(54) Title: HIGH CONTRAST RETROREFLECTIVE SHEETING AND LICENSE PLATES
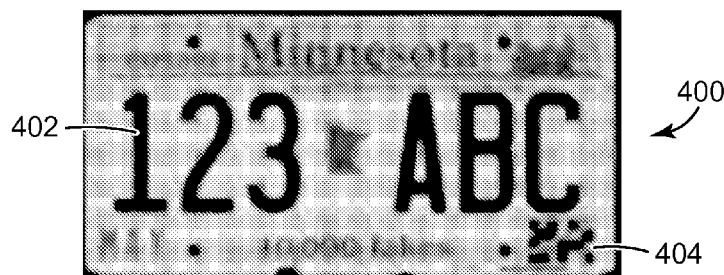
Fig. 4B

(57) Abstract: The present disclosure relates to the formation of high contrast, wavelength independent retroreflective sheeting made by including a light scattering material on at least a portion of the retroreflective sheeting. The light scattering material reduces the brightness of the retroreflective sheeting without substantially changing the appearance of the retroreflective sheeting when viewed under scattered light.

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HIGH CONTRAST RETROREFLECTIVE SHEETING AND LICENSE PLATES

TECHNICAL FIELD

[0001] The present disclosure generally relates to high contrast retroreflective sheeting and license plates, methods of making the high contrast retroreflective sheeting and license plates, and automated license plate reader systems capable of reading the high contrast retroreflective sheeting and license plates.

BACKGROUND

[0002] Automatic Vehicle Recognition (AVR) is a term applied to the detection and recognition of a vehicle by an electronic system. Exemplary uses for AVR include, for example, automatic tolling, traffic law enforcement, searching for vehicles associated with crimes, and facility access control. Ideal AVR systems are universal (*i.e.,* they are able to read all license plates with 100% accuracy). The two main types of AVR systems in use today are (1) systems using RFID technology to read an RFID tag attached to a vehicle and (2) systems using a machine or device to read a machine-readable code attached to a vehicle.

[0003] One advantage of RFID systems is their high accuracy, which is achieved by virtue of error detection and correction information contained on the RFID tag. Using well known mathematical techniques (cyclic redundancy check, or CRC, for example), the probability that a read is accurate (or the inverse) can be determined. However, RFID systems have some disadvantages, including that not all vehicles include RFID tags. Also, existing unpowered "passive" RFID tag readers may have difficulty pinpointing the exact location of an object. Rather, they simply report the presence or absence of a tag in their field of sensitivity. Moreover, many RFID tag readers only operate at short range, function poorly in the presence of metal, and are blocked by interference when many tagged objects are present. Some of these problems can be overcome by using active RFID technology or similar methods. However, these techniques require expensive, power-consuming electronics and batteries, and they still may not determine position accurately when attached to dense or metallic objects.

[0004] Machine vision systems (often called Automated License Plate Readers or ALPR systems) use a machine or device to read a machine-readable code attached to a vehicle. In many embodiments, the machine readable code is attached to, printed on, or adjacent to a license plate. One exemplary ALPR system is shown schematically in Fig. 1, which illustrates the process of illuminating and viewing a retroreflective tag. The term "retroreflective" as used herein refers to the attribute of reflecting an obliquely incident light ray in a direction antiparallel to its incident direction, or nearly so, such that it returns to the light source or the immediate vicinity thereof. An infra-red light source 106 illuminates a retroreflective tag 102, which is located on a license plate 104. Retroreflective tag 102 reflects the infra-red light emitted by light source 106 straight back to the infra-red light source 106, where it is captured by an infra-red sensor 108, such as, for example, an infra-red camera. One advantage of ALPR systems is that they are can be used almost universally, since almost all areas of the world require that vehicles have license plates with visually identifiable information thereon. However, the task of recognizing visual tags can be complicated. For example, the read accuracy from an ALPR system is largely dependent on the quality of the captured image as assessed by the reader. Existing systems have difficulty distinguishing tags from complex backgrounds and handling variable lighting. Further, the accuracy of ALPR systems suffers when license plates are obscured or dirty.

[0005] Prior art methods of creating high contrast license plates for use in ALPR systems involve including materials that absorb in the infra-red wavelength range and transmit in the visible wavelength range. For example, U.S. Patent No. 6,832,728 describes license plates including visible transmissive, infra-red opaque indicia. U.S. Patent Publication No. 2007/139775 describes license plates including infra-red blocking materials that create contrast on the license plate. U.S. Patent No. 3,758,193 describes infra-red transmissive, visible absorptive materials for use on retroreflective sheeting.

SUMMARY

[0006] The present inventors recognized the need for retroreflective sheeting having high contrast in the infra-red wavelength range while maintaining the color characteristics of the retroreflective sheeting in the visible wavelength range. The present inventors also recognized the need for wavelength independent, high contrast retroreflective sheeting.

The present inventors also recognized the need for license plates including such sheeting and OCR and/or ALPR systems capable of detecting such license plates.

[0007] The present inventors recognized that high contrast, wavelength independent retroreflective sheeting could be made by including a light scattering material on at least a portion of the retroreflective sheeting. The light scattering material reduces the brightness of the retroreflective sheeting without substantially changing the appearance of the retroreflective sheeting when viewed under scattered light.

[0008] Some preferred embodiments of the present disclosure relate to retroreflective sheeting, comprising: indicia including a light scattering material. Other preferred embodiments of the present disclosure relate to a license plate comprising the retroreflective sheeting described above. Other preferred embodiments of the present disclosure relate an optical character recognition system, comprising: an optical character recognition camera; a light source emitting infra-red light that is coaxial with the optical character recognition camera; and a license plate including the retroreflective sheeting described above.

BRIEF DESCRIPTION OF DRAWINGS

[0009] Fig. 1 is a schematic of a prior art ALPR system.

[0010] Fig. 2A is a photograph of a license plate viewed in diffuse visible light.

[0011] Fig. 2B is a photograph of the license plate of Fig. 2A viewed in retroreflected infra-red light.

[0012] Fig. 3A is a photograph of a license plate viewed in diffuse visible light.

[0013] Fig. 3B is a photograph of the license plate of Fig. 3A viewed in retroreflected infra-red light.

[0014] Fig. 4A is a photograph of a license plate viewed in diffuse visible light.

[0015] Fig. 4B is a photograph of the license plate of Fig. 4A viewed in retroreflected infra-red light.

DETAILED DESCRIPTION

[0016] The systems, methods, and apparatuses of the present disclosure generally describe the inclusion of a light scattering material on at least a portion of retroreflective sheeting.

The light scattering material reduces the brightness of the retroreflective sheeting without substantially changing the appearance of the retroreflective sheeting when viewed under scattered light, thereby creating a high contrast, wavelength independent, retroreflective sheeting. Although existing license plates have included infra-red absorbing, blocking, opaque, and transmissive materials, none of have included light scattering materials to create high contrast. The use of light scattering materials has certain advantages over existing infra-red absorbing, blocking, opaque, and transmissive materials. For example, the contrast of a license plate including light scattering material is wavelength independent in that the indicia formed using light scattering materials has high contrast in retroreflection but a license plate viewed under normal (scattering) lighting conditions will still have whatever aesthetically pleasing look that is desired. This wavelength independence permits greater flexibility in the choice of a camera for use in an OCR or ALPR system that reads license plates including light scattering materials. Further, while it is difficult and expensive to find materials that absorb infra-red light but show color in visible, scattered light, it is relatively easy and inexpensive to find materials that that scatter infra-red light without substantially changing the appearance of the retroreflective sheeting when viewed under scattered light.

[0017] The light scattering material is preferably used to create indicia on the retroreflective sheeting or license plate. Exemplary indicia include, for example, the license plate number or identifier. The light scattering material can be a surface-scattering material or can be a bulk-scattering material. Where a bulk-scattering material is used, it can be included in the indicia ink or can be placed under the indicia ink. If the light scattering material is placed under the indicia ink, it is preferably the same color as the substrate (*e.g.*, retroreflective sheeting) so that it does not change the appearance of the indicia in scattered light. Exemplary infra-red light scattering materials include, for example, inks, toners, dyes, and tapes. Where inks, toners, or dyes are used, they are preferably flat (rather than glossy) since glossy inks, toners, and dyes may not adequately scatter the infra-red light. Alternatively, the license plate can simply be selectively roughed by, for example, sanding or bead blasting, in the areas that are meant to be light scattering. In such implementations, the top surface of the license plate acts as the light scattering material.

[0018] Some exemplary embodiments of a license plate onto which has been printed a light scattering material are shown in Figs. 2A – 4B.

[0019] Fig. 2A is a photograph of a prior art Iowa license plate 200 viewed in visible light. License plate 200 includes indicia 202 ("SAM PLE") that are visible to the human eye in scattered, visible light. Indicia 202 were printed on retroreflective sheeting 204 using a Digital License Plate thermal ribbon license plate printer (sold by 3M Company) using a colored ink (in this instance, TTR1301 Dark Blue (sold by 3M Company)). This yields a 2.25:1 contrast ratio under diffuse lighting conditions. Fig. 2B is a photograph of the license plate of Fig. 2A under retroreflected, infra-red light.

[0020] Fig. 3A is a photograph of an Iowa license plate 300 when viewed in diffuse visible light. License plate 300 includes indicia 302 ("SAM PLE") printed with a light scattering material. Specifically, indicia 302 were printed using a Digital License Plate thermal ribbon license plate printer (sold by 3M). First, a light scattering white ink (for example, DPL Thermal Transfer Ribbon, TTR1321 in White, available from 3M Company) was printed on retroreflective sheeting 304. Next, a colored ink (in this instance, DLP Thermal Transfer Ribbon TTR1301 in Dark Blue, available from 3M Company) was printed over the light scattering white ink. Indicia 302 are visible to the human eye in diffuse visible light. Fig. 3B is a photograph of the license plate of Fig. 3A under retroreflected, infra-red light. White ink will scatter infra-red light so that indicia 302 look black when viewed in retroreflected lighting conditions. One immediately notices the high contrast (about 20:1) between indicia 302 and retroreflective sheeting 304 when the license plate is viewed under retroreflected, infra-red light. Further, this contrast is significantly greater than the contrast evident in the prior art license plates. Increased contrast results in higher license plate read-rate accuracy when the license plates are read by an ALPR system.

[0021] The contrast of a digital image is the grey value of the appropriately selected light areas in a ratio to the grey value of the appropriately selected dark areas. The contrast of an object is theoretically the same as the contrast of an image of that object. However the lighting conditions need to be specified and the exposure needs to be carefully controlled. The light areas must not saturate the detector and the dark areas must be sufficiently above the noise level that the noise does not substantially affect the measurement. For these reasons, it is difficult (sometimes impossible) to measure the contrast of high contrast

objects from a single image. An 8 bit camera can theoretically measure a contrast of up to 256:1. However, if the noise level is about 10 counts, one would prefer to use a minimum measurement of about 30 counts. In order to avoid saturation of the image, one would prefer to use a maximum of about 200 counts. This limits the maximum contrast from a single image to 200/30 or about 6.7:1. In order to overcome these problems, one can use several images at different, carefully controlled lighting and exposure settings to extend the dynamic rage of the measurement.

[0022] Fig. 4A is a photograph of a Minnesota license plate 400 when viewed in diffuse visible light. License plate 400 includes indicia 402 ("123 ABC") and a registration sticker 404 located in the lower right-hand corner of license plate 400. Registration sticker 404 includes a light scattering material. Specifically, registration sticker 404 includes (1) machine-readable information in the form of a bar code that is visible in retroreflected infra-red light (methods of forming such a bar code are described in greater detail in, for example, U.S. Patent Application Matter Nos. 65853US002 and 65859US002, filed concurrently herewith); (2) a colored ink (in this instance, a red Sharpie™ permanent marker) was used to form the number "10" on the registration sticker which is visible the naked human eye in scattered, visible light; and (3) pieces of clear, Scotch® brand tape (a light scattering material) were placed over the registration sticker to form a 2D bar code. Fig. 4B is a photograph of the license plate of Fig. 4A when viewed in retroreflected infra-red light. The licence plate and registration sticker maintain all of their present functions of conveying information to the human reader when viewed under normal (diffuse) lighting conditions and, in addition, digital information is available to a bar code reader when viewed under retroreflective lighting conditions.

[0023] Some preferred embodiments of the present disclosure also describe OCR and/or ALPR systems capable of detecting the retroreflective sheeting and license plates described above. One exemplary OCR or ALPR system could include an OCR camera (e.g., Model 832, Spike™ sold by PIPS Technology, a division of Federal Signal Company); an infra-red light source; and a license plate as described above. The light source preferably emits light that is nearly coaxial with the viewer of the OCR camera.

[0024] The recitation of all numerical ranges by endpoint is meant to include all numbers subsumed within the range (i.e., the range 1 to 10 includes, for example, 1, 1.5, 3.33, and 10).

[0025] Those having skill in the art will appreciate that many changes may be made to the details of the above-described embodiments and implementations without departing from the underlying principles thereof. Further, various modifications and alterations of the present invention will become apparent to those skilled in the art without departing from the spirit and scope of the invention. The scope of the present application should, therefore, be determined only by the following claims.

What is claimed is:

1. Retroreflective sheeting, comprising:
   indicia including a light scattering material.

2. The retroreflective sheeting of claim 1, wherein the light scattering material is one of a surface-scattering material and a bulk-scattering material.

3. The retroreflective sheeting of claim 1, wherein the light scattering material is one of an ink, a toner, a dye, and a tape.

4. The retroreflective sheeting of claim 1, wherein the light scattering material is a surface that has been selectively roughened.

5. The retroreflective sheeting of claim 1, wherein the light scattering material is one of colored, clear, and white.

6. The retroreflective sheeting of claim 1, wherein the light scattering material is one of under, within, and over the indicia.

7. A license plate comprising the retroreflective sheeting of any of claims 1-6.

8. An optical character recognition system, comprising:
   an optical character recognition camera;
   a light source emitting infra-red light that is coaxial with the optical character recognition camera; and
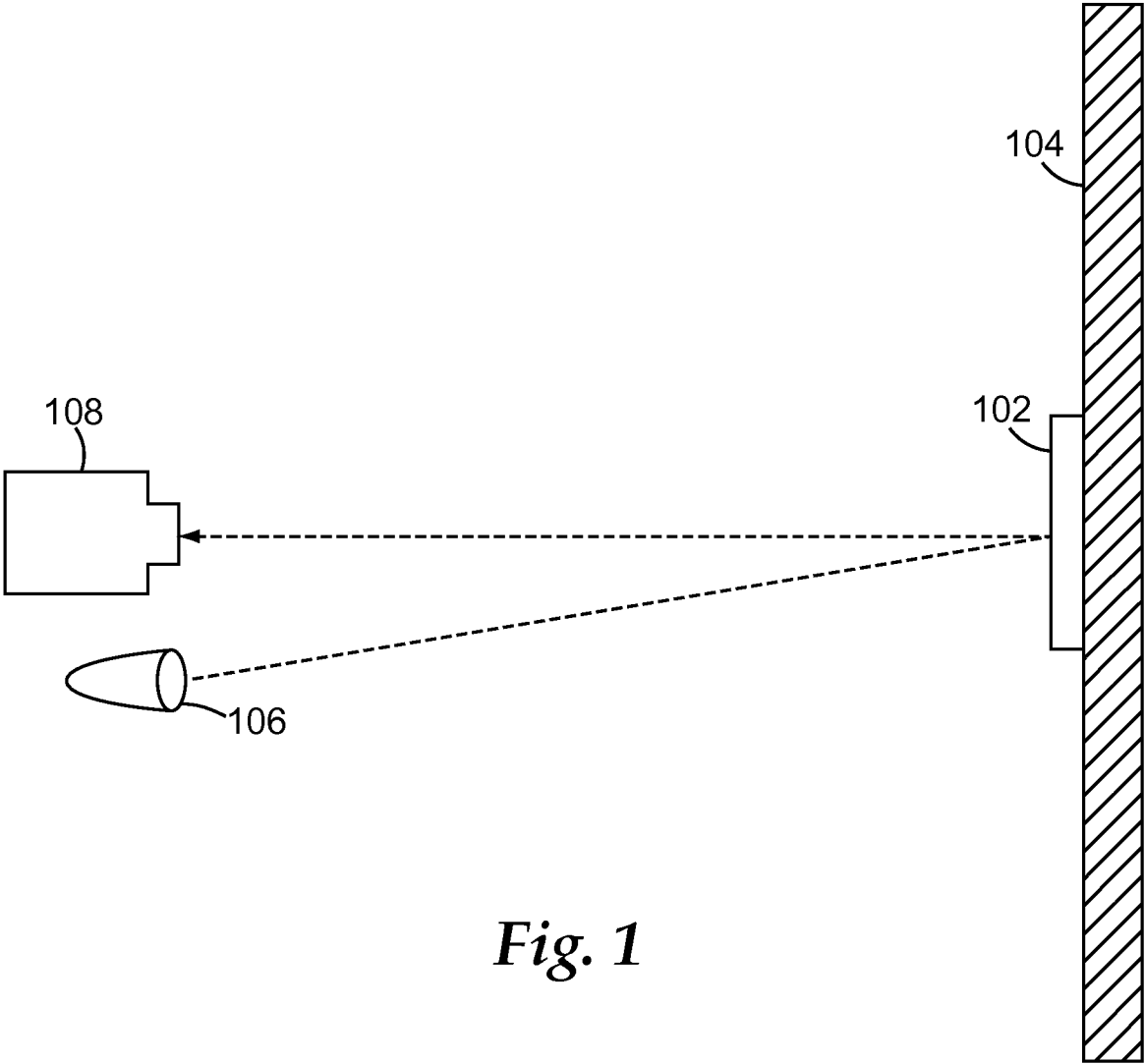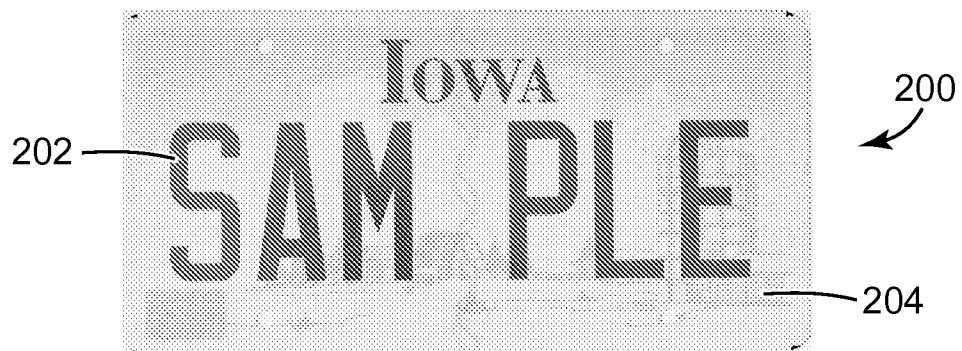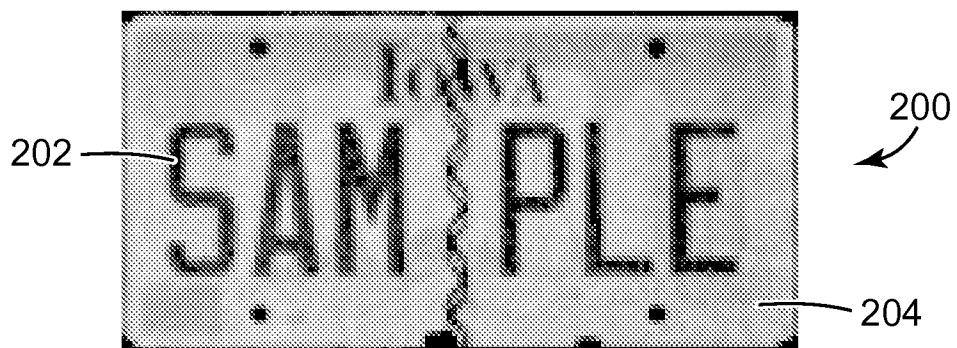   a license plate including the retroreflective sheeting of any of claims 1-6.

104

108

102

106

Fig. 1

Fig. 2A

Fig. 2B
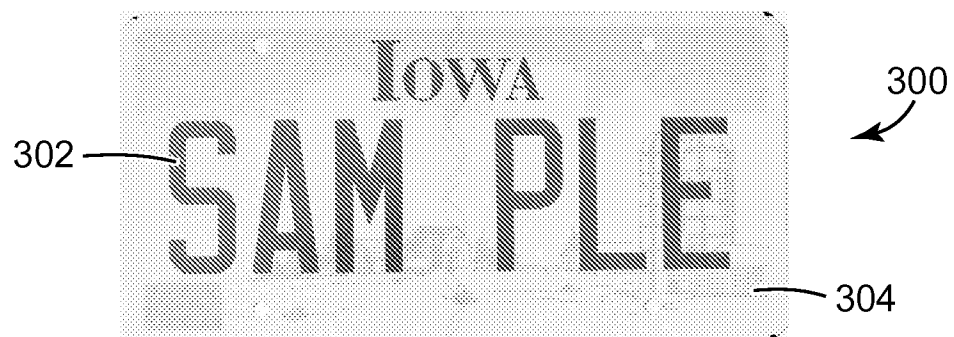
Fig. 3A

Fig. 3B

Fig. 4A
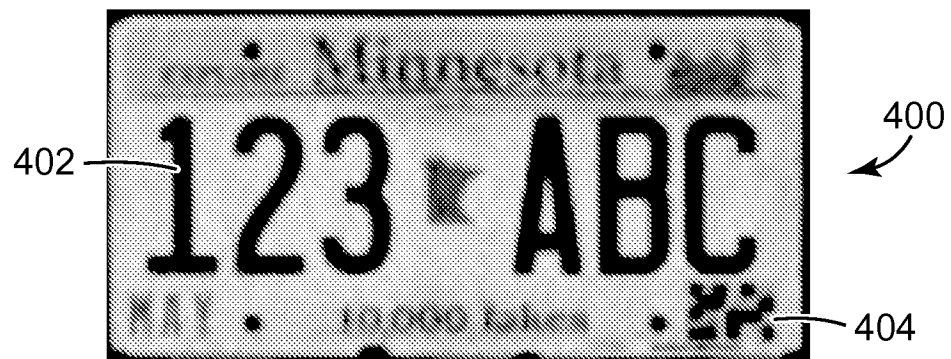
Fig. 4B

INTERNATIONAL SEARCH REPORT	International application No.
	PCT/US2010/051507

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B41M 5/00 (2010.01)
USPC - 428/195.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B41M 5/00, G02B 5/12, and G06K 7/10 (2010.01)
USPC - 428/195.1, 359/515 and 235/468

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

MicroPatent and Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007/0139775 A1 (REICH et al) 21 June 2007 (21.06.2007) entire document	1-8
Y	US 2009/0097034 A1 (GRYGIER et al) 16 April 2009 (16.04.2009) entire document	1-8
Y	US 5,029,023 A (BEARDEN et al) 02 July 1991 (02.07.1991) entire document	4
Y	US 6,832,728 B2 (KENNEDY) 21 December 2004 (21.12.2004) entire document	7

☐ Further documents are listed in the continuation of Box C.   ☐

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 November 2010	0 2 DEC 2010

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450	Blaine R. Copenheaver
Facsimile No. 571-273-3201	PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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