DEFENSE INTELLIGENCE AGENCY

WASHINGTON, D.C. 20340-5100

FOIA-00117-2022
U-22-3606/IMO-2 (FOIA) September 20, 2022

John Greenewald
27305 W. Live Oak Rd. Suite #1203
Castaic, CA 91384

Dear Mr.Greenewald,

This responds to your Freedom of Information Act (FOIA) request, dated March 23, 2022 that you submitted to the Defense Intelligence Agency (DIA) for requesting a copy of records (which includes videos/photos), electronic or otherwise, of the following document: Nanotechnology Applications in Chemical Warfare, published 3 March 2011. I apologize for the delay in responding to your request as DIA continues its efforts to eliminate the large backlog of pending requests.

A search of DIA's systems of records located one document (12 pages) responsive to your request.

Upon review, while considering the foreseeable harm standard, I have determined that some portions of the document must be withheld in part from disclosure pursuant to the FOIA. The withheld portions are exempt from release pursuant to Exemptions 1, 3, and 6 of the FOIA, 5 U.S.C. § 552 (b)(1), (b)(3), and (b)(6). Exemption 1 applies to information properly classified under the criteria of Executive Order 13526. Exemption 3 applies to information specifically exempted by a statute establishing particular criteria for withholding. The applicable statutes are 10 U.S.C. § 424 and 50 U.S.C. § 3024(i). Statute 10 U.S.C. § 424 protects the identity of DIA employees, the organizational structure of the agency, and any function of DIA. Statute 50 U.S.C. § 3024(i) protects intelligence sources and methods. Exemption 6 applies to information which if released would constitute an unwarranted invasion of the personal privacy of other individuals. DIA has not withheld any reasonably segregable non-exempt portions of the records.

If you have additional questions/concerns you may:

Contact the FOIA Public Liaison	Email: FOIA1@dodiis.mil Phone: 301-394-6253
File an administrative appeal (must be submitted within 60 days of the date on the letter) please contact us via one of the following and use FOIA-00117-2022 when referencing your case)	Email: FOIA1@dodiis.mil Mail: Defense Intelligence Agency ATTN: IMO-2C (FOIA) 7400 Pentagon Washington, DC 20301-7400
For mediation services, you may	Email: ogis@nara.gov Phone: 202-741-5770

contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire	Toll-Free 1-877-684-6448 Facsimile: 202-741-5769 Mail: Office of Government Information Services National Archives and Records Administration 8601 Adelphi Road-OGIS College Park, MD 20740-6001

Sincerely,

(for)
Cheryl Cross-Davison
Chief, Records and Open Government

Defense Intelligence Agency

Defense Analysis Report

~~S~~-350-09/(b)(3):10 USC 424 **29 June 2009**

(U) Technology Forecast: Nonconventional Energy Sources for the Future Soldier

~~(C~~//(b)(3):10 USC 424 ***Compact, efficient, lightweight, and long-lasting energy technologies are emerging as a force multiplier in military affairs. Innovative power sources that can outperform the energy density of current batteries and fuel cells promise major weight and volume reductions. Advances in nanotechnologies are playing a crucial role in the development of new energy sources, generators, and harvesters. Many countries, including China, Iran, Japan, Russia, South Korea, and Taiwan, are researching these technologies. DIA judges with moderate confidence that while the United States can maintain its technological superiority in nonconventional energy sources for the next 5 to 10 years, technologies with strong commercial and humanitarian applications could be assimilated by foreign countries with relative ease. These dual-use technologies could then be adapted and implemented into military systems in support of future soldier programs.***

(U) This Defense Analysis Report summarizes the more technically detailed Defense Intelligence Assessment DI-1850-07-09, *(U) Technology Review: Nonconventional Energy Sources for the Future Soldier*, dated June 2009. This document is available on JWICS via hyperlink at: http://www.dia.ic.gov/intel/world_wide/dia/DI-1850-07-09/DI-1850-07-09.htm

(U) Source Summary Statement

~~(S~~//(b)(3):10 USC 424 This analysis relies almost exclusively on open-source intelligence reporting. DIA has moderate confidence in this assessment.

(U) Energy Requirements for the Future Soldier

(U) Many countries around the world have launched initiatives to develop fully integrated infantry soldiers who promise overwhelming battlefield superiority through superior lethality, maneuverability, survivability, endurance, and real-time situational awareness.[1] In order to accomplish this, soldiers must carry an increasing number of power-consuming devices, such as ruggedized computers and communications, global positioning system, remote sensing, and video devices. Currently, a typical 72-hour mission requires each soldier to carry up to 30 pounds of rechargeable batteries (or 20 pounds of nonrechargeable batteries) to supply them with 20 watts of average power for their electronic equipment (based on U.S. equipment). The mission is effectively limited by the weight and charge lifetime of the batteries soldiers carry.

(U) Electrochemical batteries have a primary drawback: an electronic or electrical device's operating time is limited by the size and weight of its battery and any spares carried with it. Although current developments in novel battery and fuel cell power sources have improved their performance considerably, new energy source technologies are needed to mitigate the material limitations of current technologies.

(U) A Plausible Regional Conflict in 2030

(U) Soldiers' special missions currently are limited by their physical endurance and food and water supplies. Their electronic equipment takes advantage of very-large-scale integration techniques and uses isotopic batteries and various energy-harvesting technologies that complement soldiers' battery packs. Small, nonthermal nuclear batteries continuously recharge their conventional batteries while performing their missions. Soldiers' uniforms are embedded with piezoelectric fibers and nanoantennas that convert motion and body heat into electrical power. While resting, soldiers deploy a short, narrow device that captures wind and converts it into electricity to recharge their few batteries. For short-duration missions, soldiers carry only small microturbine-based power generators that are fed by cartridges of hydrogen gas. Their battery packs weigh only one-third as much as, and are twice as small as, battery packs used at the beginning of the 21st century.

(U) Transport vehicles are equipped with wireless power transmitters that charge the soldiers' electronic equipment's batteries while they are being transported to and from the field. Some of the available power in the transport vehicle comes from thermoelectric generators that convert the waste heat from the vehicle's engine into electricity. Soldiers returning from patrol charge their batteries by just leaving their backpacks in a large tent that houses wireless power transmitters.

(U) Some parts of the tents' fabric contain nanoantennas that collect solar radiation (exterior) and heat (interior) and convert them into electricity. Tall, thin masts positioned at various locations throughout the base are actually wind power harvesters that supply the base with extra electrical power.

(U) Motion and chemical sensors powered by small fuel cells containing bacteria are placed on the ground around the base camp to provide early warning against attacks. These sensors require minimal-to-no servicing for years.

(U) Batteries, Fuel Cells, Generators, and Energy Harvesters

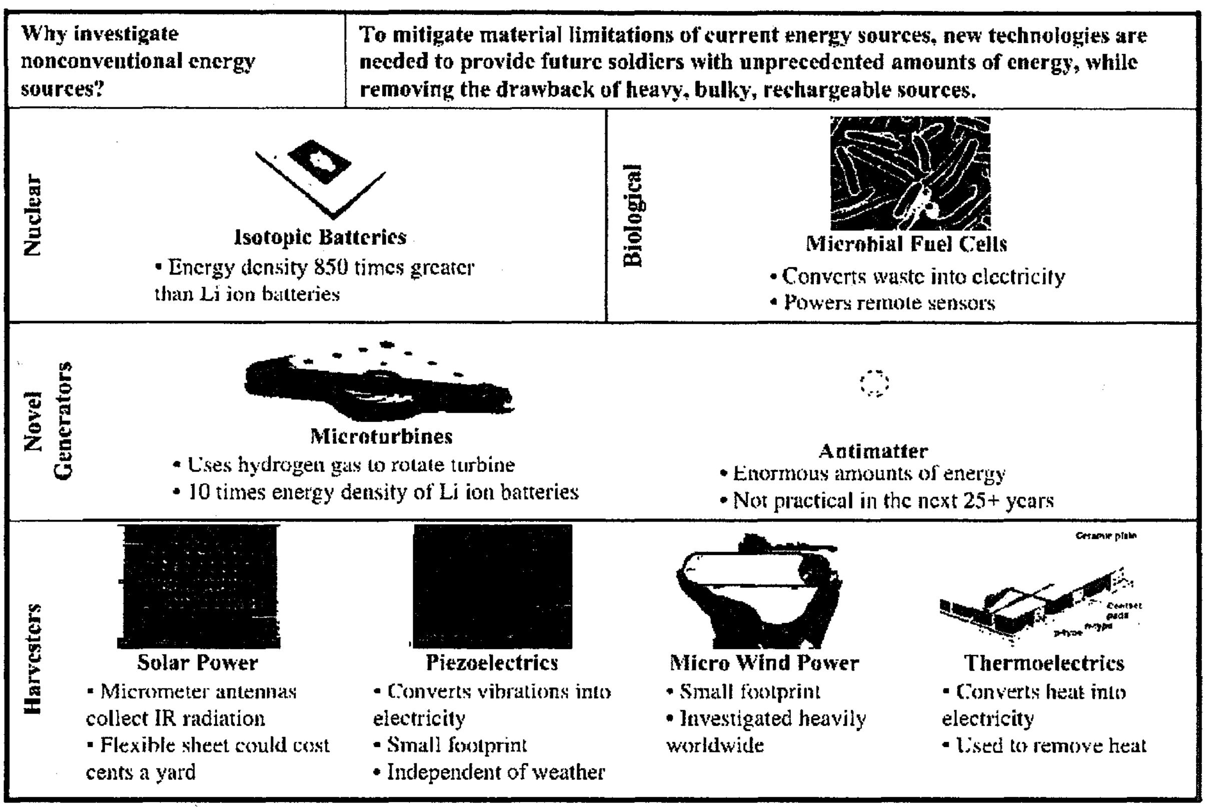
(U) Advances in nanotechnologies are playing a crucial role in the development of compact and efficient energy sources, generators, and harvesters.

- (U) Researchers in a number of countries investigated some promising energy technologies in the 1990s, including isotopic batteries and piezoelectric and thermoelectric generators, but later abandoned this research after failing to achieve progress. However, recent developments in nanotechnology have sparked new interest in these technologies and may make them more feasible.

~~(C/~~(b)(3):10 USC 424 Although betavoltaic batteries have the highest energy density (131,400 watts·hour/kilogram) among power sources, the most promising and practical energy source appears to be microturbine generators (up to 1,500 W·h/kg). Microturbine generators have the potential to produce 10 times more power than today's best lithium-ion batteries of the same weight (see Table 1).

~~(C/~~(b)(3):10 USC 424 The most promising energy harvesters are those made up of piezoelectric generators. These generators do not depend on external sources (the sun or wind, for example) and can almost continuously supply power to electronic devices or rechargeable batteries.

UNCLASSIFIED



(U) Figure 1. Review of Nonconventional Energy Sources for the Future Soldier[2, 3, 4, 5, 6, 7]

(U) Table 1. Summary of Batteries, Fuel Cells, Generators, and Energy Harvesters

~~CONFIDENTIAL~~/(b)(3):10 USC 424

	Technology	Energy/Power Density	Impact*	TRL†
Batteries	Betavoltaics	131,400 (W·h/kg)[8]	Medium	3
	Isotopic Cantilevers	0.00164 (W·h/cm^3)[9]	Medium	3
	Rechargeable Lithium-Ion	150 (W·h/kg)	High	9
Fuel Cells	Micro Direct Methanol	0.385 (W·h/cm^3)[10]	High	7
	Microbial	0.0015 (W/cm^3)[11]	[redacted]	[redacted]
Generators	Antimatter	6.5×10^{20} (W·h/kg)	[redacted]	[redacted]
	Microturbine	1,500 (W·h/kg)[12]	High	4
Harvesters	First-Generation Solar Cells	0.01 (W/cm^2)	Medium	9
	Flexible Piezoelectric Flaps	0.0004 (W/cm^3)[13]	Medium	3
	Micro Wind Power	0.15 (W·h/cm^2)[14]	Medium	8
	Nanoantenna Solar Cells	Not Available	Medium	3
	Nanowire Piezoelectrics	0.000008 (W/cm^2)[15]	Medium	3
	Quantum Dot Solar Cells	Not Available	Medium	3
	Thermoelectric Generators	0.00034 (W/cm^2)[16]	Medium	4
	Vibrating Piezoelectrics	0.00031 (W/cm^3)[17]	Medium	3
	Zero-Point Energy	2.5×10^{104} (W·h/cm^3)[18]	[redacted]	[redacted]

(U) Various technologies can be combined to provide a truly continuous flow of power to electronic devices. For example, betavoltaic batteries and isotopic cantilevers can share the same radioactive element, or a quantum dot solar panel could incorporate thermoelectric generators that can use the heat reflected by the solar cell.

(U) Foreign Research

(U) Microturbines

~~(C//RELIDO)~~ Countries with well-established microchip-fabrication industries, such as China, Japan, Singapore, and South Korea, are conducting concept feasibility, basic research, and structural studies on the development of microengines.[19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29] Because of their associations with the semiconductor industry, these countries could have the potential to become world leaders in microengine development.

* (U) The impact level column refers to the likelihood that a technology will be applied to a future operational environment within a noted time: Low = unlikely within 25 years; Medium = likely within 15 to 25 years; High = likely within 10 to 15 years.

† (U) Technology readiness level, a measure of the maturity of evolving technologies.

(U) Nuclear Batteries

(U) Only a few countries are investigating using nuclear (including isotopic and betavoltaic) batteries for various long-duration missions, such as powering pacemakers or sensors. Austria, Canada, China, Egypt, Malaysia, Russia, and the United States are among the countries with active research efforts in this field.[30, 31, 32]

- (b)(1); Sec. 1.4(c)
- ~~(C//~~ (b)(3):10 USC 424 A comparison of Chinese and U.S. scientific papers on betavoltaic batteries based on porous silicon shows that China's research appears to follow U.S. initiatives in the field.[35]
- (U) Egypt and Malaysia are collaborating on developing cantilever isotopic batteries.[36]
- (U) Canada and the United States are jointly pursuing porous silicon-based betavoltaic batteries.[37]

(U) Piezoelectric Generators

~~(C//~~ (b)(3):10 USC 424 Piezoelectric generators use pressure applied to crystals to generate electricity. Research in Asia appears concentrated in China, where scientists are developing piezoelectric cantilever beam generators for powering sensors and wireless network nodes.[38, 39, 40, 41, 42]

~~(C)~~ South Korean scientists investigated optimizing the circuits of a vibration-based piezoelectric energy generator to efficiently supply power to wireless sensors and electronics for ubiquitous sensor networks, (b)(1); Sec. 1.4(c) In addition, South Korean and U.S. researchers collaborated on developing a cantilever-based piezoelectric power generator.[44]

(U) Other countries interested in piezoelectric generators are Belgium (investigated the power-processing circuits of vibration-based piezoelectrics), France, Taiwan, and the United Kingdom (researched piezoelectric cantilever beam generators).[45, 46, 47, 48]

~~(C//~~ (b)(3):10 USC 424 The Georgia Institute of Technology, the world's leading organization investigating nanowire piezoelectric generators, is actively working with several Chinese and Taiwan universities and institutes on the technology.[49, 50, 51, 52] DIA is uncertain of the impact of this collaboration on the Chinese, Taiwan, or U.S. programs.

- (U) Georgia Tech's work is partly funded by the U.S. Department of Energy, National Science Foundation, Defense Advanced Research Projects Agency, Director Defense Research & Engineering, and National Air and Space Administration.

(U) Solar Power

(C//RELIDO) The currently available solar cells use semiconductor materials to convert solar energy into electrical energy. A new generation of solar cells is being proposed that could use quantum dots (specially engineered nanoscale crystals of semiconductor compounds) to convert energy more efficiently. DIA expects that countries conducting research on commercial applications of quantum dots, such as sensors, lasers, light-emitting diodes, and other optoelectronic devices, will acquire most of the necessary know-how to develop quantum dot solar cells. Japan and the United States are the leaders in solar energy research and have demonstrated forefront research programs in quantum dot solar cells. The European Union identified solar cells as having market potential and is likely to increase funding for quantum dot solar cell research in the near term.[53]

- (U) Japan's University of Tsukuba is currently researching quantum dot solar cells and predicts practical applications with 40 percent conversion efficiency (unconcentrated) by 2020, according to open-source technical reports.[54, 55]

(C//RELIDO) Interlocking arrays of nanometer-sized antennas are another promising technology for collecting solar radiation, especially the infrared part of the spectrum. Several countries are developing and applying these nanoantennas to a wide range of applications, including multispectral sensors, advanced optical telecommunications systems, high-resolution microscopes, secure computer networks, more efficient optical data-storage devices, extremely sensitive pathogens and biowarfare detectors, and brighter and more efficient light-emitting diodes.[56] Countries developing nanoantennas include China, Hungary, Singapore, Switzerland, Taiwan, and the United Kingdom.[57, 58, 59, 60, 61, 62] In addition, Germany and Switzerland; Denmark, France, and the United States; the Netherlands and Spain; Iran and Switzerland; Germany and Russia; and Germany and Spain have collaborated on nanoantenna research.[63, 64, 65, 66, 67, 68] DIA expects these countries to develop the know-how to also apply nanoantennas to solar cells.

(U) Thermoelectric Generators

(U) Thermoelectric generators directly convert heat into electricity. Countries researching various aspects of nano-scale thermoelectric generators include Australia, China, Germany, Japan, Switzerland, and Taiwan.

- (U) Swiss researchers reported the highest energy density (0.00034 watts/cm^2) for an experimental flexible thermoelectric power generator that could be used as a wearable power source.[69]

- (U) Australia, China, and Taiwan recently published scientific papers that characterized and evaluated thermoelectric nano- and micro-sized materials.[70, 71, 72, 73] Germany, meanwhile, showed interest in developing micro-sized thermoelectric generators for use in stand-alone sensor systems for wireless data transmission.[74]

(U) Forecast

(U) Advances in nanotechnologies are playing a crucial role in the development of compact and efficient energy sources, generators, and harvesters.

- (U) Advances in signal processing and very-large-scale integration techniques are likely to reduce the power requirement of portable electronic devices, enhancing the feasibility of nonconventional energy sources. Development of innovative electronic circuits for collecting, managing, and distributing the power produced by these sources will also help their adaptation.

(C/ (b)(3):10 USC 424 [redacted] DIA judges with high confidence that the United States maintains technological superiority in the technologies reviewed and should continue to dominate for the next 5 to 10 years.

(C/ (b)(3):10 USC 424 [redacted] DIA also assesses with high confidence that energy source technologies with strong commercial and humanitarian applications, such as quantum dot solar cells, fuel cells, wind power, and microbial fuel cells for the treatment of sewage and potential purification of water, will probably be developed and incorporated into military systems more quickly and at less cost than will technologies lacking such applications.

(U) Prepared by: (b)(3):10 USC 424; (b)(6) [redacted]

Derived from: (b)(3):10 USC 424 [redacted]
Declassify on: [redacted]

(U) Appendix

(U) Associated Technologies

(U) Wireless Power Transmission

(U) Wireless power transmission devices are capable of transmitting electric power nearly omnidirectionally and with high efficiency.[75, 76] The power transmission is independent of the geometry of the surrounding space and is not affected when objects obstruct the line of sight between the sending and receiving devices. Such a wireless power transmission system could be used on the battlefield to charge a soldier's electronic equipment if the soldier is near a wireless power transmitter. It can also be incorporated in military transport vehicles to enable soldiers to charge their electronics while they are transported to or from the field.

(U) The Casimir Effect

(U) The Casimir effect plays a major role in modern microelectromechanical systems (MEMS) and nanoelectromechanical (NEMS) systems, such as sensors, actuators, and generators, because of its relatively short range. MEMS' and NEMS' small size (typically far less than 1 micrometer) makes them vulnerable to an attractive molecular force (the van der Waals force) that causes friction, limiting the systems' reliability and efficiency. Research teams from China, Mexico, the Netherlands, Norway, and Russia are investigating the means to predict, detect, and dynamically control the Casimir effect in order to counteract the attractive molecular force and produce more efficient and reliable energy-generating MEMS and NEMS.[77, 78, 79, 80, 81, 82]

---

[1] (U) IDA; Sep 2008; **"(U) Worldwide Future Soldier Modernization Programs"**; Overall document classification is U.

[2] (U) Website; *USSOCOM Daily Intel Home Page*; **"(U) Betavoltaic Battery Teases Us with 30 Year Life Span"**; <http://www.socom.us.qlat/oscc/ttr/07/0710/071012/071012pw01.htm>; Overall document classification is **U**.

[3] (U) Website; **"(U) Engine on a Chip"**; <http://thefutureofthings.com/articles.php?itemID=49/58/>; Last accessed 1 Dec 2008; Overall document classification is **U**.

[4] (U) Website; **"(U) Harvesting the Sun's Energy with Antennas"**; <http://inlportal.inl.gov/portal/server.pt?open=514&objID=1269&mode=2&featurestory=DA_101047>; Last accessed 1 Dec 2008; Overall document classification is **U**.

[5] (U) Journal; Y.B. Jeon, R. Sood, J.H. Jeong, S.G. Kim; Jul 2005, *Sensors and Actuators A: Physical*; **"(U) MEMS Power Generator with Transverse Mode Thin Film PZT"**; Vol. 122, Issue 1, pp. 16-22; Overall document classification is **U**.

[6] (U) Website; **"(U) Humdinger Wind Energy"**; <http://www.humdingerwind.com>; Last accessed 16 Oct 2008; Overall document classification is **U**.

[7] (U) Journal; Cronin B. Vining; Oct 2001; *Nature*; **"(U) Semiconductors Are Cool"**; Vol. 413, pp. 577-78; Overall document classification is **U**.

[8] (U) Briefing; M.V.S. Chandrashekhar, C.I. Thomas, Hui Li, M.G. Spencer, Amit Lal; Oct 2005; Cornell Multidisciplinary Sensor Network Workshop; **"(U) Design and Fabrication of a 4H SiC Betavoltaic Cell"**; Overall document classification is **U**.

[9] (U) Journal; A. Lal, R. Duggirala, H. Li; Jan-Mar 2005; *IEEE Journal of Pervasive Computing*; **"(U) Pervasive Power: A Radioisotope-Powered Piezoelectric Generator"**; Vol. 4, Issue 1, pp. 53-61; Overall document classification is U.

[10] (U) Website; **"(U) Micro Fuel Cells Get Closer to Replacing Batteries"**; <http://www.physorg.com/news146139643.html>; Last accessed 7 Apr 2009; Overall document classification is U.

[11] (U) Website; Aug 2007; **"(U) Breakthrough in Microbial Fuel Cell Design Boost Electricity Production"**; <http://www.engr.oregonstate.edu/news/story/2185>; Last accessed 31 Oct 2008; Overall document classification is U.

[12] (U) Website; **"(U) Engine on a Chip"**; <http://thefutureofthings.com/articles.php?itemID=49/58/>; Last accessed 1 Dec 2008; Overall document classification is U.

[13] (U) Journal; William Robbins, Ian Marusic; Feb 2006; *Proceedings from Reforming the Electric Energy Systems Curriculum Workshop*; **"(U) Wind-Generated Electricity Using Flexible Piezoelectrics"**; Overall document classification is U.

[14] (U) Website; **"(U) Micro Wind Turbines: Small Size, Big Impact"**; <http://www.inhabitat.com/2007/03/21/micro-wind-turbines-small-size-big-impact>; Last accessed 17 Dec 2008; Overall document classification is U.

[15] (U) Website; **"(U) Remarkable New Clothing May Someday Power Your iPod"**; <http://www.nsf.gov/news/news_summ.jsp?cntn_id=111038>; Last accessed 5 Dec 2008; Overall document classification is U.

[16] (U) Journal; E. Schwyter, W. Glatz, L. Durrer, C. Hierold; May 2008; *arXiv.org*; **"(U) Flexible Micro Thermoelectric Generator based on Electroplated $Bi_{2+x}Te_{3-x}$"**; <http://arxiv.org/ftp/arxiv/papers/0805/0805.0937.pdf>; Overall document classification is U.

[17] (U) Journal; N.E. Dutoit, B.L. Wardle; Nov 2006; *Integrated Ferroelectrics*; **"(U) Performance of Microfabricated Piezoelectric Vibration Energy Harvesters"**; Vol. 83, Issue 1, pp. 13-32; Overall document classification is U.

[18] (U) Book; Charles W. Misner, Kip S. Thorne, John A. Wheeler; 1973; ***(U) Gravitation***; Overall document classification is U.

[19] (U) Journal; P. Jin, Y.L. Gao, N. Liu, J.B. Tan, K. Jiang; Oct 2006; *International Symposium on Instrumentation Science and Technology*; **"(U) Design and fabrication of Alumina Micro Reciprocating Engine"**; Overall document classification is U.

[20] (U) Journal; W.M. Yang, S.K. Chou, H. Xue, Z.W. Li, D.T. Li, J.F. Pan; Sep 2003; *Energy Conversion and Management*; **"(U) Microscale Combustion Research For Application To Micro Thermophotovoltaic Systems"**; Vol. 44, Issue 16, pp. 2625-34; Overall document classification is U.

[21] (U) Journal; M. Ishiham, Y. Sakai, K. Matsuzuki, T. Hikone; Nov 2003; *International Gas Turbine Congress*; **"(U) Structural Analysis Of Rotational Pars Of An Ultra-Micro Gas Turbine"**; Overall document classification is U.

[22] (U) Journal; X.C. Shan, Q.C. Zhang, Y.F. Sun, Maeda; R.; Apr 2006; *Symposium on Design, Test, Integration and Packaging of MEMS and MOEMS*; **"(U) A Micro Turbine Device With Enhanced Micro Air Bearings"**; Overall document classification is U.

[23] (U) Journal; K. Hashimoto, J. Ogawa, T. Toriyama, S. Sugiyama; Oct 2003; *Proceedings from Micromechatronics and Human Science*; **"(U) Design And Fabrication of a Resonant Micro Reciprocating Engine For Power Generation"**; Overall document classification is U; pp. 293-97.

[24] (U) Journal; T. Nagazaki, R. Tokue, S. Kashima, Y. Ito; Nov 2003; *International Gas Turbine Congress*; **"(U) Conceptual Design of Recuperator for Ultramicro Gas Turbine"**; Overall document classification is U.

[25] (U) Journal; X.C. Shan, Q.C. Zhang, Y.F. Sun, Maeda, R.; Apr 2006; *Symposium on Design, Test, Integration and Packaging of MEMS and MOEMS*; **"(U) A Micro Turbine Device With Enhanced Micro Air Bearings"**; Overall document classification is U.

[26] (U) Journal; M. Wu, J.S. Hua, K. Kumar; Oct 2005; *Micromechanics and Microengineering*; **"(U) An Improved Micro-Combustor Design For A Micro Gas Turbine And Numerical Analysis"**; Vol. 15, No. 10, pp. 1817-23; Overall document classification is U.

[27] (U) Journal; W.M. Yang, S.K. Chou, H. Xue, Z.W. Li, D.T. Li, J.F. Pan; Sep 2003; *Energy Conversion and Management*; **"(U) Microscale Combustion Research For Application To Micro Thermophotovoltaic Systems"**; Vol. 44, Issue 16, pp. 2625-34; Overall document classification is U.

~~SECRET//NOFORN~~

---

[28] (U) Journal; X.C. Shan, Q.C. Zhang, Y.F. Sun, Maeda, R.; Apr 2006; *Symposium on Design, Test, Integration and Packaging of MEMS and MOEMS*; **"(U) A Micro Turbine Device With Enhanced Micro Air Bearings"**; Overall document classification is U.

[29] (U) Journal; J.S. Kim, H.C. Choi, K.H. Kim; Aug 2005; *International Energy Conversion Engineering Conference*; **"(U) Performance Characteristics Of Scale-Up Models With Two-Dimensional Rotors For A Micro Gas Turbine"**; Overall document classification is **U**.

[30] (U) Journal; A. Janek, C. Trummer, C. Steger, R. Weiss, J. Preishuber-Pfluegl, M. Pistauer; Aug 2007; *Euromicro Conference on Digital System Design Architectures, Methods, and Tools*; **"(U) Simulation Based Verification of Energy Storage Architectures for Higher Class Tags Supported by Energy Harvesting Devices"**; pp. 462-63; Overall document classification is **U**.

[31] (U) Journal; V.M. Andreev, A.G. Kevetsky, V.S. Kaiinovsky, V.P. Khvostikov, V.R. Larionov, V.D. Rumyantsev, M.Z. Shvarts, E.V. Yakimova, V.A. Ustinov; 2000; *IEEE Conference on Photovoltaic Specialists*; **"(U) Tritium-Powered Betacells based on $Al_xGa_{1-x}As$"**; pp. 1253-56; Overall document classification is **U**.

[32] (U) Journal; A.A. Pustovalov, V.V. Gusev, V.V. Zadde, N.S. Petrenko, L.A. Tsvetkov, A.V. Tikhomirov; Mar 2008; *Atomic Energy*; **"(U) ^{63}Ni-Based β–Electric Current Source"**; Vol. 103, No. 6, pp. 939-45; Overall document classification is U.

(b)(1); (b)(3):10 USC 424; Sec. 1.4(c)

[redacted]

[35] (U) Journal; Hang Guo, Hui Yang, Ying Zhang; Jan 2007; *IEEE Conference on Micro Electro Mechanical Systems*; **"(U) Betavoltaic Microbatteries Using Porous Silicon"**; pp. 867-70; Overall document classification is **U**.

[36] (U) Journal; M.H. Hassan, W.F. Faris; Aug 2007; *International Conference on Mechatronics and Automation*; **"(U) Modeling of a Self Reciprocating Cantilever for a MEMS Nuclear Battery Power by an Alpha Source"**; pp. 2758-62; Overall document classification is **U**.

[37] (U) Journal; T. Kosteski, N.P. Kherani, P. Stradins, F. Gaspari, W.T. Shmayda, L.S. Sidhu, S. Zukotynski; Aug 2003; *IEEE Proceedings on Circuits, Devices and Systems Conference*; **"(U) Tritiated Amorphous Silicon Betavoltaic Devices"**; Vol. 150, Issue 4, pp. 274-81; Overall document classification is **U**.

[38] (U) Journal; Xiaozhen Du, Jinkui Chu, Shuanghui Wei; Jan 2007; *Proceedings from Integration and Commercialization of Micro and Nanosystems Conference 2007*; **"(U) Analysis of Output Voltages for Piezoelectric Cantilever Generator Based on Vibration Energy Harvesting"**; Overall document classification is **U**.

[39] (U) Journal; Huabin Fang, Jingquan Liu, Zhengyi Xu, Lu Dong, Li Wang, Di Chen, Bingchu Cai, Yue Liu; Nov 2006; *Microelectronics Journal*; **"(U) Fabrication and Performance of MEMS-Based Piezoelectric Power Generator for Vibration Energy Harvesting"**; Vol. 37, Issue 11, pp. 1280-84; Overall document classification is **U**.

[40] (U) Journal; Huabin Fang, Jingquan Liu, Zhengyi Xu, Xinhui Mao, XiuCheng Shen, Di Chen, Bingchu Cai, Hang Liao; May 2008; *Microelectronics Journal*; **"(U) A MEMS-Based Piezoelectric Power Generator Array for Vibration Energy Harvesting"**; Vol. 39, Issue 5, pp. 802-06; Overall document classification is **U**.

[41] (U) Journal; J.H. Lin, X. M. Wu, T.L. Ren, L.T. Liu; Dec 2007; *Integrated Ferroelectrics*; **"(U) Modeling and Simulation of Piezoelectric MEMS Energy Harvesting Device"**; Vol. 95, Issue 1, pp. 128-141; Overall document classification is **U**.

[42] (U) Journal; Jingquan Liu, Huabin Fang, Zhengyi Xu, Xinhui Mao, Xiucheng Shen, Di Chen, Hang Laio, Bingchu Cai; May 2008; *Microelectronics Journal*; **"(U) A MEMS-Based Piezoelectric Power Generator Array for Vibration Energy Harvesting"**; Vol. 39, Issue 5, pp. 802-06; Overall document classification is **U**.

[43] (U) (b)(3):50 USC 3024(i) [redacted] *(U) The South Korean Research Paper On Circuit Requirements For Mems-Based Mechanical-To-Electrical Power Conversion Presented At The Photonics West Symposium in January 2008*; Overall document classification is **C**.

[44] (U) Journal; Y.B. Jeon; R. Sood, J.H. Jeong, S.G. Kim; Jul 2005; *Sensors and Actuators A*; **"(U) MEMS Power Generator with Transverse Mode Thin Film PZT"**; Vol. 122, Issue 1, pp. 16-22; Overall document classification is U.

[45] (U) Journal; R. D'hulst, J. Driesen; Jun 2008; *Proceedings from IEEE Power Electronics Specialists Conference*; **"(U) Power Processing Circuits for Vibration-Based Energy Harvesters"**; Overall document classification is U.

[46] (U) Journal; Swee L. Kok, Neil M. White, Nick R. Harris; Oct 2008; *IEEE Sensors*; **"(U) A Free-Standing, Thick-Film Piezoelectric Energy Harvester"**; Overall document classification is U.

[47] (U) Journal; B.S. Lee, W.J. Wu, W.P. Shih, D. Vasic, F. Costa; Oct 2007; *IEEE Ultrasonic Symposium*; **"(U) Power Harvesting Using Piezoelectric MEMS Generator with Interdigital Electrodes"**; pp. 1598-1601; Overall document classification is U.

[48] (U) Journal; Romain Guigon, Jean-Jacques Chaillout, Thomas Jager, Ghislain Despesse; Jan 2008; *Smart Materials and Structures*; **"(U) Harvesting Raindrop Energy: Experimental Study"**; Vol. 17; Overall document classification is U.

[49] (U) Journal; Xudong Wang, Jun Zhou, Jinhui Song, Jin Liu, Ningsheng Xu, Zong L. Wang; 2006; *Nano Letters*; **"(U) Piezoelectric Field Effect Transistor and Nanoforce Sensor Based on a Single ZnO Nanowire"**; Vol. 6, No. 12, pp. 2768-72; Overall document classification is U.

[50] (U) Journal; Zhonglin Wang, Jinhui Song; Apr 2006; *Science*; **"(U) Piezoelectric Nanogenerators Based on Zinc Oxide Nanowire Arrays"**; Vol. 312, No. 5771, pp. 242-46; Overall document classification is U.

[51] (U) Journal; Jin Liu, Peng Fei, Jun Zhou, Rao Tummala, Zhonglin Wang; 2008; *Applied Physics Letters*; **"(U) Toward High Output-Power Nanogenerator"**; Vol. 92; Overall document classification is U.

[52] (U) Journal; Jinhui Song, Xudong Wang, Jin Liu, Huibiao Liu, Yuliang Li, Zhonglin Wang; 2008; *Nano Letters*; **"(U) Piezoelectric Potential Output from ZnO Nanowire Functionalized with p-Type Oligomer"**; Vol. 8, No. 1, pp. 203-07; Overall document classification is U.

[53] (U) Website; 21 Sep 2007; **"(U) Merging Optics and Nanotechnology (MONA) Roadmap"**; <http://www.ist-mona.org>; Last accessed 1 Mar 2008; Overall document classification is U.

[54] (U) OSC; **PP20070711134003**; 2007; *(U) Japan: Experiment of Quantum-Dot Type Solar Cell Shows Better Solar Power Output*; Overall document classification is U.

[55] (U) OSC; **JPP20080425134001**; 2008; *(U) Japan: Team Seeks To Achieve 40-Percent Conversion Efficiency of Solar Cell*; Overall document classification is U.

[56] (U) DIA; Defense Intelligence Digest; 26 Nov 2007; *(U) Low Cost Wide-Band Sensors Could Threaten U.S. Weapons*; Overall document classification is C.

[57] (U) Journal; Sergei Kuhn, Ulf Hakanson, Lavinia Rogobete, Vahid Sandoghdar; Jul 2006; *Physics Review Letters*; **"(U) Enhancement of Single-Molecule Fluorescence Using a Gold Nanoparticle as an Optical Nanoantenna"**; Vol. 97; Overall document classification is U.

[58] (U) Journal; W. Dickson, G.A. Wurtz, P. Evans, D. O'Connor, R. Atkinson, R. Pollard, A.V. Zavats; Sep 2007; *Physical Review B*; **"(U) Dielectric-Loaded Plasmonic Nanoantenna Arrays: A Metamaterial with Tunable Optical Properties"**; Vol. 76; Overall document classification is U.

[59] (U) Journal; M.W. Chen, F.H. Ho, M.C. Lin, D.P. Tsai; Sep-Oct 2004; *Scanning*; **"(U) Localization of Optical Fields Using a Bow-Tie Nanoantenna"**; Vol. 26; Overall document classification is U.

[60] (U) Journal; L. Yang, C. Du, X. Luo; Jul 2008; *Applied Physics B*; **"(U) Numerical Study of Optical Properties of Single Silver Nanobowtie with Anisotropic Topology"**; Vol. 92, No. 1, pp. 53-59; Overall document classification is U.

[61] (U) Journal; Gabor Matyi, Arpad Csurgay, Wolfgang Porod; Aug 2006; *Proceedings from IEEE International Symposium on Circuits and Systems*; **"(U) Nanoantenna Design for THz-Band Rectification"**; pp. 197-99; Overall document classification is U.

[62] (U) Journal; Yuming Wu, Lewei Li, Bo Liu; 2007; *Proceedings from ISAP 2007*; **"(U) Nanoantennas: From Theoretical Study of Configurations to Potential Applications"**; Overall document classification is U.

[63] (U) Journal; T. Kalkbrenner, U. Hakanson, A. Schadle, S. Burger, C. Henkel, V. Sandoghdar; Nov 2005; *Physics Review Letters*; **"(U) Optical Microscopy Via Spectral Modifications of a Nanoantenna"**; Vol. 95; Overall document classification is U.

[64] (U) Journal; R.M. Bakker, A. Boltasseva, Z.T. Liu, R.H. Pedersen, S. Gresillon, A.V. Kildishev, V.P. Drachev, V.M. Shalaev; Oct 2007; *Optics Express*; **"(U) Near-Field Excitation of Nanoantenna Resonance"**; Vol. 15, No. 21, pp. 13682-88; Overall document classification is U.

[65] (U) Journal; T.H. Taminiau, R.J. Moerland, F.B. Segerink, L. Kuipers, N.F. van Hulst; 2007; *Nanoletters*; **"(U) $\lambda/4$ Resonance of an Optical Monopole Antenna Probed by Single Molecule Fluorescence"**; Vol. 7, No. 1, pp. 28-33; Overall document classification is U.

[66] (U) Journal; A. Mohammadi, V. Sandoghdar, M. Agic; Oct 2008; *arXiv:0807.4082v2*; **"(U) Gold, Copper, Silver and Aluminum Nanoantennas to Enhance Spontaneous Emission"**; Overall document classification is U.

[67] (U) Journal; A. Christ, G. Leveque, O.J.F. Martin, T. Zentgraf, J. Kuhl, C. Bauer, H. Giessen, S.G. Tikodeev; May 2007; *Microscopy*; **"(U) Near-Field-Induced Tunability of Surface Plasmon Polaritons in Composite Metallic Nanostructures"**; Vol. 229, Issue 2, pp. 344-53; Overall document classification is U.

[68] (U) Journal; F. Neubrech, A. Pucci, T. Cornelius, S. Karim, A. Garcia-Etxarri, J. Aizpurua; Oct 2008; *Physics Review Letters*; **"(U) Resonant Plasmonic and Vibrational Coupling in a Tailored Nanoantenna for Infrared Detection"**; Overall document classification is U.

[69] (U) Journal; E. Schwyter, W. Glatz, L. Durrer, C. Hierold; May 2008; *arXiv.org*; **"(U) Flexible Micro Thermoelectric Generator based on Electroplated $Bi_{2+x}Te_{3-x}$"**; <http://arxiv.org/ftp/arxiv/papers/0805/0805.0937.pdf>; Overall document classification is U.

[70] (U) Journal; W.J. Xie, X.F. Tang, G. Chen, Q. Jin, Q.J. Zhang; Jun 2007; *Proceedings of IEEE*; **"(U) Nanostructure and Thermoelectric Properties of P-Type $Bi_{0.5}Sb_{1.5}Te_3$ Compound Prepared by Melt Spinning Technique"**; pp. 23-26; Overall document classification is U.

[71] (U) Journal; Q.M. Lu, J.X. Zhang, X. Zhang, Q. Wei; Aug 2006; *Proceedings of IEEE*; **"(U) Synthesis and Thermoelectric Properties of Nano/Micro-Meter $CoSb_3$ Based Bulks Processed by In-Situ Spark Plasma Sintering"**; pp. 148-50; Overall document classification is U.

[72] (U) Journal; L. Chia, L. Gao, T. Chun, L. Yu, C. Li; Jun 2007; *Proceedings of IEEE*; **"(U) Thermoelectric Characteristics of Solvothermally Prepared $(BiSb)_2Te_3$ Mats Containing Nanosize Of Sheet-Tubes"**; pp. 30-33; Overall document classification is U.

[73] (U) Journal; H. Bottner, J. Nurmus, A. Schubert, F. Volkert; June 2007; *Proceedings of IEEE*; **"(U) New High Density Micro Structured Thermogenerators For Stand Alone Sensor Systems"**; pp. 306-09; Overall document classification is U.

[74] (U) OSC; **EUP20060727374013**; 31 May 2006; *(U) Nanomaterials in Energy-Conversion Applications*; Overall document classification is U.

[75] (U) Journal; Aristeidis Karalis, J.D. Joannopoulos, Marin Soljacic; 2008; *Annals of Physics*; **"(U) Efficient Wireless Non-Radiative Mid-Range Energy Transfer"**; Vol. 323, pp. 34-48; Overall document classification is U.

[76] (U) Journal; Andre Kurs, Aristeidis Karalis, Robert Moffatt, J.D. Joannopoulos, Peter Fisher, Marin Soljacic; Jul 2007; *Science*; **"(U) Wireless Power Transfer Via Strongly Coupled Magnetic Resonances"**; Vol. 317, No. 5834, pp. 83-86; Overall document classification is U.

[77] (U) Journal; W.H. Lin, Y.P. Zhao; Feb 2005; *Microsystem Technologies*; **"(U) Casimir Effect on the Pull-In Parameters of Nanometer Switches"**; Vol. 11, No. 2-3; pp. 80-85; Overall document classification is U.

[78] (U) Journal; R. Esquivel-Sirvent, L. Reyes, J. Barcenas; Oct 2006; *New Journal of Physics*; **"(U) Stability and the Proximity Theorem in Casimir Actuated Nano Devices"**; Vol. 8; Overall document classification is U.

[79] (U) Journal; F. Chen, G.L. Klimchitskaya, V.M. Mostepanenko, U. Mohideen; 2006; *Physical Review Letters*; **"(U) Demonstration of the Difference in the Casimir Force for Samples with Different Charge-Carrier Densities"**; Vol. 97; Overall document classification is U.

[80] (U) Journal; M. Lisanti, D. Iannuzzi, F. Capasso; Aug 2005; *Proceedings of the National Academy of Sciences*; **"(U) Observation of the Skin-Depth Effect on the Casimir Force Between Metallic Surfaces"**; Vol. 102, No. 34, pp. 11989-11992; Overall document classification is U.

[81] (U) Journal; M. Lisanti, D. Iannuzzi, F. Capasso; Mar 2004; *Proceedings of the National Academy of Sciences*; **"(U) Effect of Hydrogen-Switchable Mirrors on the Casimir Force"**; Vol. 101, No. 12, pp. 4019-23; Overall document classification is U.

[82] (U) Journal; I. Brevik, J.B. Aarseth, J.S. Hoye, K.A. Milton; May 2005; *Physical Review E*; **"(U) Temperature Dependence of the Casimir Effect"**; Vol. 71; Overall document classification is U.