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THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY
Technology Transfer Center

Invention Disclosure Form

SECTION I: GENERAL INFORMATION

1. Title of Invention :
(An invention is a novel, non-obvious and useful process, machine, article of manufacture, composition of matter, or related improvement. The inventive process consists of two steps: conception (mental formulation of the complete means by which a desired result is achieved) and reduction to practice (physically constructing or carrying out the mental formulation and testing by appropriate means to demonstrate the invention achieves the desired results).)

Thermally stabilized Polymer azo dye composite Photo-Alignment Layer

Title of Invention (in Chinese) :

热稳定聚合物偶氮染料复合光定向层

2. Inventors (An inventor or co-inventor is an individual who contributed to the conception of the invention and its reduction to practice. Co-author, collaborator, co-investigator are not necessarily co-inventors. Inclusion of an individual who is not legally an inventor of a patent or exclusion of an individual who is legally an inventor will invalidate the patent.) : (Notes A & C)

2.1 **HKUST Inventors** (Note B)
(Note: The first person listed below will be the person liaising with the Technology Transfer Center (TTC). TTC will send all correspondence to this person, and he/she will be responsible for communicating correspondence with other inventors. Please note that the sequence of inventors given below may be the same as in the future granted patent, if any.)

(A) Inventor's Name *(Prof/*Dr/Mr/Ms)* (* *Please delete where inappropriate*) :

Tseng	Man Chun	
Last	*First*	*Middle*

Name in Chinese (if any) : 鄭文俊 Job Title : Research Associate

HKUST Address : Department of Electronic and Computer Engineering/Centre for Display Research, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.
School / Department / Laboratory / Center

Residential Address : Flat 3714, Ching Ping House, Ching Ho Estate, SheungShui, N.T. Hong Kong

Office Tel. : 23588528 Home Tel. : Email Address: mcken@ust.hk

HKID/Passport No.: P761375(3) Citizenship : Hong Kong

(B) Inventor's Name *(Prof/*Dr/Mr/Ms)* (* *Please delete where inappropriate*) :

Srivastava	Abhishek	Kumar
Last	*First*	*Middle*

Name in Chinese (if any) : Job Title : Research Assistant Professor

HKUST Address : Department of Electronic and Computer Engineering/Centre for Display Research, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.
School / Department / Laboratory / Center

Residential Address : 268/181 Achar Wali Gali, Aishbagh Lucknow-226004, India

Office Tel. : 23588528 Home Tel. : Email Address: abhishek_lc@rediffmail.com

HKID/Passport No.: F6952636 Citizenship : India

(C) Inventor's Name *(Prof/*Dr/Mr/Ms)* (* *Please delete where inappropriate*) :

MENG	Cuiling	
Last	*First*	*Middle*

Name in Chinese (if any) : 蒙翠玲 Job Title : PhD student

HKUST Address : Department of Electronic and Computer Engineering/Centre for Display Research, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.
School / Department / Laboratory / Center

Residential Address : Flat H4, 27/F, Yuanzhou Garden, Yuanzhou Town, Huizhou City, Guangdong Province, China.

Office Tel. : 23588528 Home Tel. : 55131844 Email Address: cmengab@connect.ust.hk

HKID/Passport No.: E55605007 Citizenship : China

(D) Inventor's Name *(*Prof/~~Dr/Mr/Ms~~)* (* *Please delete where inappropriate*) :

Chigrinov	Vladimir	Grigorievich
Last	*First*	*Middle*

Name in Chinese (if any) Job Title : Emeritus Professor

HKUST Address : Department of Electronic and Computer Engineering/Centre for Display Research, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.
School / Department / Laboratory / Center

Residential Address : No.80A, Nam Shan, DD 220, LOT No 1015, Sai Kung, New Territories, Hong Kong.

Office Tel. : 23588522 Home Tel. : 26032277 Email Address: eechigr@ust.hk

HKID/Passport No.: P876291(4) Citizenship : Russia

(E) Inventor's Name *(*Prof/Dr/Mr/Ms)* (* *Please delete where inappropriate*) :

Kwok	Hoi Sing	
Last	*First*	*Middle*

Name in Chinese (if any) : 郭海成 Job Title : Chair Professor

HKUST Address : Department of Electronic and Computer Engineering/Centre for Display Research, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.
School / Department / Laboratory / Center

Residential Address : Flat H, 56/F, Tower 1, Metro Town, Tiu Keng Leng, New Territories, Hong Kong

Office Tel. : 23587056 Home Tel. : 23351011 Email Address: eekwok@ust.hk

HKID/Passport No.: A949416(6) Citizenship : USA

2.2 **Non-HKUST Inventors** (Note B)

(For those inventions that involve non-Members of HKUST, prior written consent should be obtained from the appropriate authority of the collaborating institution(s) that full ownership of all rights, title and interest, including all patent rights associated with the inventions should reside with HKUST. The written consent of the collaborating institution(s) should be submitted as an attachment to this Invention Disclosure Form. For such cases, all non-HKUST inventors will also be required to assign all rights, title and interest associated with the invention to HKUST. The inventors' share of revenue from licensing or sale of the potential intellectual property rights will be distributed in accordance with an agreement among the inventors (see Section IV).)

(A) Inventor's Name (*As in passport*) *(*Prof/Dr/Mr/Ms)* (* *Please delete where inappropriate*) *:*

_____ _____ _____

Last *First* *Middle*

Name in Chinese (if any) : _____ Job Title : _____

Name of Organization : _____

Organization Address : _____

_____

Residential Address : _____

_____

Office Tel. : _____ Home Tel. : _____ Email Address: _____

HKID/Passport No.: _____ Citizenship : _____

(B) Inventor's Name (*As in passport*) *(*Prof/Dr/Mr/Ms)* (* *Please delete where inappropriate*) :

_____ _____ _____

Last *First* *Middle*

Name in Chinese (if any) : _____ Job Title : _____

Name of Organization : _____

Organization Address : _____

_____

Residential Address : _____

_____

Office Tel. : _____ Home Tel. : _____ Email Address: _____

HKID/Passport No.: _____ Citizenship : _____

[If more than two non-HKUST inventors, please add additional sheet]

3. The subject area of the invention is (Please indicate the specific technology area and sub-category in 'Others' if the invention falls into a TRC approved technology area):

☐ Biological Sciences and Biotechnology	✓ Energy and Environment	✓Nanoscience and Nanotechnology
☐ Chemical Engineering	☐ Information Technology	✓Physics
☐ Chemistry and Material Science	☐ Manufacturing	☐ Others (please specify) :
☐ Computer Engineering	☐ Mechanical System	
✓ Electronics	☐ Multimedia	

4. Is this submission related to another invention disclosure previously submitted to TTC?

✓ Yes Please give the title of that submission and the TTC Reference Code No. (TTC.PA.0894):
Title: Polymer azo dye composite Photo-Alignment Layer

☐ No

5. Did this invention result from sponsored research? If so, please give details. Please attach Inventions and Copyright / Intellectual Property Section of the related agreements/documents. (If no, please insert 'NIL")

Sponsor : Nil

Total Funding (HK$): _____ Project No.: _____

ITF Patenting Budget (HK$): _____

Project Start Date : _____ Project End Date : _____

Project Title : _____

Name of Principal Investigator(s)	Position	Unit	Institution

Name of Co-Investigator(s)	Position	Unit	Institution

Contract Handling Office: * OCGA / HKUST R and D Corp (** Please delete where inappropriate*)

6. Please list the agreement(s) that have been signed regarding this invention such as consulting agreement(s), collaborative research agreement(s), material transfer agreement(s), non-disclosure agreement(s), etc. (If no, please insert 'NIL")

Nil

7. Date of conception : 1-3-2016

8. Has the invention been reduced to actual practice *(i.e., have products, apparatus or compositions, etc. actually been made and tested)*? Bare ideas or mental processes cannot be patented. Patents can be obtained only on a tangible embodiment of an idea.

✓ Yes If yes, date of reduction to practice 10-5-2016

☐ No If no, please explain why you want to file the application now instead of waiting until the concept has been experimentally proven.

9. Has the invention been disclosed? (Note E)

(Any public, non-confidential disclosure of the invention (orally, in writing, electronically, by actual use, demonstration by means of poster, abstract, paper, talk, news articles, project report, thesis, thesis presentation, conference presentation, journal publication, web posting, etc.) constitutes disclosure which may bar patent protection. Student theses are also considered as publications once catalogued and indexed in the library. Please note that if a disclosure is made before filing, it will not be possible to get a patent in most countries. Only the US allows exemptions for disclosures made by the inventor, if such disclosures were made within one year prior to the filing of the patent application. If unavoidable or exceptional circumstances have resulted in the disclosure of your invention, please give a six-month time allowance (i.e. six months before the end of the one year grace period) to TTC so as to ensure the completion of the review process and the preparation of applications by the patent attorney. Failure to provide sufficient processing time may diminish the chances of approval of the application.)

☐ Yes If yes, please give details of the disclosure below and the relevant disclosure MUST be attached to this form.

✓No

Type of Disclosure	Disclosure Date and Venue	Party to which the Invention has been Disclosed

10. Is a publication or other disclosure planned in the next twelve months? (Note E)

(Please submit the Invention Disclosure Form at least 90 days before any future publication date in order to allow enough time to complete the review process and facilitate the filing of a patent application, if the case is approved.)

✓ Yes If yes, please give details of the planned disclosure and attach the relevant disclosure, if available. Soft matter in OCT 2016

☐ No

Type of Disclosure	Planned Disclosure Date and Venue	Party to which the Invention will be Disclosed
Article	15- OCT 2016	Soft matter

11. In which countries do you recommend HKUST to file a patent application for the invention? Please prioritize your recommendation and give a brief explanation on each of your recommendations.

(HKUST will usually seek patent protection for an approved case in ONE COUNTRY only. HKUST, under exceptional circumstances, may consider filing patent applications in other countries, e.g. if commercialization activities are contemplated for related technology. This will be the case where a commercial party has expressed interest in the invention and/or the commercial partner has expressed their willingness to sponsor the filing expenses in other countries. In such case, TTC will assist the inventor in the pursuance of commercial applications of the related technology and will negotiate with the commercial part(ies) for a mutually acceptable arrangement.)

Recommended Country (Prioritize in descending order)	Brief Explanation
1. USA	Most important
2.	
3.	
4.	

12. To speed up the patent filing process, would you be willing to file a provisional patent application at your own expense. Please refer to Item 2 of Note F (*page 13*) regarding the new arrangement on provisional patent filing? (Note F)

✓ Yes Remarks : _____

☐ No

13. Summary of the invention (NO MORE THAN 200 WORDS)
(The detailed description of the invention should be submitted under separate attachment.) (Note D)

This invention discloses a liquid crystal photo-alignment layer, which is a composite of monomer, a thermal initiator, and azo dyes. Azo dyes alignment layer provides good alignment for the liquid crystals in display cells with high anchoring energy, small pre-tilt angle and an ability of very high pixel resolution, however, at the same time they are not stable. The key technique, introduced in this invention is the introduction of the functional polymer network into the azo-dye material to form a stabilized alignment layer by mean of the thermally initiated polymerization. Wherein the preferred orientation of the easy axis of azo dyes photo alignment layer has been done in the first step followed by the thermal polymerization in the second step. Furthermore, it offers an ability to realize multi-domain alignment with an extremely small pre-tilt angle in a single step. Thus prepared liquid crystals alignment layer provides good aligning characteristics *viz.* low pre-tilt angle, high anchoring energy, low residual DC, high voltage holding ratio, low image sticking parameter, which are comparable to that of conventional polyimide layers, and therefore, the proposed alignment layer can find application in variety of photonic elements and displays.

14. Summary of the invention (in Chinese) (NO MORE THAN 300 WORDS) (Note D)
(Submission of the summary in Chinese is a PREREQUISITE before TTC can proceed to file a patent application for the invention in the event that the University Technology Review Committee has approved the case.)

本发明研制了一种液晶光取向层，它是由聚合物单体，热催化剂和偶氮染料组成的复合材料。纯的偶氮染料取向层虽然为液晶显示单元提供了良好的取向，强锚定能以及小预倾角和极其高的像素分辨率，但是这种纯的偶氮染料取向层很不稳定。因此，本发明的关键技术引入功能性聚合物网络到偶氮染料材料中以实现稳定的取向层。其中，聚合物网络是借助热催化剂在加热条件下迅速聚合形成稳定网络，从而锁住已排列好的偶氮染料分子以实现稳定取向。其中偶氮染料光取向层的易轴的优先取向通过第一步的偏振紫外光照射完成，而聚合物网络则是通过第二步聚合物热聚化完成。此外，利用该复合材料还可一步实现非常小预倾角的多畴取向层。总之，该发明中的液晶取向层具有与传统聚酰亚胺取向层相媲美的各项参数，包括低预倾角，强锚定能，低残留直流电流，高电压保持率以及低的图像残留。这些优良的性能使得其特别适合应用于各种光子元件以及 IPS 和 FLC 显示器。

SECTION IIA: TECHNICAL INFORMATION

1. Detailed description of invention (Note D)

(Please attach separate sheets for the detailed description. This information is needed for the review process and is intended for consideration by internal reviewers, Technology Review Committee members and patent attorney.)

Detailed description **MUST** include the following items:
(Please refer to the Patsnap: http://library.ust.hk/cgi/db/com.pl?patsnap/ or USPTO: http://patft.uspto.gov/ for sample format of patent in different areas)

1.1 General introduction

The latest demand of a display cell includes fast response, wide viewing angle and high resolution. Recently, in-plane switching (IPS) displays, fringe field switching (FFS) and field sequential color display based on ferroelectric liquid crystal display has become very popular because of the extreme optical quality and high-resolution. It has been realized that the multi domain alignment in a pixel improves the visual appearance in particular the viewing characteristics. However, all of these electro-optical modes and pixel structure manipulations, particularly for the high resolution displays, demand exceptionally optimized photo-alignment technology that can offer almost zero pre-tilt angle, large surface uniformity and ability to offer multi-domain alignment. The most important applications of LC display cell with fast response, high resolution and optical contrast may also include fast response Photonics devices, such as modulators, filters, attenuators and high resolution requirement displays such as pico-projector, 3D display, micro-display, HDTV, UHD displays etc. However, the present state of art for the photo alignment material do not offer all of these qualities. The Photo-alignment layer based on the azo dyes are considered to meet the requirement of the modern displays, however, the Azo dyes are poorly stable against the chemical, thermal and photo exposure. The present invention relates to a liquid crystal (hereinafter abbreviated LC) alignment layer that shows a preferred alignment direction after being irradiated by the light with sufficiently high irradiation energy of certain wavelength.

The conventional alignment technique i.e. rubbing causes several mechanical damages that is not good for the yield of the high resolution displays. Nowadays, photo-alignment remains among the most promising candidates to replace rubbing procedure in LC devices. The photo-alignment technique minimizes mechanical damage and electric charging by avoiding any mechanical contact with the aligning layer. Additionally, it offers an ability of micro-scale or even nano-scale multi-domain alignment. Furthermore, it is highly desirable for a number of new developments when LC alignment is needed on a curved surface or on surfaces with microscopic confinements. For LC devices, azo-dye materials bear advantages, like sufficiently high polar and azimuthal anchoring energy, high Voltage Holding Ratio (hereinafter abbreviated VHR) and appropriate pre-tilt angles, to achieve uniform alignment. It has been reported in the past that photo-aligning azo-dyes, which can be easily rotated with blue light, provides anchoring energy comparable to a commercial polyimide film with very low pre-tilt angle, and therefore, it has a potential for applications as alignment layers for wide range of the LC devices. The alignment characteristics of the photo-alignment, based on the Azo dyes, can be tuned by controlling the irradiation energy doses. Recently, it has been shown that the said photo-alignment technique offer an opportunity to provide the multi-domain alignment with distinctly defined easy axis in the adjacent alignment domains, even at the nanoscale, which is critically important for the modern devices. However, the photo and thermal instability of the alignment is a real challenge for these materials to find a place for the real

applications. In more detail, if the pre-aligned display cell is exposed to the light, the azo dye easy axis changes, and therefore, results in potential damages to the alignment quality of the display cell. Furthermore, the light flux from the backlight unit of the display system is strong enough to damage the alignment characteristic within few hours of operations. Hence, the stabilized photo-alignment layer is needed. Several attempts have been made to provide stable alignment layers but other issues like residual DC charge, VHR, and anchoring energy do not meet the industrial and consumer standards.

In this invention, a composite layer based on mixing of a liquid crystal monomer, thermal-initiator with an azo-dye material was proposed as an alignment layer for LCDs. With the optimal concentration of the monomer, thermal-initiator and SD1 Azo dye in the solution, we obtained a functional alignment film with optimal alignment characteristics that also offer an ability to align single or multiple alignment domains by a single step irradiation process. The fine alignment quality derived from azo-dyes was retained and show good photo and thermal stability including low RDC, high VHR, and low pre-tilt angle.

1.2 Description of the prior art with an emphasis on any problems

1. US Patent 6,919, 404 (2005)

   Wayne M. Gibbons, Michael G. P. Reppy, Patricia A. Rose, and Hanxing Zhen "Hybrid polymer materials for liquid crystal alignment layers" have disclosed novel hybrid polymer optical alignment layers for inducing alignment of a liquid crystal medium. Hybrid polymers of this invention are prepared form at least one component selected form the group consisting of monomer, macro monomer and polymer within the class of polyimides, poly (amic acids) and esters thereof and at least one component selected form the group consisting of addition monomer and functionalized addition polymer wherein the two components are covalently bonded to form a copolymer. The invention further describes liquid crystal displays comprising the novel branched hybrid polymer optical alignment layers.

2. U S patent, 20150056544 A1, (2015)

   Isamu Miyake, Hiroaki Asagi, Toshihiro Matsumoto, Koichi Miyachi, Youichiro OOKI, Fumitaka Kondo, in Method for manufacturing liquid crystal display device, and liquid crystal display device, have disclosed a method for manufacturing a liquid crystal display device that includes a photoalignment film. The photoalignment film is formed from a liquid crystal alignment agent, and aligns liquid crystal molecules horizontally to the main face of the at least one of the substrates. The liquid crystal alignment agent contains a solvent and at least two kinds of polyamic acids or their derivatives obtained by reacting diamine and tetracarboxylic dianhydride. At least two of the diamines and at least one of the tetracarboxylic dianhydrides are compounds represented by predetermined formulas. The method includes the steps of: (1) forming the film of the liquid crystal alignment agent; (2) pre-baking the film; (3) irradiating the pre-baked film with light; and (4) post-baking the irradiated film, the step (4) including an operation of post-baking the film multiple times at temperatures ranging from low to high temperatures.

3. Journal of Display Technology, vol. 12, (2016).

   Seung-Won Oh, Jun-Hee Park, and Tae-Hoon Yoon in the article entitled "Electro-Optical Performance of a Zero Pre-Tilt Liquid Crystal Cell Fabricated by Using the Field-Induced UV-Alignment Method", investigated a liquid crystal alignment method using a UV-curable polymer

has been reported for the zero pre-tilt angle of liquid crystals. They reported the electro-optical characteristics and parameters related to the image quality of a fringe-field switching cell fabricated using the field-induced UV-alignment method as functions of the monomer concentration and the UV irradiation time.

4. US patent, 2013/0203920 A1, (2013).

   Mayumi Tanabe, Daisuke OOTSUKI, Kie KUBOUCHI in "Polymer composition having photoalignable group, liquid crystal alignment film formed of the polymer composition, and liquid crystal display device having phase difference plate formed of the liquid crystal alignment film", discussed about a photoalignable material that can yield a photoalignable film having a high optical uniformity and no alignment defect, and allows photoalignment with exposure in a short period of time. A photoalignable polymer composition containing a specific photoalignable polymer having a silicone group or a fluorine-substituted alkyl group, and a photoalignable group, and a specific non-photoalignable polymer is manufactured, and the photoalignable film is manufactured by applying the polymer composition onto a base material or the like, drying an applied surface thereon, and irradiating the applied surface with light.

5. US Patent 5,409,635 (1995)

   Robert Rosch, Peter Wegener, and Rainer Wingen, "Alignment layers containing cyclic structural elements" have disclosed an alignment layer for liquid-crystal displays which contains at least one compound containing, as structural element, a mediocyclic or macrocyclic carbon ring, results, in displays, in significantly increase contrast, inter alia. The mediocyclic or marocyclic structural elements may also contain heteroatoms, such as for example, O, N and S atoms.

6. US patent 20070232780 A1, (2007)

   Norio Tamura, in "Photo-alignment film and liquid crystal display element", has revealed a photo-alignment film obtained by applying a polyamic acid solution on a substrate, where the polyamic acid contains, in its main chain, at least a group having unsaturated groups having 1 to 3 carbon-carbon double bonds or 1 to 4 triple bonds; vaporizing a solvent from a film formed; applying linearly polarized light to the film after the vaporization of the solvent; and then heating the film to imidize the polyamic acid.

7. US patent 7597945 B2, (2009).

   Yoshiharu Hirai, Takashi Kato, from Chisso Petrochemical Corporation, "Polymerizable liquid crystal composition containing fluorine-substituted (meth) acrylate derivatives" presented an invention that relates to a polymer satisfying at least two characteristics among the characteristics such that it has orientation of homeotropic and so forth; it has an orientation having no (or less) defects; it has a large optical anisotropy; it is tightly adhered to a supporting plate; it has a sufficient hardness; it is colorless and transparent; it has a large heat resistance; it has a large weather ability; and so forth and to a composition which is the precursor.

8. US 6,351,301 (2002)

   Kenichi Takatori, "Smectic liquid crystal which enables grayscale display and liquid crystal using the same" have disclosed a liquid crystal display includes a liquid crystal layer. The liquid crystal layer includes a liquid crystal molecule. The liquid crystal molecule has a long axis, a short axis perpendicular to the long axis, a spontaneous polarization PS along the short axis, a first permittivity

ε// along the long molecular axis, and a second permittivity $\varepsilon\perp$ along the short axis. Here, the second permittivity $\varepsilon\perp$ is derived from polarizations other than the spontaneous polarization PS. When a permittivity anisotropy $\mathbf{\Delta}\varepsilon$ defined as $\mathbf{\Delta}\varepsilon=\varepsilon//-\varepsilon\perp$, it holds $\mathbf{\Delta}\varepsilon<0$. An orientation of the liquid crystal molecule is determined by an effective electric field which is a sum of an exterior electric field applied to the liquid crystal layer and a depolarization field generated by the spontaneous polarization.

9. EP Patent 1,793,996 (2005)

   Mark Andrews and Bell Fong, "Smart composite materials for plastic substrates" have disclosed A shapeable multilayer composite, and method of making same, having dimensional stability. The composite comprises at least two polymer substrates, each polymer substrate having a first and a second surface and each of the at least two polymer substrates being positioned sequentially such that each two consecutive polymer substrates are bonded together. Furthermore, a shapeable composite material, and method of making same, for use in the fabrication of liquid crystal displays using a shapeable multilayer composite as described above.

10. Optics Express, 23, 1044, (2015).

    Seung-Won Oh, Jun-Hee Park, and Tae-Hoon Yoon in an article entitled "Near-zero pretilt alignment of liquid crystals using polyimide films doped with UV-curable polymer", proposed an alignment method for the near-zero pretilt angle of liquid crystals (LCs) using polyimide films doped with a UV-curable polymer. The near-zero pretilt angle can be obtained by UV curing of reactive mesogen monomers mixed with planar alignment material while a vertical electric field is applied to an LC cell assembled after the rubbing process. The pretilt angle can be decreased from 2.390 ° to 0.082 °by employing the proposed method.

11. EP Patent 1,989,586 (2007)

    Jonathan A. Sachs and Jerry M. Woodall, "Optically addressed spatial light modulator and method" have disclosed an optical device has an electrically insulating first barrier layer disposed over a first electrode layer, a photoconductive layer disposed over the first barrier layer, and a carrier confining layer disposed over the photoconducting layer. The carrier confining layer defines a volume throughout which pluralities of carrier traps are dispersed. Further, an electrically insulating second barrier layer is disposed over the carrier confining layer; a light blocking layer is disposed over the second barrier layer for blocking light of a selected wavelength band. A reflective layer is disposed over the light blocking layer for reflecting light within the selected wavelength band, a birefringent or dispersive layer is disposed over the reflective layer, and an optically transmissive second electrode layer is disposed over the birefringent or dispersive layer. A method is also disclosed, as are additional layers intervening between those detailed above.

12. US Paten 7955665 B2 (2006)

Isa Nishiyama, Yasuhiro Kuwana, Joji Kawamura, Kazuaki Hatsusaka, in "Photoalignment film composition, optically anisotropic medium and method for preparing thereof, disclosed a photoalignment film composition containing a compound having a hydrophilic group and a (meth)acryloyloxy group, an optically anisotropic medium using a photoalignment film comprised of the photoalignment film composition, and a method for preparation, wherein, the reactive group at the end tail represent a hydrogen atom, halogen atom, carboxyl group or alkali metal salt thereof, halogenated methyl group, halogenated methoxy group, cyano group, nitro group, or hydroxylalkyl group having 1 to 4 carbon atoms, —CONR or methoxycarbonyl group. whereas, the reactive group in the central unit independently represent a carboxyl group or alkali metal salt thereof, sulfo group or alkali metal salt thereof, nitro group, amino group, carbamoyl group, alkoxycarbonyl group, sulfamoyl group or hydroxyl group.

13. US Patent 6,760,088 (2004)

Suk Won Choi and Su Seok Choi, "Ferroelectric liquid crystal display" have disclosed a ferroelectric liquid crystal display having alignment films with different surface polarities. The alignment films induced an internal electric field through the liquid crystal. Because of the induced internal electric field, initial liquid crystal alignment, and subsequent liquid crystal alignments, can be performed without an externally applied electric field.

14. US Patent 8009264 B2 (2011)

Yasuhiro Kuwana, Isa Nishiyama, Kazuaki Hatsusaka, "Composition for photo-alignment film, photo-alignment film, and optically anisotropic medium" have disclosed a composition for a photo-alignment film, which includes an azo compound and a polymer that exhibits mutual solubility with the azo compound, an adhesion to a substrate, particularly to a plastic substrate, is improved within both a photo-alignment film having a haze of not more than 1 obtained by forming a layer of the above composition for a photo-alignment film on a substrate and subsequently irradiating the layer with light to generate a liquid crystal alignment ability; and an optically anisotropic medium, wherein a layer (A) obtained by irradiating a layer of the above composition for a photo-alignment film with light to generate a liquid crystal alignment ability, and a polymer layer (B) obtained by polymerizing a liquid crystal compound having a polymerizable group in an aligned state generated by the layer (A) are bonded and laminated together by covalent bonds.

15. EP Patent 1,224,503

Roger Baeuerle, Tom Cloots, and Jean-Pierre Tahon, "Liquid crystal alignment layer" have disclosed a method of making a liquid crystal alignment layer comprising the steps of: (i) providing a layer on a substrate, the layer comprising a polythiophene according to formula (I), wherein R1 and R2 each independently represent hydrogen or a C1-C4 alkyl group or together represent an optionally substituted C1-C4 alkylene group or cycloalkylene group; and (ii) mechanically rendering the layer liquid crystal aligning; a liquid crystal alignment layer obtainable by the above-mentioned method; a liquid crystal device incorporating the above-mentioned liquid crystal alignment layer; a liquid crystal display comprising the above-mentioned liquid crystal alignment layer or the above-mentioned liquid crystal device; and the use of the polythiophene according to formula (I) for aligning liquid crystals.

16. US Patent 0,021,913 A1 (2003)

Mary O'Neill, Stephen Malcolm Kelly, Adam Edward Alexander Contoret, Gary James Richards, and David Coates, "Liquid crystal alignment layer" have disclosed a liquid crystal alignment layer that consists of an alignment layer and a transport material chemically bound to the alignment layer. Also, methods for forming the liquid crystal alignment layer, and displays for electronic apparatus incorporating the liquid crystal alignment layer.

17. US Patent 5,973,762 (1999)

Valeri Vorfloussev, "Ferroelectric liquid crystal cell with a monochevron structure of smectic layers" have disclosed a ferroelectric liquid crystal cell with a mono chevron structure includes a pair of opposed substrates each having an alignment layer. The alignment layer includes a conventional polymer and a ferroelectric copolymer. A ferroelectric liquid crystal material is disposed between the pair of opposed substrates and interacts with the alignment layers which force the ferroelectric liquid crystal into a monochevron structure because of the interaction between the ferroelectric liquid crystal material polarization and polarization of alignment layer.

18. Liquid Crystals **43**:7, 910-919, 2016

Yuuki Kimura, Keiichi Kuboyama & Toshiaki Ougizawa, in an article entitled, "Photoinduced alignment of polymerisable liquid crystals on photoreactive polymers containing 2,6-bis(benzylidene)-1-cyclohexanone units in the main chain", have investigated the photo-alignment characteristics for the Photoreactive polymers containing 2,6-bis(benzylidene)-1-cyclohexanone (bisBC) units for the liquid crystalline polymers (LCPs). The liquid crystalline materials were aligned homogeneously on the photoalignment layers in a wide range of irradiation dose of linearly polarised UV light (LPUVL). Specifically, for the photoalignment layer baked at 80 ℃, order parameters of the liquid crystalline materials were low due to the disturbance of oriented-photoreactive polymer caused by the contact with the solvent of liquid crystalline materials. However, the liquid crystalline materials were aligned homogeneously even at low irradiation doses on the thermally cured photoalignment layer baked at 180 ℃.

19. Jpn. J. Appl. Phys., pp 5440-5446 (2004)

Eugene Pozhidaev, Vladimir Chigrinov, Danding Huang, Andrei Zhukov, Jacob Ho and Hoi Sing Kwok, "Photoalignment of Ferroelectric Liquid Crystals by Azodye Layers" explains The photoinduced alignment of ferroelectric liquid crystals (FLCs) onto photochemically stable azo-dye films was studied. The alignment quality of FLC display cells depends mainly on the difference between the FLC surface energy and the aligning substrates surface energy; however, the structure and thickness of FLC layers are also important. The effect of the thickness of photoaligning azodye layer on the alignment quality and multiplex operation of passively addressed FLC display cells has been investigated. An optimal (about 3–5 nm) azo-dye layer thickness that provides both the highest multiplex operation steadiness and the best contrast ratio of the FLC display cells was found. The photoaligned FLC display cells showed the contrast ratio CR>500:1 at the wavelength λ=0.63 μm both in surface stabilized and deformed helix FLC electrooptical modes.

20. Jpn. J. Appl. Phys., pp 2155-2164 (1992)

Martin Schadt, Klaus Schmitt, Vladimir Kozinkov and Vladimir Chigrinov, "Surface-Induced Parallel Alignment of Liquid Crystals by Linearly Polymerized Photopolymers" explains Photopolymerization of polymer-coated solid substrates with linearly polarized light is shown to induce an anisotropic, uniaxial orientation of polymer molecules. The linearly photopolymerized (LPP) layers exhibit UV dichroism and optical anisotropy. The resulting anisotropic dispersive surface interaction forces are shown to align adjacent liquid crystals parallel. A qualitative microscopic model is presented. The new LPP-alignment technique allows to generate homogeneous LC-director pattern with different azimuthal director angles on the same substrate requiring no mechanical treatment. The use of LPP substrates in liquid crystal displays (LCDs) is shown to enable to combine different electrooptical effects-such as twisted nematic (TN) and parallel configurations-in the same hybrid LCD. Besides from high-contrast LPP-aligned TN-LCDs, LPP-aligned supertwisted nematic (STN)-LCDs exhibiting steep transmission-voltage characteristics are presented.

21. Molecular Crystals and Liquid Crystals, 412:1, 293-299, 2014

Kenji Sakamoto , Manabu Kikegawa , Sukekatsu Ushioda , Kenji Sakamoto , Kiyoaki Usami & Sukekatsu Ushioda, in an article entitled "In-plane Molecular Order of a Photo-oriented Polyamic Acid Film: Enhancement upon Thermal Imidization", have disclosed about the in-plane molecular

order of a polyamic acid (PAA) film irradiated with linearly polarized ultraviolet light (LPUVL), as well as that of the polyimide film obtained by thermally imidizing it. The PAA examined in this study contains azobenzene units in the backbone structure. The in-plane molecular order of the PAA and polyimide films was determined from the anisotropy in the polarized IR absorption of the phenyl C-C stretching vibration polarized along the backbone structure.

22. Liquid crystals, 41, No. 10, 1465, 2014.

Qi Guo, A. K. Srivastava, V. G. Chigrinov, and H. S. Kwok, "Polymer and azo dye composite: a photo-alignment layer for liquid crystals, shown the way to stabilize the alignment layer based on the Azo dye however the process is restricted to two-step the first step is for the alignment and second step is for the stabilization. Because of the wide absorption band of the azo-dye the system show some screen of the alignment properties during the stabilization and therefore the alignment ability is limited to poor optical and electrical parameter. Moreover, realization of the high resolution alignment is extremely difficult.

23. Appl. Phys. Lett. **92**, 091102 (2008).

Tien-Jung Chen and Kuei-Lin Chu, in an article entitled "Pretilt angle control for single-cell-gap transflective liquid crystal cells" Doping a minute amount of photocurable monomers in a liquid crystal LC cell, the LC alignment stabilizes after UV exposure by forming a LC pretilt layer on the substrate surface. By varying the UV exposure time, one can control the pretilt angle of the LCs continuously.

24. US Patent 61/631,193 (2011)

A. K. Srivastava, et.al. in " Fast Switchable Grating With High Diffraction Efficiency" have shown the ability of the Azo-dye alignment layer to align the FLCD layers in multi-alignment domain. In this invention a diffractive element for the FLC system has been shown that shows good alignment with extreme optical quality.

25. Sot Mat., 9, 5160, 2013

E. A. Shteyner, et.al. in "Submicron-scale liquid crystal photo-alignment", have analyzed the ability to achieve highest resolution for the azo-dye alignment layers. In other words what is the minimum size of the alignment that can be aligned with distinct easy axis in comparison to the surroundings? It has been concluded that the photo-alignment based on the sulfonic azo-dyes has an ability to define alignment domain nano-scenically.

26. Appl. Phys. Lett., Vol. 101, 031112, 2012

A. K. Srivastava, et.al. "Fast Ferroelectric liquid crystal grating based on orthogonal photo alignments", has discussed about the diffraction grating made of the FLC. Wherein the FLC was aligned in two domains with distinguished orthogonally defined easy axis in the said alignment domains.

27. RSC advances, 2016

MC Tseng et.al in article entitled "Strengthening of Liquid Crystal Photoalignment on Azo Dye Films: Passivation by Reactive Mesogens" have described a method to stabilize the alignment layer by coating an liquid crystal polymer layer on the top of the azo dye alignment layer.

1.3 Summary of the invention explaining how it improves over the prior art

This invention discloses a Liquid crystal photo-alignment layer, which is a composite of monomer, a thermal initiator, and azo dyes. Azo dyes alignment layer provides good alignment for the liquid crystals in display cells with high anchoring energy, small pre-tilt angle and an ability of very high pixel resolution, however, at the same time they are not stable. The key technique, introduced in this invention is the introduction of the functional polymer network into the azo-dye material to form a stabilized alignment layer by mean of the thermally initiated polymerization. Wherein the preferred orientation of the easy axis of azo dyes photo alignment layer has been done in the first step followed by the thermal polymerization in the second step. Furthermore, it offers an ability to realize multi-domain alignment with an extremely small pre-tilt angle in a single step. Thus prepared liquid crystals alignment layer provides low pre-tilt angle, high anchoring energy, low residual DC, high voltage holding ratio, low image sticking parameter, which are comparable to that of conventional polyimide layers, and therefore, the proposed alignment layer can find application in variety of photonic elements and displays.

1.4 Detailed examples - give as many examples as possible, covering as many different forms of the invention as possible

In the first embodiment of the present invention, we claim that a LC alignment layer that is composed of monomer, thermal free radical initiator (thermal initiator) and azo dyes composite in the optimal concentration. The composite layer coated on the substrate provides the good and stable alignment, for the liquid crystal, after being irradiated by the light source and followed by the heating at 230°C for 30 minutes, see figure 1 and 2 for the detailed process flow. The concentration of the thermal initiator and monomer has been tuned to provide the good alignment and stabilization of the liquid crystal alignment. The optimal concentration of the monomer and azo-dye, i.e. Sulfonic dye (hereinafter abbreviated as SD1) is 50:50, and thereafter, the thermal initiator i.e. 5% wt/wt of the monomer has been added to the mixture. Thus, the thin film made of composite, on the substrate, provides uniform and stabilized alignment for the liquid crystals. The thermal stability of the said alignment layer has been tested for two electro-optical modes, i.e. electrically controlled birefringence Nematic (hereinafter abbreviated at ECB) and Twisted nematic (hereinafter abbreviated as TN). The fabricated LC cells have been heated at 100 °C for 24 hours. The cells do not show any degradation in the alignment characteristics because of the thermal exposure see figure 3 to 8. Secondly, the photo-stability of the said alignment layer has been tested for freshly prepared LCD cells with ECB and TN modes. The fabricated LC cells have been irradiated by the $400 J/cm^2$ energy of the light of wavelength 450 nm. The cells do not show any degradation in the alignment characteristics because of the such an intense optical exposure (see figure 9 to 12). The alignment quality for liquid crystals is comparable to the alignment quality of any other commercially available alignment layer. The TN and ECB cell for their dark and bright states under the crossed and parallel polarizers has been compared in fig 3 and 4. The transmittance against voltage curve (hereinafter abbreviated TVC) for the two modes has been shown in fig. 5 and 6 respectively.

In the second embodiment of the invention, we claim that the said liquid crystal alignment layer shows good thermal and photostability. We claim that the said LC cells made of the said alignment layer show no traces of degradation in any respect against the photo and thermal exposure (see figure 3-12).

In the third embodiment, we claim that the thin film composite photo-alignment layer provides good anchoring energy in the range of $10^{-3}J/m^2$ moreover, to provide the optimal conditions, it can be tuned by the irradiation doses.

In the next embodiment, we claim that the alignment layer made of the composite manifest low RDC. The RDC value of the composite photo-alignment layer is below than 10mV for the DC Soak of 10V for an hour at 60°C. In the same embodiment, we also claim that the said liquid crystals alignment layer provides the same electro-optical characteristics as per the conventional alignment layer. The Voltage holding ratio that has been measured for the ECB-LC cell with the said alignment layer is more than 99% of the frame rate of 60Hz at the temperature of the 60°C that is acceptable for the modern applications.

In the last embodiment of the invention, we claim that the said alignment layer offer an ability to create two or multiple alignment domains by irradiation through the phase mask in a single step. Fig. 14 shows the process flow to create the multi-domain alignment in one step. As an example, we have chosen a checkerboard pattern with a characteristic size of the 20 micrometers. Thus, the irradiated substrate shows multi-alignment domain (see fig. 15) thereafter the alignment layer has been stabilized by heating.

We claim:

1. A thermally stabilized polymer azo dye composite photo-alignment layer, which is a mixture of monomer, thermal initiators, and azo dyes spin coated to cover the substrate uniformly and then subsequently exposed to light to provide uniform alignment and afterward heated to provide stable photo-alignment for liquid crystals.
2. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein where the said azo dye material is sulfonic azo dye Tetrasodium5,5'-((1E,1'E)-(2,2'-disulfonato-[1,1'-biphenyl]-4,4'-diyl)bis(diazene-2,1-diyl))bis(2-hydroxybenzoate).
3. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the monomer is 4-(3-Acryloyloxypropyloxy)-benzoesure 2-methyl-1, 4-phenylester.
4. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the thermal initiator is 2-Cyano-2-propyl dodecyl trithiocarbonate.
5. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the polymer azo dye composite alignment layer has been realized by mixing azo dyes, monomer and thermal initiators in the optimal concentration and dissolving in a solvent which is Dimethylformamide.
6. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the concentration of azo dye, monomer is 1 % wt/wt in the used solvent whereas the concentration of the thermal initiator is fixed to 5% wt/wt of the monomer in the solvent.
7. A procedure for preparing an alignment layer for liquid crystal molecules in a liquid crystal cell consisting of the steps:
    - Mixing in a solution form a monomeric material having liquid crystal properties, a thermal initiator and an azo dye material
    - Coating such a composite material onto a substrate and allow it to form a thin film
    - Exposing the said thin film with polarized light to create a preferred alignment direction.
    - Heat it at 230°C for 30 min to form a solid thin film.
8. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the preferred orientation of the easy axis of azo dyes and thermal polymerization has been done in a single step.
9. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the thermal polymerization of the said photo alignment layer does not affect the alignment properties of the photo alignment layer such as anchoring energy and surface uniformity.
10. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1, wherein the full polymerization of the monomer provides the high liquid crystal anchoring energy.
11. A thermally stabilized polymer azo dye composite photo-alignment layer as per claim 1,

wherein the full polymerization of the monomer provides the liquid crystal anchoring energy ~$3x10^{-3}J/m^2$.

12. A polymer azo dye composite photo-alignment layer as per claim 1, wherein the alignment layer with full polymerization of the monomer provides acceptable values of the residual DC voltages, image sticking parameter, and voltage holding ratio.
13. A polymer azo dye composite photo-alignment layer as per claim 1, wherein the alignment layer with full polymerization of the monomer provides the minimum and acceptable value of 0.008 Volts of the residual DC voltages.
14. A polymer azo dye composite photo-alignment layer as per claim 1, wherein the said alignment layer with full polymerization of the monomer provides minimum and acceptable value of the image sticking parameter ratio i.e. equal to 1.01.
15. A polymer azo dye composite photo-alignment layer as per claim 1, wherein with full polymerization of the monomer provides the maximum and acceptable value of the voltage holding ratio more than 99% at the temperature of 60 °C for 60Hz frame frequency.
16. A polymer azo dye composite photo-alignment layer as per claim 1, wherein the alignment layer is thermally stable and do not show degradation after thermal exposure at 100ºC for 24 hours.
17. A polymer azo dye composite photo-alignment layer as per claim 1, wherein the said alignment layer is optically stable and do not show any degradation after the photo-exposure of more than $400J/cm^2$.
18. A polymer azo dye composite photo-alignment layer as per claim 1, wherein the multi domain alignment with at least two alignment domains with distinct alignment directions in the neighboring domains has been realized by mean of single step exposure.

Figure Caption:

Fig. 1. Schematic of the alignment process.

Fig. 2. Process flow of the alignment and stabilization process that has been realized in a single step.

Fig. 3. Twisted nematic cell made of the said photo-alignment layer under the polarizers (a) crossed polarizer, (b) parallel polarizer.

Fig. 4. ECB nematic cell made of the said photo-alignment layer under the polarizers. (a) crossed polarizer, (b) parallel polarizer and (c) crossed polarizer with 45 ºof the easy axis.

Fig. 5. The TVC curve for the TN cell (a) before the thermal exposure, (b) after thermal Exposure of 24 hours at 100C.

Fig. 6. The TVC curve for the ECB cell (a) before the thermal exposure, (b) after thermal Exposure of 24 hours at 100C.

Fig. 7. Twisted nematic cell made of the said photo-alignment layer under the polarizers, after the thermal exposure. (a) crossed polarizer, (b) parallel polarizer.

Fig. 8. ECB nematic cell made of the said photo-alignment layer under the polarizers after the thermal exposure. (a) crossed polarizer, (b) parallel polarizer and (c) crossed polarizer with 45 ºof the easy axis.

Fig. 9. The TVC curve for the TN cell (a) before the photo exposure, (b) after photo Exposure.

Fig. 10. The TVC curve for the ECB cell (a) before the photo exposure, (b) after photo Exposure.

Fig. 11. Twisted nematic cell made of the said photo-alignment layer under the polarizers, after the photo exposure. (a) crossed polarizer, (b) parallel polarizer.

Fig. 12. ECB nematic cell made of the said photo-alignment layer under the polarizers after the thermal exposure. (a) crossed polarizer, (b) parallel polarizer and (c) crossed polarizer with 45 ºof the easy axis.

Fig. 13. The time dependence of the residual voltage of the said photo alignment layer after the stress of the 10V for 1 hour.

Fig. 14. Process flow for the 2-domain alignment.

Fig. 15. The example of the multi-domain alignment with distinct alignment direction in the adjacent alignment domains.

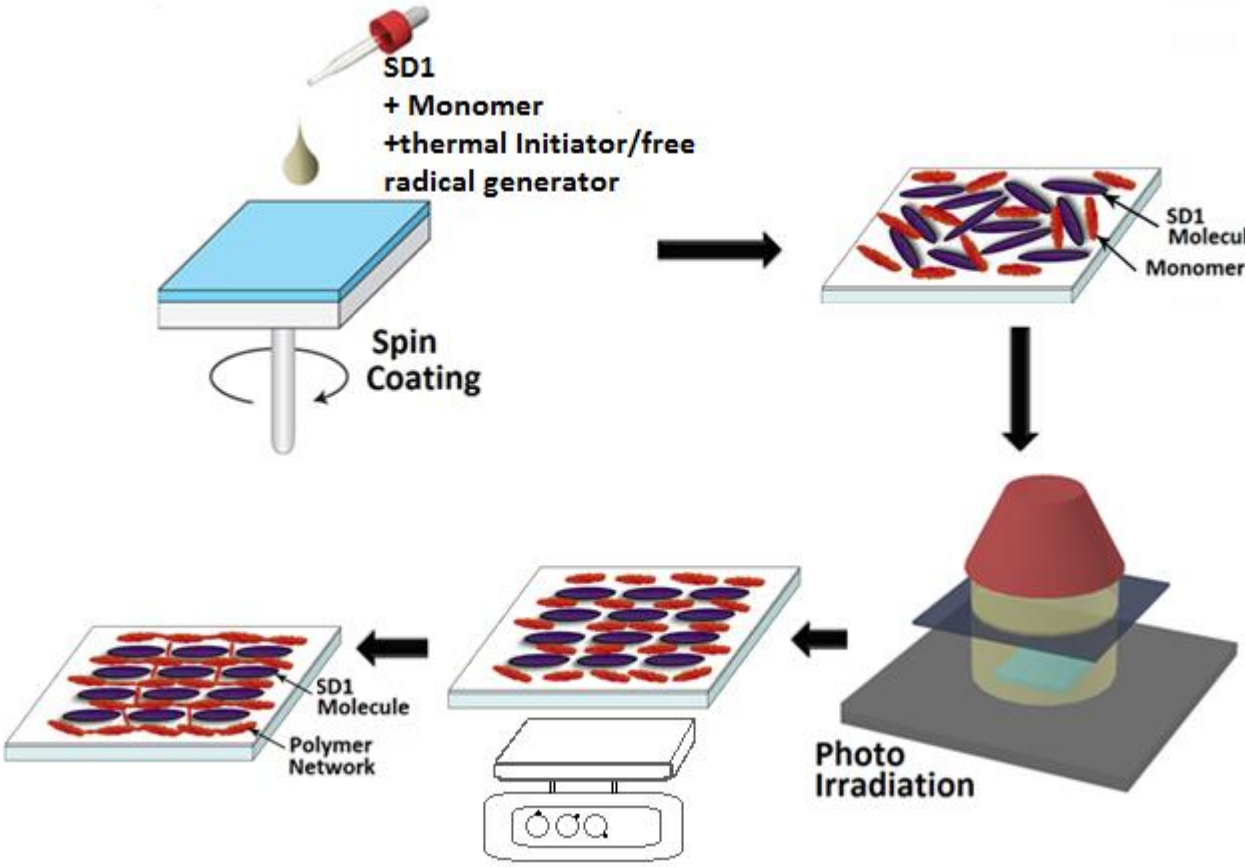

SD1
+ Monomer
+thermal Initiator/free
radical generator
Spin
Coating
SD1
Molecule
Monomer
Photo
Irradiation
SD1
Molecule
Polymer
Network

Fig. 1.

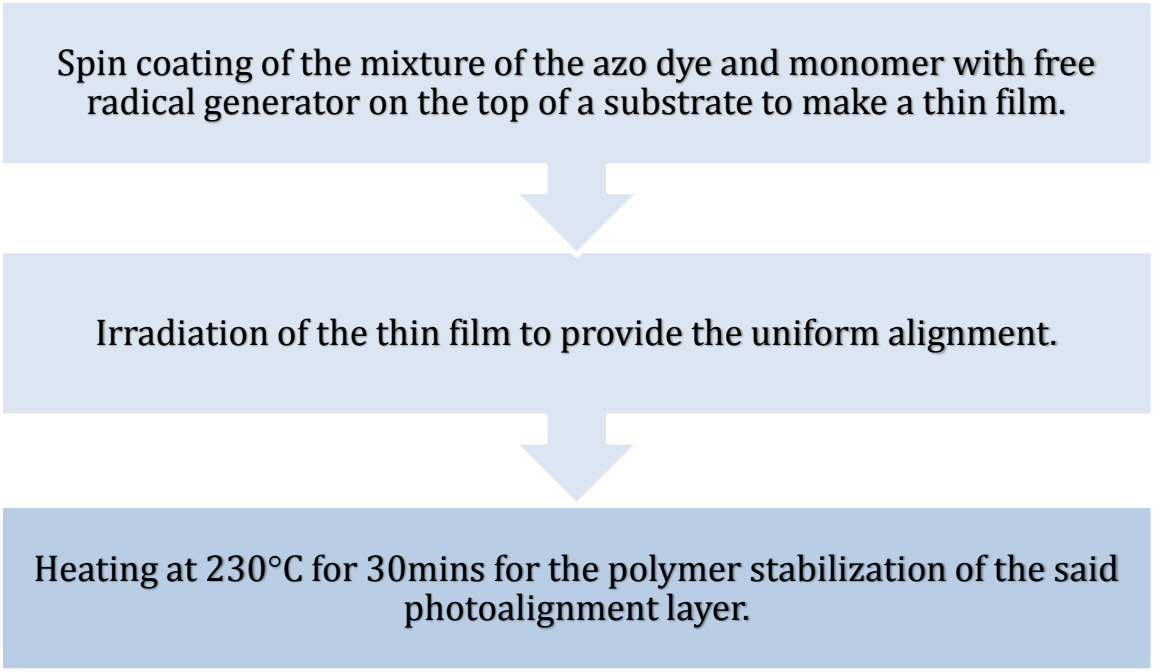

Spin coating of the mixture of the azo dye and monomer with free radical generator on the top of a substrate to make a thin film.
Irradiation of the thin film to provide the uniform alignment.
Heating at 230°C for 30mins for the polymer stabilization of the said photoalignment layer.

Fig. 2

(a) (b)

Fig. 3.

(a) (b) (c)

Fig. 4.

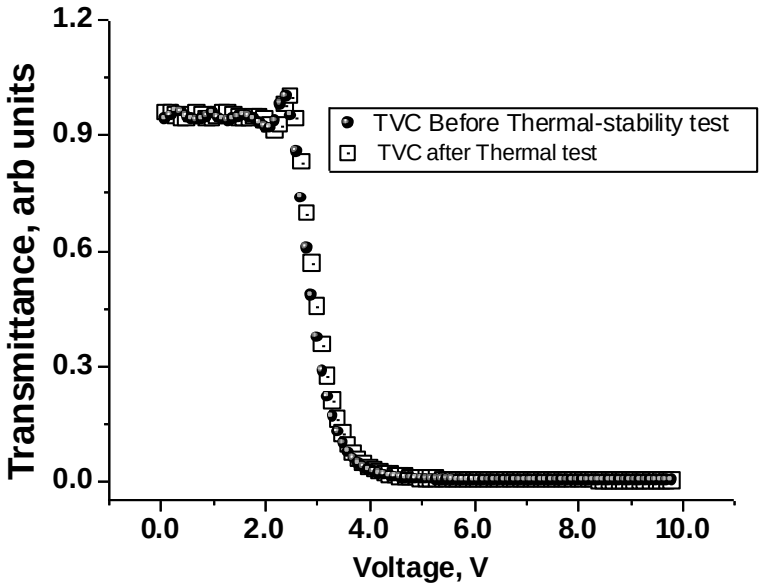

Transmittance, arb units
Voltage, V
TVC Before Thermal-stability test
TVC after Thermal test
1.2
0.9
0.6
0.3
0.0
0.0
2.0
4.0
6.0
8.0
10.0

Fig. 5.

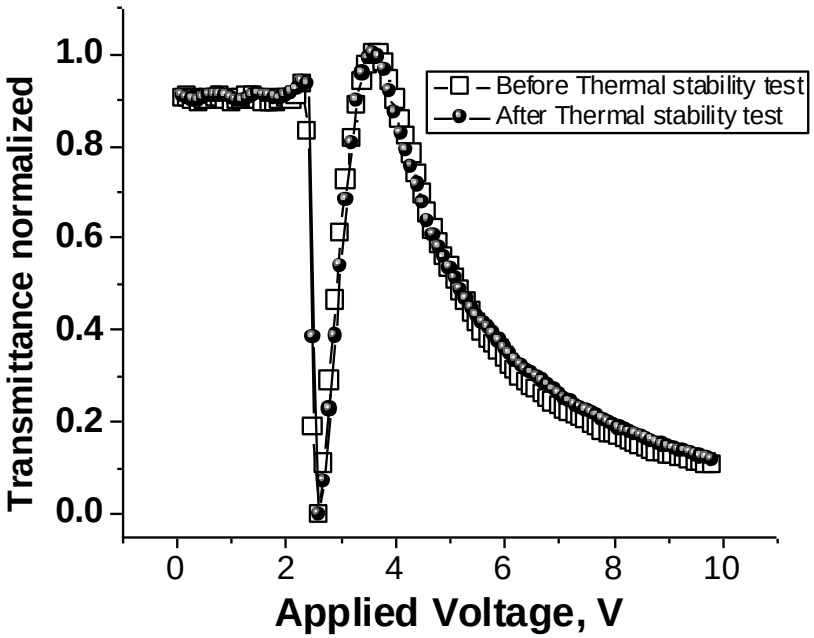
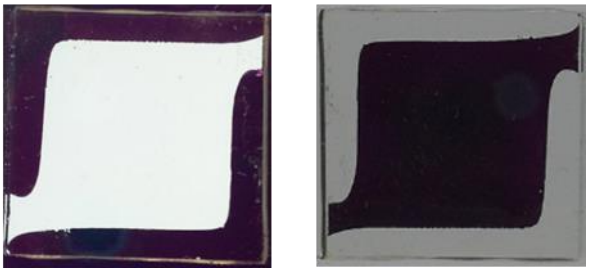

Transmittance normalized
Applied Voltage, V
Before Thermal stability test
After Thermal stability test
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10

Fig. 6.



(a) (b)

Fig. 7.

(a) (b) (c)

Fig. 8.

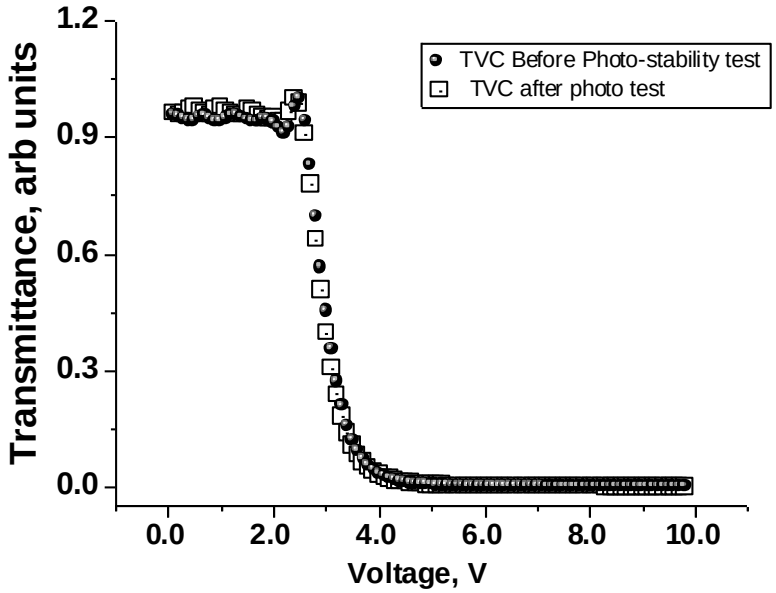

TVC Before Photo-stability test
TVC after photo test
Transmittance, arb units
1.2
0.9
0.6
0.3
0.0
0.0
2.0
4.0
6.0
8.0
10.0
Voltage, V

Fig. 9.

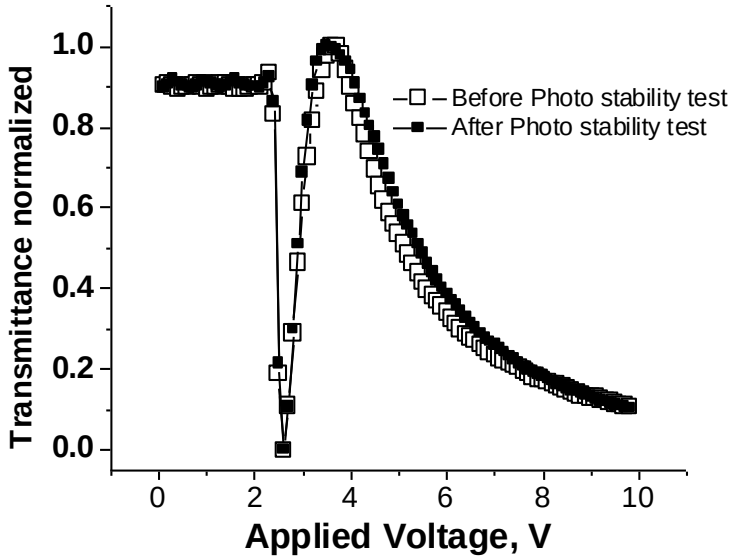
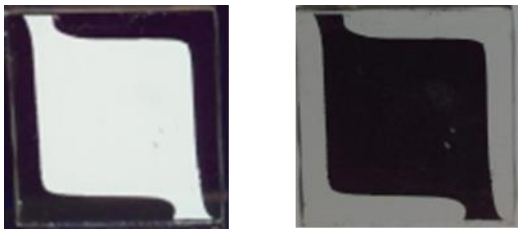

Before Photo stability test
After Photo stability test
Transmittance normalized
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Applied Voltage, V

Fig. 10.



(a) (b)

Fig. 11.

(a) (b) (c)

Fig. 12.

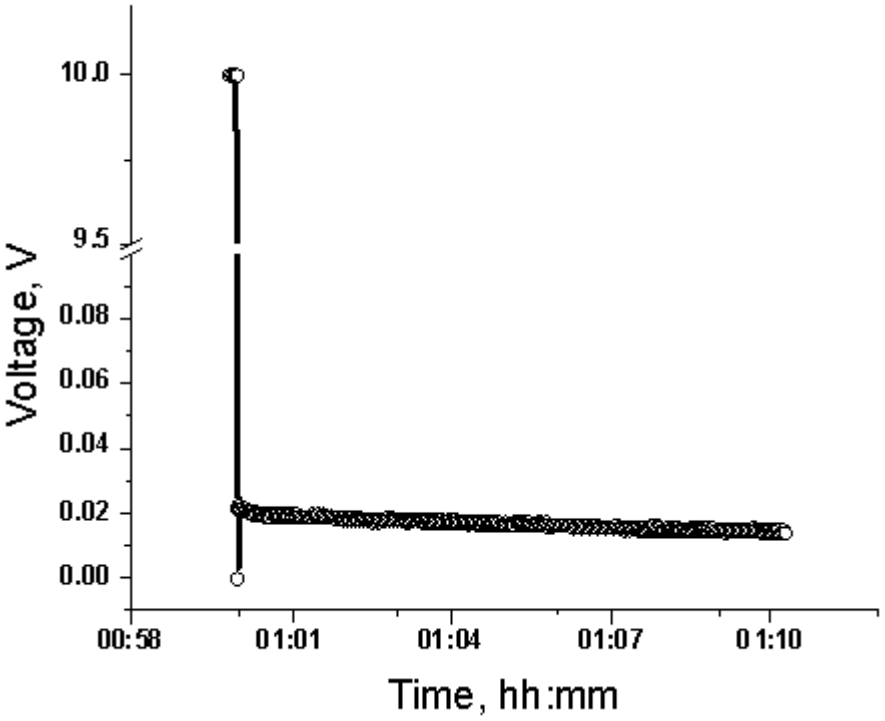

10.0
9.5
0.08
0.06
0.04
0.02
0.00
Voltage, V
00:58
01:01
01:04
01:07
01:10
Time, hh:mm

Fig. 13

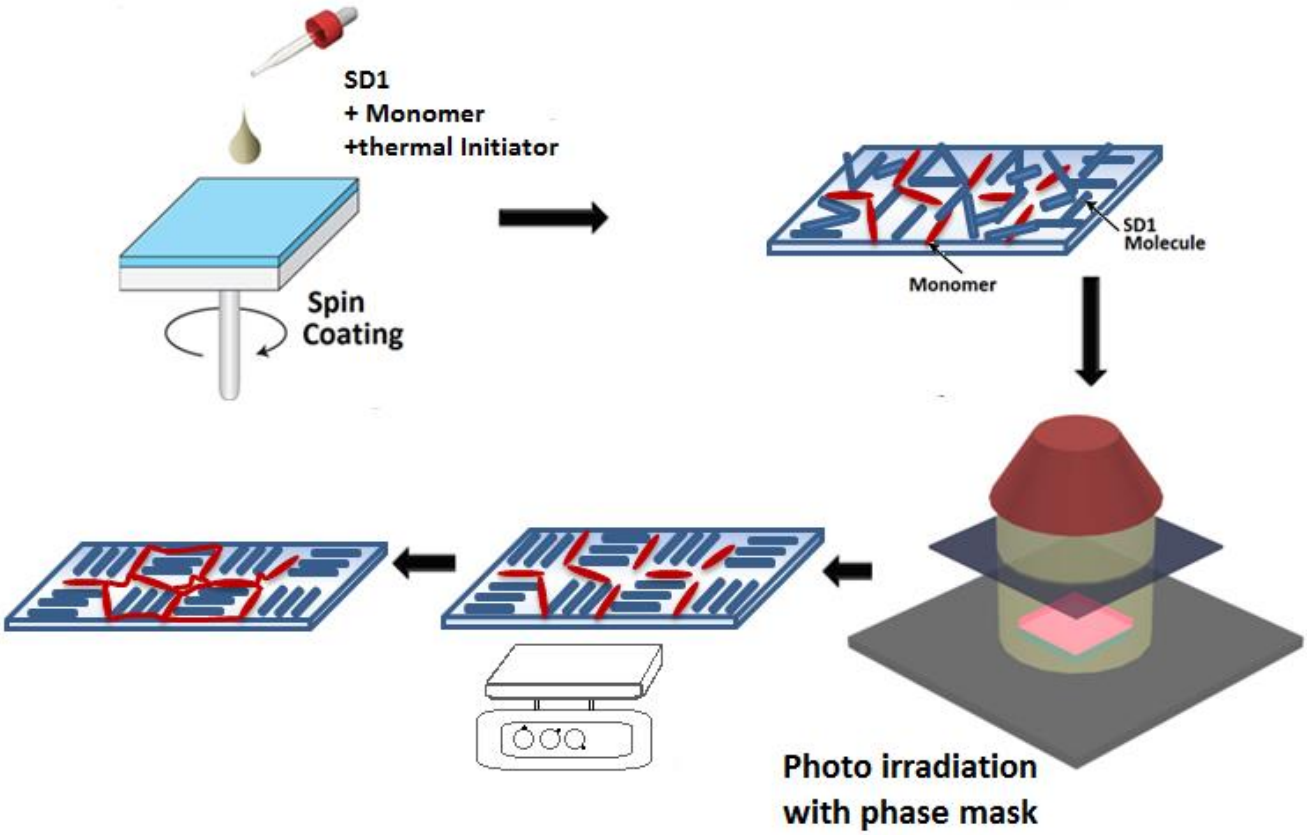

SD1
+ Monomer
+thermal Initiator
Spin
Coating
SD1
Molecule
Monomer
Photo irradiation
with phase mask

Fig. 14.

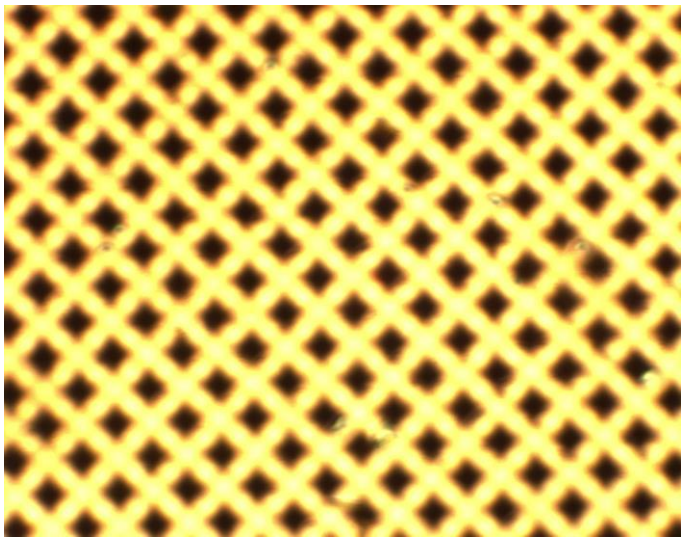


Fig. 15.

SECTION IIB: SUPPORTING TECHNICAL INFORMATION

1. Please undertake a careful patent and literature search in relation to your invention and fill in Attachment 1 (*Page 11*) and attach the relevant results to this Form. (Note D)

2. Please indicate the physical location of laboratory records of invention. Please DO NOT attach records.
(Please keep detailed records about the development of the invention from its conception to actual building and testing of system and the records should be clearly dated and signed.)

PSKL, HKUST

3. What is the breakthrough of the invention? How does the invention allow the breakthrough? What are its novel and unusual features?

One step photo-aligned and stabilized alignment layer

4. Why and how is the invention better than present and/or alternative technologies?

This offers one-step irradiation, thus demand less energy and offers an ability to realize multi-domain alignment in single exposure.

5. How difficult can the invention be bypassed?
(Please provide a brief account of other potentially competing ways of developing the invention.)

it is highly restricted and it is almost impossible to achieve the same optical, electrical and other parameter for the any other dye based photo-alignment layer.

6. What is the product or service that will be offered to users through its application? What or who will directly benefit from this technology?

Liquid crystal Display cell in any device.

7. What are the limitations or disadvantages of this invention? What are the hurdles to be overcome prior to practical application?

The light source required for the purpose is different and most of the industries have irradiation source in deep UV region but the proposed system needs 365nm of light source that is the only hurdle at the moment but it can be solved very easily.

8. What other research groups are working on similar inventions and where are they located?

The group of Prof. P. Bos at kent state university in USA.

9. Is work on the invention continuing?

☐ Yes x No

If yes, please list the major areas that must be addressed to complete the additional research work:

When will be the expected completion date? _____

10. Please give an estimate of the time (in months or years) and cost required to develop the invention into a commercially viable product/process.

1 year and less than 10 MHKD.

11. HKUST patent application procedures require the opinion of experts at HKUST to comment on the patentability of the invention. Please suggest two individuals, not associated with the invention, who might be willing to provide this information in confidence.

Name : I. D. Williams Department : Chemistry

Name : M. Wong Department : ECE

SECTION III: MARKET INFORMATION

(Note: This market information is needed for the review process)

1. What is the market for this invention? (Please provide information on composition and various segments of the market.)

LCD industry.

2. What factors would have impact on the demand for the invention in the market?

High resolution, good uniformity, high anchoring energy, low pre-tilt, low RDC and image sticking, and high VHR.

3. Based on the function(s) or feature(s) of the invention, please list the top saleable benefits.

(1) High resolution,
(2) good uniformity,
(3) high anchoring energy,
(4) low pre-tilt,
(5) low RDC and image sticking,
(6) high VHR.

4. What is the estimated size of the market in annual dollars?

☐ Under HK$ 10Million ☐ HK$ 10Million – 100Million x Above HK$ 100Million

Please provide supporting data for how you derived this estimate.

The total Display market size has crossed the mark of 130BUS$ last year that reflect the market size of the alignment layer is over 100MHK$.

5. What companies currently make products in the market that may compete with this invention? List some of the key companies.

1. BOE
2. Samsung
3. LG
4. Apple
5. AUO
6. CSOT

6. Please list the companies and specific contacts of parties that have expressed interest or may be interested in the invention. NA

Company	Contact Person	Correspondence Address	Email Address	Tel No & Fax No

SECTION IV: SIGNATURES

1. Execution by Inventor(s)

I/we Inventor(s) hereby affirm that I/we am/are the only inventor(s) of this invention and that I/we have not knowingly omitted any other inventor(s) besides me/us.

Consistent with my/our obligations set out in the Intellectual Property Policies and any other relevant policies or regulations of the Hong Kong University of Science and Technology (hereinafter referred to as "HKUST") which may issue or amend from time to time, receipt of which is acknowledged and contents of which are noted[1]. I/we hereby execute this Assignment and agree to execute any other documents as required to comply with the provisions of the policies or regulations mentioned above.

I/we, as Member(s) of the University[2], for the sum of USD 1.00 and other good and valuable consideration, the receipt and sufficiency of which is acknowledged, hereby assign and convey to HKUST, its successors and assigns (collectively hereinafter referred to as "Assignee"), the full and exclusive right, title and interest in and to the invention (whether patentable or not) described in this disclosure and its improvements and to the patents that may issue thereon (including any and all worldwide patents granted), devices, products, works of authorship, processes (including without limitation to processes of using devices or of manufacturing such devices), methods, compositions, materials, products or software (whether patentable or not) and any related intellectual property, such intellectual property rights including but not limited to copyrights, patents (including any related or subsequent applications, continuations-in-part, continuations, divisional, reissues, foreign counterparts and other equivalents), trade secrets, mask works and any other related know-how (collectively hereinafter referred to as "Intellectual Property"), or any other rights for this Intellectual Property worldwide. I/we agree to supply, without further consideration, all information and execute all papers necessary for the purpose of protecting the Intellectual Property in any country including but not limited to prosecute patent application. I/we understand that the Assignee reserves the right to abandon the prosecution of any patent application.

I/we agree to cooperate with HKUST and attorneys acting on behalf of HKUST on the prosecution of the patent applications and to cooperate with the Technology Transfer Center of HKUST in the protection and commercialization of this Intellectual Property.

I/we understand that revenue generated from commercialization of the Intellectual Property, if any, will be distributed among the inventor(s), and other entities within HKUST according to the Intellectual Property Policies of HKUST. I/we agree that the portion of revenue to inventor(s), if any, after costs are recovered, will be distributed as per the current Intellectual Property Policies of HKUST according to the percentage of shared interest as stipulated underneath.

Note 1
Content of the Intellectual Property Policies of HKUST can be viewed at "http://www.ust.hk/~webvprdo/intellectual_property.htm".

Note 2
According to the Intellectual Property Policies of HKUST, the term "Members of the University" is defined to include all part-time and full-time members of the faculty and staff and all other agents, employees, students, and fellows of HKUST.

Inventor's Signature	Date	Inventor's Signature	Date
ABHISHEK SRIVASTAVA	20%	Tseng Man Chun	20%
Name (Please use BLOCK letters)	Shared Interest	Name (Please use BLOCK letters)	Shared Interest
Unit ECE Department, HKUST		Unit ECE Department, HKUST	

Inventor's Signature MENG Cuiling	20%	Inventor's Signature CHIGRINOV VLADIMIR	Date 20%
Name (Please use BLOCK letters)		Name (Please use BLOCK letters)	Shared Interest
Unit ECE Department, HKUST		Unit ECE Department, HKUST	
Inventor's Signature	Date		
KWOK HOI SING Name (Please use BLOCK letters)	20% Shared Interest		
Unit ECE Department, HKUST			

2. Execution by Witnesses

This invention was disclosed and explained to me by the inventor(s) whose signature(s) appears in Section IV – Item 1 on :

the _____ day of _____, 20 _____.

Name of Witness : _____

Signature of Witness : _____ Date : _____

This invention was disclosed and explained to me by the inventor(s) whose signature(s) appears in Section IV – Item 1 on :

the _____ day of _____, 20 _____.

Name of Witness : _____

Signature of Witness : _____ Date : _____

Note: Sections I – IV MUST be completed by the inventor(s) before the review procedures of the invention can be initiated.
Please return the completed form (with attachments) marked CONFIDENTIAL to Technology Transfer Center, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong. For enquiries, please contact our staff members by phone at 2358-7916 or by e-mail ttalice@ust.hk.

SECTION V : INTERNAL ROUTING (FOR TTC USE ONLY)

1. The invention has been reviewed by:

Associate Director / Development Manager of TTC _____ Date _____

Signature _____

Comments: _____

2. Endorsed by:

Director of TTC _____ Date _____

Signature _____

Comments: _____

Patent Search and Review of Prior Art

Note : The inventors are required to conduct a thorough patent and literature search and review.

Please refer to the Library Patsnap - Global Patent Search and Analysis Platform (Patsnap) to conduct your patent search (Note D):

Patsnap http://library.ust.hk/cgi/db/com.pl?patsnap	Patsnap provides access to more than 50 million worldwide patents published by the U.S., European (EP), Chinese (CN), Japanese, Korean, and Norwegian patent offices as well as the World Intellectual Property Organization (WO) and the International Patent Documentation Center. Full text/images are available for US, EP, WO, and CN patents and patent applications. This database also offers a number of analytical tools including citation analysis, patent tagging and indexing with multi-dimensional analysis charts. Users can create an individual account to access more features, such as downloading, saving and exporting queries and patent information, and receiving email alert of newly published patents based on the search query.

You can also refer to the TTC web page under the topic "IP & Patent Search Links" http://www.ttc.ust.hk/en/useful-links-ip-and-patent-search-links.asp" to conduct your patent search.

[Please attach additional sheet if more space is required]

1(A). Key words used in the patent search.

Photo-alignment, polymer composites, azo dyes

1(B). Key words used in the literature search.

Photo-alignment, polymer composites, azo dyes

2(A). Number of similar patents found.
(Please list the patent numbers and their titles.)

1. US Patent 6,919, 404 (2005)
2. EP Patent 1,710,617 (2006)
3. US Patent 5,310,502 (1994)
4. US Patent 5,859,680 (1999)
5. US Patent 5,409,635 (1995)
6. US Patent 0,016,295 A1 (2013)
7. US Patent 6,671,028 (2003)
8. US Patent 5,753,139 (1998)
9. US 6,351,301 (2002)
10. EP Patent 1,793,996 (2005)
11. EP Patent 1,989,586 (2007)
12. US Patent 5,552,916 (1996)
13. US Patent 6,760,088 (2004)
14. US Patent 0,284,973 A1 (2008)
15. EP Patent 1,224,503
16. US Patent 0,021,913 A1 (2003)
17. US Patent 5,973,762 (1999)
18. US Patent 61/631,193 (2011)

2(B). Number of similar literature found.
(Please list the literature and their titles.)

1. Jpn. J. Appl. Phys., pp 5440-5446 (2004)
2. Jpn. J. Appl. Phys., pp 2155-2164 (1992)
3. Appl. Phys. Lett., 57, 1398(1990)
4. Liquid crystals, 41, No. 10, 1465, 2014.
5. Sot Mat., 9, 5160, 2013
6. Appl. Phys. Lett., Vol. 101, 031112, 2012
7. RSC advances, 2016

3(A). Comparison between the current invention and existing processes, products, etc. in the areas of novelty and usefulness. Please attach a copy of the KEY patent(s) that is/are found most relevant to the invention.

Thermal energy has been used to stabilized the pre-aligned azo dye alignment layer that makes it distinguishable than others and offer high resolution, uniform alignment and good stabilization.

3(B). Comparison between the current invention and existing processes, products, etc. in the areas of novelty and usefulness. Please attach a copy of the KEY literature(s) that is/are found most relevant to the invention.

Thermal energy has been used to stabilized the pre-aligned azo dye alignment layer that makes it distinguishable than others and offer high resolution, uniform alignment and good stabilization.

NOTES TO INVENTOR

A. PATENT POLICY OF THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Please refer to the Faculty Handbook (http://www.ust.hk/~webaa/AcademicPersonnel) or the web site of the Technology Transfer Center (TTC) (http://www.ttc.ust.hk) for the Patent Policy of the Hong Kong University of Science and Technology.

B. ASSIGNMENT OF RIGHTS

All "Members of HKUST" (which term is defined to include all part-time and full-time members of the faculty and staff and all other agents, employees, students, and fellows of HKUST) as a condition of employment (or enrolment) with HKUST, assign all rights, title and interest to and in all intellectual properties developed in the general field of expertise for which they are employed by the Hong Kong University of Science and Technology (hereinafter referred to as "HKUST") and during such period they are in the employment of HKUST, to HKUST.

Subject to restrictions imposed by contracts with sponsoring organizations, HKUST shall have the sole right to determine the disposition of all inventions by the Members resulting from their employment or use of facilities administered by HKUST. If an invention occurs under a sponsored grant or contract, HKUST will attempt to have the sponsor follow HKUST patent policy but, failing that, the sponsor's policy terms will be controlling in the matter of limitations on the inventor's share or other differences.

For those inventions that involve non-Members of HKUST and provided no restrictions are imposed by contracts with any collaborating institutions, prior written consent should be obtained from the appropriate authority of the collaborating institution(s) that allowance is granted to their relevant staff members engaging in the research work in relation to the inventions and the full ownership of all rights, title and interest, including all patent rights associated with the inventions should reside with HKUST. The written consent of the collaborating institution(s) should be submitted as an attachment to the Invention Disclosure Form. For such cases, all non-HKUST inventors will also be required to assign all rights, title and interest associated with the invention to HKUST.

The Director of TTC shall negotiate with the collaborating institution(s) for a mutually agreeable arrangement should special cases arise. The recommended arrangement will be submitted to the Vice-President for Research and Development for decision.

C. PATENT APPLICATION PROCEDURES

1. The inventor(s) are required to submit the Invention Disclosure Form to TTC with the necessary attachments of the required information specified in Note D. The soft copy of the Invention Disclosure Form can be downloaded from the TTC web site http://www.ttc.ust.hk/.
2. The invention disclosure will be preliminarily screened and reviewed by the Development Managers or the Director of TTC. The invention disclosure that does not meet the requirements for submission to the Technology Review Committee (TRC) will be returned to the inventor(s) for further actions.
3. An acknowledgment will be forwarded to the inventor(s) upon acceptance of the case to be submitted to the TRC for review.
4. The invention disclosure will then be passed on to the relevant internal reviewers for seeking scientific expert comments. (This will take about two to three weeks' time)
5. The inventor(s) will be invited to present their case to the TRC. The TRC will meet approximately once every two months depending upon the number of invention disclosures received and the availability of the Committee members.
6. Decision will be made by the Vice-President for Research and Development upon seeking the advice from the TRC.
7. The inventor(s) will be notified of the decision.
8. The approved invention will then be passed on to the HKUST assigned patent attorney for filing a patent application.
9. If HKUST decides not to pursue the invention, the inventor(s) can claim release of the rights in the invention to the inventor(s) by written request directed to the Vice-President for Research and Development subject to the provisions of the Patent Policy of HKUST.
10. The inventor(s) will be notified of the result.

D. SUBMISSION OF REQUIRED INFORMATION AND ENQUIRY

The application will **NOT** be considered by the TRC unless the following information is provided:

1. A copy of the relevant literatures if the invention has been disclosed (Section I - Item 9)
2. Summary of the invention in both English and Chinese (Section I - Items 13 & 14)
3. Detailed description of the invention (Section IIA – Item 1)
   (Please refer to the USPTO: http://patft.uspto.gov/ or Patsnap: http://library.ust.hk/cgi/db/com.pl?patsnap/ for sample format of patent in different areas)
4. Results of a thorough patent and literature search – Attachment 1 (Section IIB - Item 1)

The above information is necessary for the reviewers to appreciate the invention disclosure. This will also shorten the lead time required by the patent attorney to file the case if the invention disclosure is recommended by the TRC to file for a patent application.

Please return the completed form (with attachments) marked CONFIDENTIAL to Technology Transfer Center, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong. For enquiries, please contact our staff members by phone at 2358-7916 or by e-mail ttalice@ust.hk.

E. SPECIAL NOTES TO INVENTOR

- It is highly recommended that the invention not be made public in any way (for example, in a public seminar, a poster display at a conference, a conference presentation, or a journal publication) before filing a patent application. Please note that if a disclosure is made before filing, it will NOT be possible to get a patent in most countries. Only the US allows exemptions for disclosures made by the inventor, if such disclosures were made within one year prior to the filing of the patent application.
- It is highly recommended that the application be submitted prior to any disclosure. Please submit your patent application as early as possible and allow enough lead time for the processing of the application prior to the review by the TRC.
- If unavoidable or exceptional circumstances have resulted in the disclosure of your invention, please give a six-month time allowance (i.e. six months before the end of the one year grace period) to TTC so as to ensure the completion of the review process and preparation of applications by the patent attorney. Failure to provide sufficient processing time may diminish the chances of approval of the application.

F. NEW ARRANGEMENT - PROVISIONAL PATENT FILING

The purpose of this new arrangement - Provisional Patent filing - is to reduce costs and speed up the processing time while protecting the essential intellectual property rights of HKUST. When an application is granted on provisional basis by the United States Patent and Trademark Office, it will allow a one year grace period to file a formal application with no loss of the initial filing date. Provisional patent applications can be processed at a significantly lower cost and shorter time.

Under the new arrangement, the VP-RG may approve the application for a provisional patent in the following circumstances:

1. The Technology Review Committee considers that additional time is needed to clarify the usefulness of an application but that a filing date is of the essence. It may recommend the filing of a provisional patent in such cases. During the interim, the applicant will do the necessary work to provide clarifications and, with the assistance of TTC, may seek possible technology recipients who may be prepared to support the patent expenses;

2. The inventor(s) believe that there is a strong commercial interest in the invention such that the securing of a filing date is highly desirable, and the inventor is willing to make this provisional filing at his/her expense. The inventor should indicate this situation in the Invention Disclosure Form (Section I - Item 12). In this circumstance, the cost of filing the provisional patent application will be borne by the inventor(s), but may be repaid by HKUST as deemed appropriate if the Technology Review Committee subsequently agrees to proceed with the patent application.