternatively some or all of the preceding additives may be added separately and/or incorporated directly into the bulk of the sheet optionally during and/or prior to the sheet formation (e.g. incorporated as part of the original polymer composition by any suitable means for example compounding, blending and/or injection) and thus may or may not form layers or coatings as such.

Such additives may be added to the polymer resin before the film is made, or may be applied to the made film as a coating or other layer. If the additive is added to the resin, the mixing of the additives into the resin is done by mixing it into molten polymer by commonly used techniques such as roll-milling, mixing in a Banbury type mixer, or mixing in an extruder barrel and the like. The mixing time can be shortened by mixing the additives with unheated polymer particles so as to achieve substantially even distribution of the agent in the mass of polymer, thereby reducing the amount of time needed for intensive mixing at molten temperature. The most preferred method is to compound the additives with resin in a twin-screw extruder to form concentrates which are then blended with the resins of the film structure immediately prior to extrusion.

Formation of a film of the ~~invention~~ disclosure (optionally oriented and optionally heat-set as described herein) which comprises one or more additional layers and/or coatings is conveniently effected by any of the laminating or coating techniques well known to those skilled in the art.

For example a layer or coating can be applied to another base layer by a coextrusion technique in which the polymeric components of each of the layers are coextruded into intimate contact while each is still molten. Preferably, the coextrusion is effected from a multi-channel annular die such that the molten polymeric components constituting the respective individual layers of the multi-layer film merge at their boundaries within the die to form a single composite structure which is then extruded from a common die orifice in the form of a tubular extrudate.

A film of the ~~invention~~ disclosure may also be coated with one or more of the additives described herein using conventional coating techniques from a solution or dispersion of the additive in a suitable solvent or dispersant. An aqueous latex, (for example prepared by polymerising polymer

precursors of a polymeric additive) in an aqueous emulsion in the presence of an appropriate emulsifying agent is a preferred medium from which a polymeric additive or coating may be applied.

Coatings and/or layers may be applied to either or both surfaces of the sheet. The or each coating and/or layer may be applied sequentially, simultaneously and/or subsequently to any or all other coatings and/or layers. If a gas-barrier coating of the present ~~invention~~ disclosure is applied to only one side of the sheet (which is preferred) other coatings and/or layers may be applied either to the same side of the sheet and/or on the reverse (other) side of the sheet.

Additionally or alternatively further layers can be provided in the film by coextrusion through a multiple-annuli die, to produce for example two, three, four or more layers in the coextrudate exiting the die.

A coating composition may be applied to the treated surface of sheet (such as the polymer film) in any suitable manner such as by gravure printing, roll coating, rod coating, dipping, spraying and/or using a coating bar. Solvents, diluents and adjuvants may also be used in these processes as desired. The excess liquid (e.g. aqueous solution) can be removed by any suitable means such as squeeze rolls, doctor knives and/or air knives. The coating composition will ordinarily be applied in such an amount that there will be deposited following drying, a smooth, evenly distributed layer having a thickness of from about 0.02 to about 10 µm, preferably from about 1 to about 5 µm. In general, the thickness of the applied coating is such that it is sufficient to impart the desired characteristics to the substrate sheet. Once applied to the sheet a coating may be subsequently dried by hot air, radiant heat or by any other suitable means to provide a sheet of the present ~~invention~~ disclosure with the properties desired.

It would also be possible to use combinations of more than one of the above methods of applying additives and/or components thereof to a film. For example one or more additives may be incorporated into the resin prior to making the film and the one or more other additives may be coated onto the film surface.

In a multi-layer film in accordance with the ~~invention~~ disclosure having at least a substrate layer and a skin layer, the skin layer is preferably ink printable. The skin layer has a thickness of from about 0.05μm to about 2μm, preferably from about 0.1μm to about 1.5μm, more preferably from about 0.2μm to about 1.25μm, most preferably from about 0.3μm to about 0.9μm.

The film may have at least one region thereon having reduced opacity compared to the surrounding film. The opacity of the film may be at least partially provided by the presence in the film of voided (or cavitated) regions. Such voided regions may for example be created by providing in the film at least one voiding agent. The production of voided films is of course well known, and any suitable voiding agent may be used here. Voiding agents are generally particulate materials and may be selected from organic, inorganic or polymeric materials. US 4,377,616 of Mobil Oil Corporation describes a number of these. Voiding agents may be substantially spherical particulate in nature, or may have a higher aspect ratio. For example, the voiding agents described in WO-A-03/033574 may be used.

The opacity of the film may be supplemented with further materials which are not voiding agents, but are opacifying agents. Inorganic fillers such as TiO_2 may be mentioned in this connection.

The ~~invention~~ disclosure is particularly useful where the film is a film made by the bubble process. The bubble process results in films which have balanced

orientation, well-defined and uniform thicknesses and other properties (high tensile strength, low elongation, high gloss and clarity, good puncture and flex-crack resistance, resistance to oils and greases, good water-impermeability) which define a "signature" of the film which indicate that it has been prepared by the bubble process.

Previous attempts to securitize film have included the incorporation of one or more taggants into the film in low concentrations, in an attempt to identify the film by detecting a stimulation response. However, the incorporation of taggants adds cost and complexity, and can interfere with other additives. The present ~~invention~~ disclosure allows the assessment and analysis of the information which is inherently and already written into the structure of the film. It is preferable that the identification of the present ~~invention~~ disclosure includes identification of a core layer rather than a surface layer, thereby enhancing security by authenticating a layer which is enveloped within the film to the extent that tampering with or manipulation of such layer would be very burdensome and difficult.

In order to differentiate between films (e.g. BOPP films and others) the overall thickness of the film, as well as the thickness of individual layers, for example a laminating layer, may be measured. This allows determination of particular characteristics which are dependent on particular processes, for example a particular bubble process. Additionally, or alternatively, the unique birefringent signature of the film may be assessed and used to determine whether the film was made by a particular process and accordingly whether it is, for example, a genuine bank note or counterfeit. Birefringence depends on the anisotropy of the material and films made by bubble process have different anisotropies and hence different birefringent properties to films made by other processes. Furthermore the precise conditions used in the bubble process will affect the birefringent signature.

Thus the present ~~invention~~ disclosure recognises that, rather than needing to add security or identification features, the inherent properties of films made by particular processes, such as the bubble process, are unique and act as a signature.

The authentication processes of the present application, and the devices used for such processes, are generally applicable to a range of polymer film materials, and can be tailored to specific substrates and thicknesses by criteria known in the art. As regards authentication by thickness measurement using white light interferometry, a spectrometer's wavelength range is determined by the line spacing of the spectrometer grating, the length of the detector array and the focal length of the spectrometer optics. The thickness range that can be measured is relative to the size of the spectral range used. In the present ~~invention~~ disclosure it is preferred to measure thicknesses of between 0.5 and 100μm, which corresponds to a spectral range of around 500 — 1000nm. Depending on the kind of device used, the desirability of a large spectral range can be balanced against other factors, particularly in small devices. The factors that ideally require balancing in a small device include the spectral range, the spectral resolution and the slit width; these factors determine the thickness range possible, the ability to resolve thin layers and the time taken to obtain a response. In a small device, a large spectral range can be offset by the use of narrower slits so as to obtain satisfactory resolution, sufficient sensitivity and acceptable measuring times. According to the ~~invention~~disclosure, devices may be provided which are specific for authentication of a particular defined thickness.

The detection time of the spectrometer is determined by the minimum amount of time needed to saturate the detector array in the spectrometer. Consequently, the brighter the light, the quicker the saturation. However, the desirability of quick detection times must be balanced by the need to avoid heat damage to the film being authenticated. The use of a pulsed

light source, such as a short pulsed xenon white flash lamp can mitigate this problem.

Accordingly, one ~~aspect~~ exemplary embodiment of the present ~~invention~~ disclosure involves the use of a pulsed light source in measurement.

~~From a further aspect~~In another exemplary embodiment, the present ~~invention~~ disclosure provides a detection unit ~~which is designed to carry out the method of the present invention~~. Such a detection unit is tailored to recognise the characteristics of the specific signature of a secure polymer-based material. The detection unit may be used to check the authenticity of the materials; for example in banks, ATMs or note readers used by cashiers.

~~From a further aspect~~In another exemplary embodiment, the present ~~invention~~ disclosure provides the use of interferometry and/or birefringence measurement in determining the authenticity of a polymer film-based secure item.

Interferometry relies on optical interference between rays which are reflected from the various surfaces within a film. The interference gives a measure of the optical path length between the surfaces and therefore the film (or layer) thickness. The homogeneity of the boundaries between the layers also affects the measurement. The reflection occurs where the layers have different refractive indices.

The interferometry used in the present ~~invention~~ disclosure is white light interferometry because monochromatic interferometry is not sufficiently distinguishing.

Typically a narrow light beam is directed into the material to be measured, and the detector detects the light reflected from the boundaries between the layers. A series of peaks are obtained in an interferogram, showing the location of the corresponding layers. Thus it is possible quickly to

inspect multilayer films and webs, without needing to contact or destructively analyse the materials.

The orientation in polymers not only affects properties (mechanical, optical, barrier, and others) but also affects the birefringence due to anisotropy in the refractive indices. Birefringence is the separation of light into two rays caused by such anisotropy and is clearly a function of the process of preparation of the film. For example, BOPP films produced by the bubble process have a particular anisotropic character due to the uniform stretching.

The film is preferably a collapsed bubble film, i.e. contains two half-bubbles laminated together. The lamination layer is preferably a terpolymer.

Some aspects of the ~~invention~~ disclosure will now be described by way of example in non-limiting detail by reference to Figures 1 to 3 which show components of apparatus for different methods of observing birefringence according to the present ~~invention~~disclosure.

With reference to Figure 1, a first method of observing birefringence is via the use of crossed polarisers. Linear polarisers allow one type of either s- or p-polarised light to pass through them, so that when a second linear polariser is presented and twisted 90° relative to the first, the remaining light made from a single polarised type is filtered out; this technique is referred to as using cross polarisers. Birefringent materials effectively rotate the axis of polarisation and so, when placed between two crossed polarisers will affect how much light is permitted to pass through them. Rotating the birefringent material whilst between the crossed polarisers causes the intensity of light to vary as the angles of birefringence alters. Thin polymer films operate on the first order of birefringence and will tend to rotate light between 0 and 90°; a fully birefringent material will vary from

CLAIMS

1. A method of identifying a counterfeit item comprising ~~authenticating~~ a polymer film multilayer substrate, the method comprising: measuring the thickness of a layer of the multilayer substrate ~~therein~~ by white light interferometry; comparing a thickness measurement value obtained in said measurement step with a predefined thickness value indicative of a designated non-counterfeit film; and determining if said item comprising said polymer film multilayer substrate is counterfeit or otherwise based upon said comparison.

2. A method according to claim 1 wherein the measurement is made on a core layer of the film.

~~3. A method of authenticating a polymer film comprising measuring the birefringence of a core layer therein.~~

~~4. A method of authenticating a polymer film comprising measuring the thickness of a layer therein by white light interferometry and/or measuring the birefringence of a core layer therein.~~

~~5. A method according to claim 4 wherein the measurement of thickness is made on a core layer of the film.~~

~~6.~~3. A method as claimed in any preceding claim wherein measurement is carried out on more than one layer of the film.

~~7.~~4. A method as claimed in any preceding claim wherein measurement is carried out using a pulsed light source.

~~8.~~5. A method as claimed in any preceding claim wherein measurement is carried out using a detuned light source.

~~9.~~6. A method as claimed in any preceding claim wherein measurement is carried out using an LED light source.

~~10.~~7. A method as claimed in any preceding claim wherein the film comprises at least one clarifying agent.

~~11.~~ 8. A method as claimed in any preceding claim wherein the film is prepared by a bubble process.

~~12.~~ 9. A method as claimed in any preceding claim wherein the film comprises a layer of biaxially oriented polypropylene (BOPP).

~~13.~~ 10. A method as claimed in any preceding claim wherein the film is a monoweb of three or more polymeric layers.

~~14.~~11. A method as claimed in any preceding claim wherein the film is a double web of five or more polymeric layers.

~~15.~~12. A method as claimed in any preceding claim wherein the method differentiates between films made a bubble process and films made by a different process.

~~16. A method of authenticating an object comprising a polymer film, wherein authentication is carried out by authenticating the polymer film as claimed in any preceding claim.~~

~~17.~~13. A method as claimed in claim 12~~6~~ wherein ~~the object is~~ said item comprises:

a bank note;
a governmental document;
a non-governmental document;
an identity document;
a passport;
a security thread;
an Optical Variable Device (OVD); or
a wrapper of or an attachment to an item.

~~18.~~ 14. A method as claimed in any preceding claim utilised for ~~of~~ identifying a counterfeit ~~an authentic~~ film ~~or object~~ on the basis of the film or object not meeting a specified pre-defined criterion of thickness. ~~and/or birefringence, utilizing a method as claimed in any preceding claim.~~

~~19. A method of identifying a non-authentic or counterfeit film or object on the basis of the film or object not meeting a specified pre-defined criterion of thickness and/or birefringence, utilizing a method claimed in any preceding claim.~~

~~20. A method according to claim 18 or claim 19 which is a forwards-compatible method suitable for identifying a film or object to be created in the future.~~

~~21. A method according to claim 18 or claim 19 which is a backwards-compatible method for identifying a film or object already in existence.~~

~~22.~~ 15. A detection unit adapted to carry out the method of any preceding claim.

~~23. The use of white light interferometry and/or birefringence measurement to determine the authenticity of a secure item comprising a polymer film substrate.~~