(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 June 2012 (14.06.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/078024 A1

(51) International Patent Classification:
*H01L 35/00* (2006.01)

(21) International Application Number:
PCT/MY2011/000102

(22) International Filing Date:
17 June 2011 (17.06.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI2010700092 10 December 2010 (10.12.2010) MY

(71) Applicant *(for all designated States except US)*: **MIMOS BERHAD** [MY/MY]; Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **WAN JAMIL, Wan, Adil** [MY/MY]; c/o Mimos Berhad, Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY). **AHMED KHOZIM, Amilia** [MY/MY]; c/o Mimos Berhad, Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY). **WITJAKSONO, Gunawan** [ID/ID]; c/o Mimos Berhad, Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY). **ABD RAHMAN, Airul, Azha** [MY/MY]; c/o Mimos Berhad, Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY). **M KARIM, Aymen** [IQ/IQ]; c/o Mimos Berhad, Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY).

(74) Agent: **MOHAN, K.**; Adastra Intellectual Property Sdn Bhd., A-28-10, Menara UOA Bangsar, No. 5, Jalan Bangsar Utama 1, 59000 Kuala Lumpur (MY).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,

*[Continued on next page]*

(54) Title: THERMOELECTRIC GENERATOR FOR SOIL SENSOR MOTE

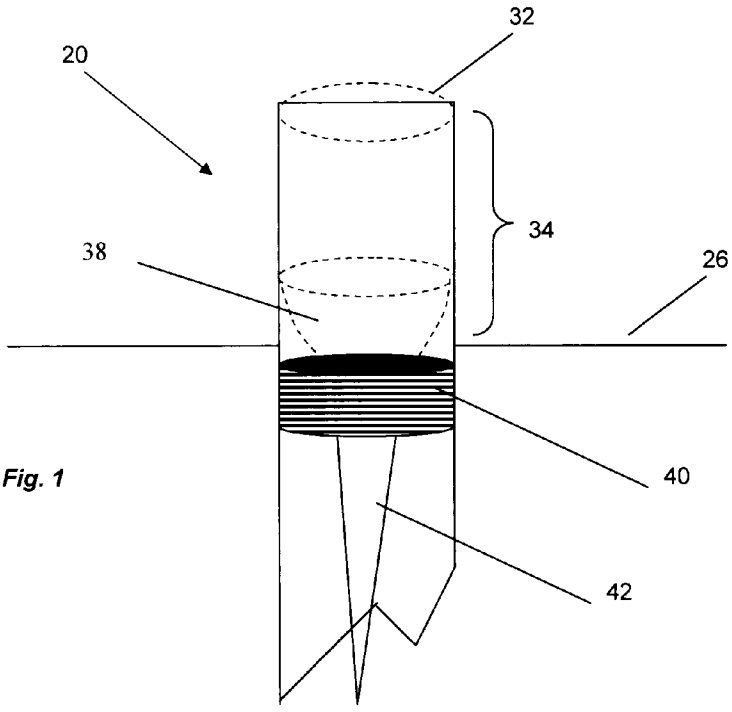



*Fig. 1*

(57) Abstract: The present invention provides a thermoelectric generator for soil sensor mote (20). In the ambient energy harvester, a lens (32) and heat trap compartment (36) provides light concentration (40) which increases the temperature gradient between the ground layers and ground surface (26) of the earth's soil which is detected by cold junction (22) and hot junction (24) respectively. A charge is developed and accumulated in the thermal element (40). The harvested power is then transformed to electrical potential. The micro thermal energy harvester in the soil sensor mote (20) device shall replace the usage of batteries, works even in rain and dry spells seasons, eliminate maintenance drawback and improve the deployment in locality where human assistance is remote.

WO 2012/078024 A1

TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published**:

— *with international search report (Art. 21(3))*

# THERMOELECTRIC GENERATOR FOR SOIL SENSOR MOTE

The present invention relates to thermal gradient power generation, more particularly to thermal power generation for soil sensor mote wireless device to be used in remote monitoring systems.

## BACKGROUND ART

Soil sensor device is used in remote monitoring systems mainly in farming activities. The parameter monitored is mainly soil moisture. The use of soil sensor has been expanded to monitor soil temperature and soil nutrient content. Due to the wide deployment and coverage of sensors required, wireless network is envisioned as the way forward for remote monitoring systems.

Present wireless sensor network rely on battery powered mechanism for power source. However, in term of lifespan, batteries are not sustainable source. For lush areas, the act of changing batteries of exhausted motes is just impractical. Therefore reliable and indefinite power source is required where the underlying lifeline requirement is a stable and zero downtime power management. Efforts are being made to develop a working prototype on non volatile energy source as a substitute for conventional batteries cells in soil monitoring system.

Presently, there is a prior art of a battery-less soil sensor where the solution is based on mechanical vibration. This sensor includes a mechanical energy harvester. The sensor is configured to sense with the power supplied by the mechanical harvester where then non-volatile memory is configured to store output from the sensor.

Another prior art listed a battery-less soil sensor device using RFID. This approach proposes a radio frequency electromagnetic waves energy harvester to run the wireless, battery-less sensor.

The above prior arts have unique specialty and limitation individually. The present invention is made in view of the need to provide energy without requiring routine maintenance by using the existing available resources. A simpler and minimal structure is proposed to achieve this aim while tapping power from an alternative source of power.

## SUMMARY OF INVENTION

The present invention proposes a thermoelectric generator for soil sensor mote device. Thermal power is harvested from temperature gradient between ground layer and surface of the earth's soil. Light is concentrated to achieve an enormous temperature gradient. The harvested energy provides energy even in rain and dry spell seasons without requiring routine maintenance. The thermal-powered soil sensor mote device is an autonomous device working with two section system mechanism: ambient energy harvester and electronic hardware. In the ambient energy harvester section, essential power is harvested from temperature gradient between ground layer and surface of the earth's soil which has shown to be enormous after light concentration. The harvested power is then transformed to electrical potential via the electronic section. The micro thermal energy harvester in the soil sensor device shall replace the usage of batteries, eliminate maintenance drawback and improve the deployment in locality where human assistance is remote.

## BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a sectional drawing of the thermal-powered soil sensor mote.
Fig. 2 is a sectional drawing of the light mechanism and heat trap compartment.
Fig. 3 is a diagram of the thermal element.
Fig. 4 is a block diagram of the thermal energy harvester architecture.

## DESCRIPTION OF EMBODIMENTS

Hereinafter, the present invention is described in detail.

The invention involves a thermal-powered soil sensor device as an autonomous device. The soil sensor mote [20] with the micro energy harvester is shown in Fig. 1.

For the ambient energy harvester, both cold junction [22] and hot junction [24] are exposed at two different temperatures, where cold temperature is obtained in the underground level and the hot temperature is found on the ground surface [26]. The cold temperature underground can have a prevailing temperature of 28°C while the hot temperature of the ground surface after light concentration [28] is raised from nominal 33°C to 80°C. With this, the temperature gradient, $\Delta t$ is approximately 50°C.

Light concentration treatment starts with incident light [30] of the sun being concentrated by means of using lens [32] on top of the heat-trap compartment [34]. A heating plate [36] is housed at the bottom while a reflector [38] is used to preserve heat for an extended period of time. The reflector is a funnel shaped reflector. The pointing light heats up the micro thermal element [40], which by far has recorded a temperature up to 100°C. Likewise, nominal temperature 4 inches below the ground surface is 28°C with a typical variance most of the time of ±3°C. The light concentration mechanism and heat trap compartment [34] are shown in Fig. 2.

A thermal element [40], as shown in Fig. 3, is sandwiched by hot junction [24] on top and cold junction [22] at the bottom to convert heat into electricity. The hot junction [24] is connected to the heat compartment while the cold junction [22] is coupled to a damper rod [42] which is buried underground. This damper rod [42] is to dissipate heat to the ground level.

Inside the thermal element, the temperature gradient develops a charge around the thermal sensitive plates. In the electronic hardware section, accumulated charge is captured by the highly-sensitive capacitor and the dc-converter converts the charge to voltage potential to a certain level that sufficient enough to run wireless sensor mote. Prior to output distribution, the voltage is stored in a storage reservoir such as super capacitor. The large reservoir ensures continuous current flows to the entire system without interruption. As a result a stable output voltage is achievable.

The main blocks of the electronic hardware can be divided into 4 main functions. They are micro thermal element [40], dc-dc converter, storage element and voltage stabilizer prior to stable output voltage. A stable accumulated dc output voltage is developed from thermal element [40] whereby both surface expose to two different temperature gradient, ground and soil surface. This gradient accumulates positive and negative charge electrically. Potential developed at both junctions approximately 10mV/$\Delta$t. This level is sufficient to drive step-up dc-to-dc converter to a satisfactory level to run wireless sensor network motes, transmitter and receiver efficiently.

A stable dc is uncompromised for reliable sensor motes. In securing uninterruptable power supply an efficient storage element is proposed. This could be fulfilled in the form of super-capacitor. As the element is capable to store large charge in a long period of time, continuous current supply to wireless sensor node is tenable. The expected current consumption by wireless sensor note is between 100 -200 mA/h, depending on load

characteristics. The overall architecture of the thermal energy harvester is illustrated in detail in Fig. 4.

Accordingly, the invention disclosed a thermoelectric generator for soil sensor mote [20] device. The thermoelectric generator for soil sensor mote [20] device is an autonomous device working with a two section system mechanism, ambient energy harvester and electronic hardware. In the ambient energy harvester section, the heat trap compartment [36] provides light concentration [28] which increases the temperature gradient between the ground layers and ground surface [26] of the earth's soil which is detected by cold junction [22] and hot junction [24] respectively. A charge is developed and accumulated in the thermal element [40]. The harvested power is then transformed to electrical potential via electronic section. A gradient of 10mV/$\Delta$t is sufficient to drive step-up dc-to-dc converter to a satisfactory level to run wireless sensor network motes efficiently where the expected current consumption by wireless sensor note is between 100 -200 mA/h depending on load characteristics.

CLAIMS

1. A thermoelectric generator [20] for soil sensor mote comprising:
   a thermal element [40] to convert heat into electricity;
   a hot junction element [24] at one end of thermal element [40];
   a lens [32] to concentrate heat on hot junction;
   a heat trap compartment [34] between lens and hot junction element;
   a cold junction element [22] at the other end of thermal element [40]; and
   a damper rod [42] coupled to cold junction;
   wherein hot junction element can receive concentrated and preserved heat while cold junction element can dissipate heat via damper rod to soil, thereby creating a temperature gradient over thermal element.

2. A generator according to claim 1, further comprising a reflector [38] near hot junction.

3. A generator according to claim 1, wherein the reflector [38] is a funnel shaped reflector.

4. A generator according to claim 1, further comprising a heating plate [36] near hot junction to preserve heat.

5. A generator according to claim 1, wherein the damper rod [42] is buried in the soil.

*Fig. 1*

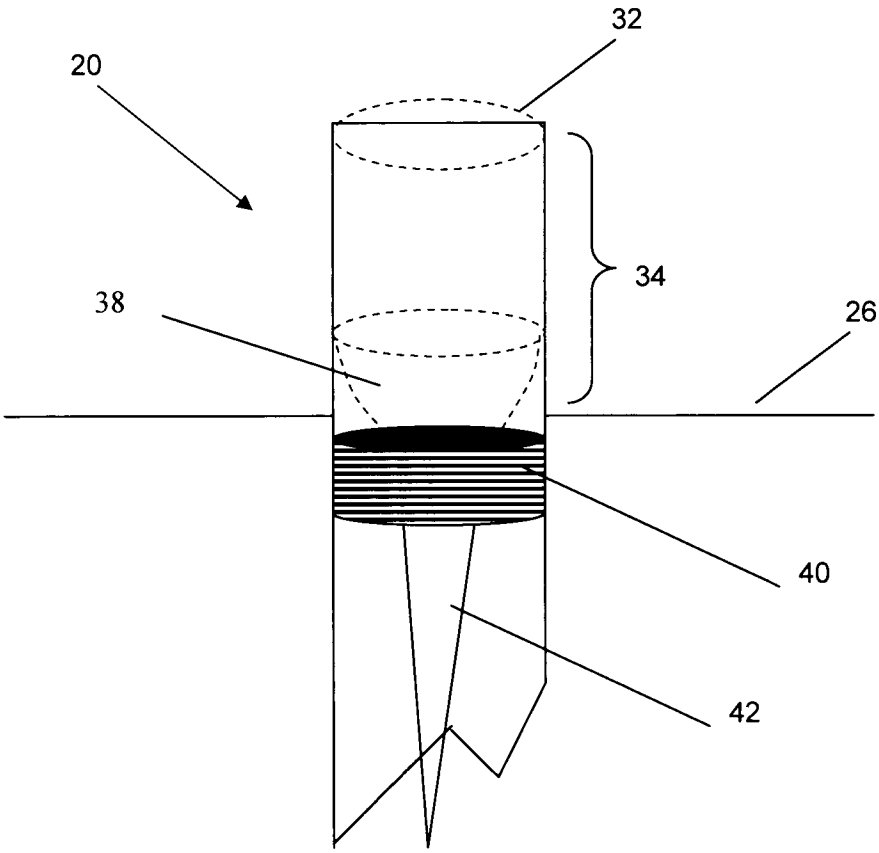


*Fig. 2*

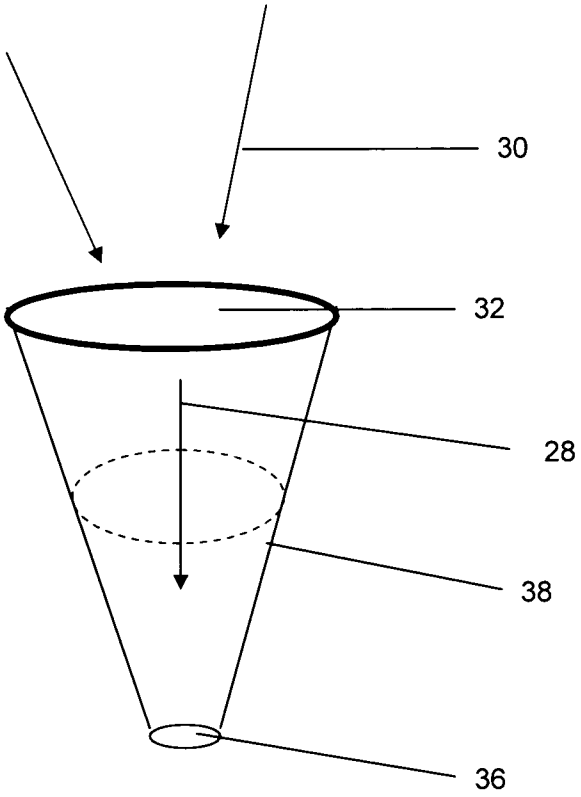


*Fig. 3*

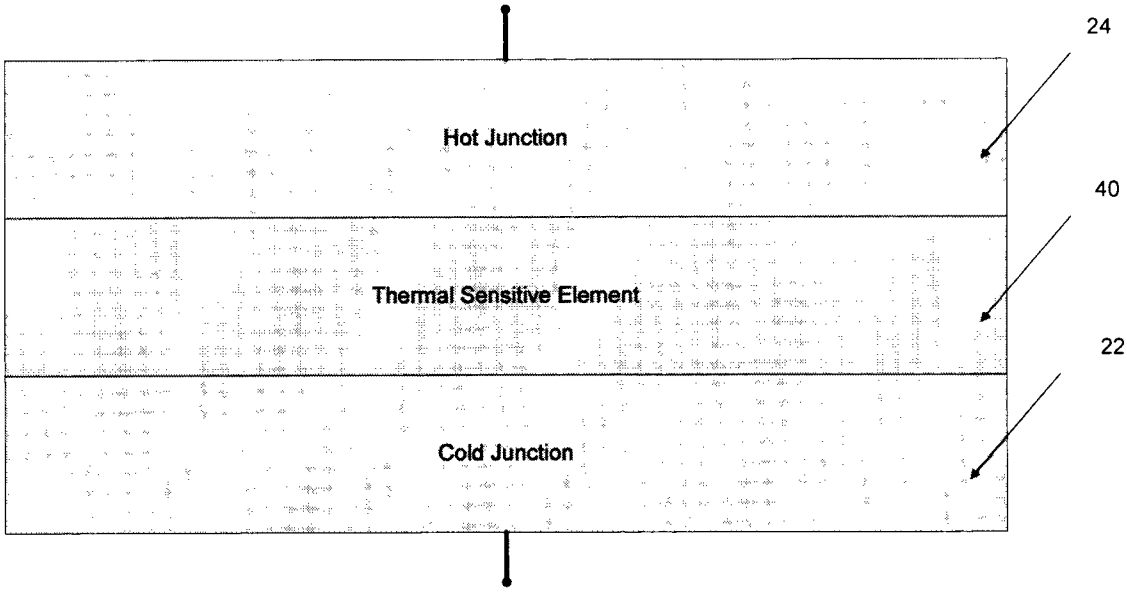
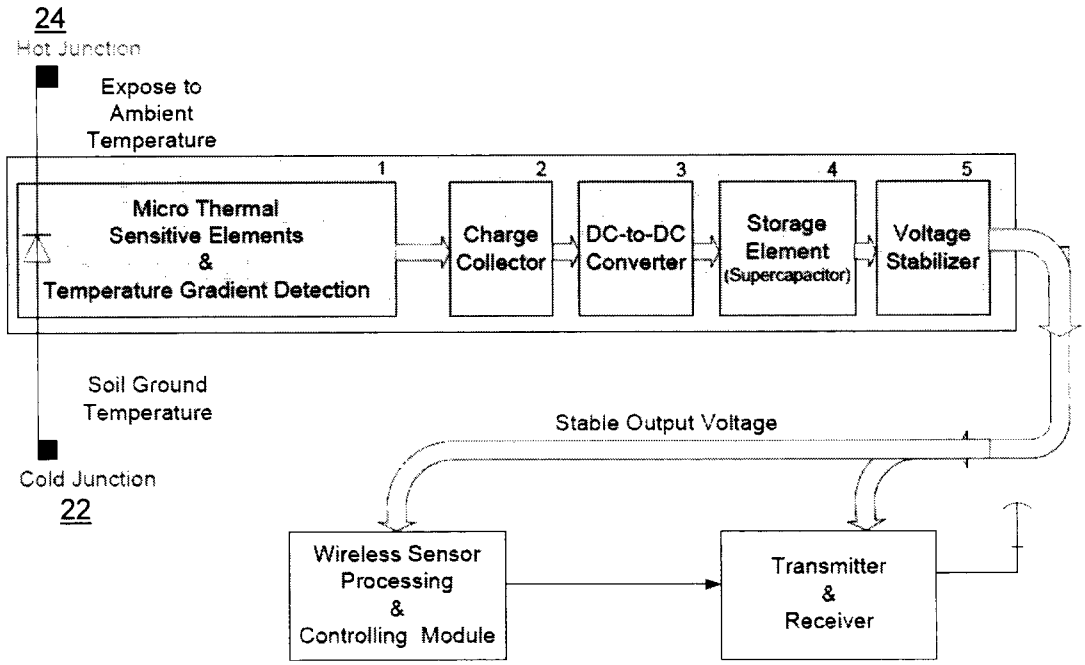

24
Hot Junction
40
Thermal Sensitive Element
22
Cold Junction

*Fig. 4*


24
Hot Junction
Expose to Ambient Temperature
1
Micro Thermal Sensitive Elements & Temperature Gradient Detection
2
Charge Collector
3
DC-to-DC Converter
4
Storage Element (Supercapacitor)
5
Voltage Stabilizer
Soil Ground Temperature
Cold Junction
22
Stable Output Voltage
Wireless Sensor Processing & Controlling Module
Transmitter & Receiver

**INTERNATIONAL SEARCH REPORT**

International application No.
**PCT/MY2011/000102**

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

***H01L 35/00*** (2006.01)

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)

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)
WPI, EPODOC, ESP@CE and Google: Keywords (thermoelectric, generator, sensor, remote, concentrated, soil) and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2005/0115600 A1 (DeSTEESE et al.) 2 June 2005<br>See paragraphs 8, 16 and figure 2 | 1 - 5 |
| Y | US 2009/0260667 A1 (CHEN et al.) 22 October 2009<br>See paragraphs 82, 87 and 95 and figures 6A and 11 | 1 - 5 |
| A | US 2004/0140902 A1 (STAPLES) 22 July 2004<br>see abstract and figures 1 and 3 | |
| A | US 2002/0145538 A1 (BOCKO et al.) 10 October 2002<br>See abstract, paragraph 25 and figures 9 - 13 | |

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

"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

"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)

"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

"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

"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

"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

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 12 September 2011 | 14.09.2011 |
| Name and mailing address of the ISA/AU<br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>E-mail address: pct@ipaustralia.gov.au<br>Facsimile No. +61 2 6283 7999 | Authorized officer<br>**BEN TUOHY**<br>AUSTRALIAN PATENT OFFICE<br>(ISO 9001 Quality Certified Service)<br>Telephone No : +61 2 6283 7918 |

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/MY2011/000102**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent Document Cited in Search Report | | Patent Family Member | | | | | |
|---|---|---|---|---|---|---|---|
| US | 2005115600 | CA | 2549826 | CN | 1890821 | EP | 1692731 |
| | | JP | 2007518252 | KR | 20060110348 | US | 7834263 |
| | | US | 2008173537 | US | 7851691 | US | 2005115601 |
| | | US | 2005139250 | US | 2007125413 | WO | 2006001827 |
| | | WO | 2009045662 | | | | |
| US | 2009260667 | AU | 2007322176 | CA | 2668460 | CN | 101669221 |
| | | EP | 2082442 | EP | 2190041 | JP | 2010509899 |
| | | WO | 2008063474 | | | | |
| US | 2004140902 | US | 6975236 | US | 2006001540 | US | 7439867 |
| US | 2002145538 | US | 6747572 | | | | |

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX