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NANO-ANTENNA: A WINDOW TO A WIRELESSLY CONNECTED WORLD

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ABSTRACT

A nano-antenna is a type of solar cell that makes use of infrared radiation to create electricity instead of harnessing visible light to create electricity where infrared radiation is often believed as heat and exists beyond the visible range for humans. Infrared light is emitted from the Earth and also from various industrial processes like waste energy and coal-fired power plants. One version of the nano-antenna takes the shape of a microscopically small gold square or spiral of metal wire about 1/25th the diameter of a human hair that is embedded in a flexible polyethylene plastic sheet. In researches, the devices have been shown to be as high as 92% efficient at converting the frequencies of infrared light which they capture and convert into electrical energy. Finally, we conclude the current status of this field and the major establishments and emerging lines of analysis in this area of research. The sharing and coordination of information among these nano-devices leads towards the development of nano-networks in the future, increasing the range of applications of nanotechnology in the environmental, biomedical and military fields.

INTRODUCTION

Robert Bailey and James C. Fletcher filled a patent in 1973 for an electromagnetic wave converter. In 1984, Alvin M. Marks patented a device which explicitly stated the use of sub-micron antennas for the direct conversion of light power to electrical power. Guang H. Lin in 1996 reported resonant light absorption by a fabricated nanostructure and rectification of light with frequencies in the visible range. And in 2002, ITN Energy Systems, Inc. published a report on their work on optical antennas coupled with high frequency diodes. ITN build a nano-antenna array with single digit efficiency. Although they were unsuccessful, the issues associated with building a high efficiency nano-antenna were better understood. Research on nano-antennas is ongoing. Nano-antennas are useful for converting solar radiation into electricity. Adamant supplies of clean energy result in the growth of economic prosperity, global stability and quality of life. One of the societies challenge is to find energy resources to satisfy the world's growing demand for the next half century.

MATERIALS AND METHODS

Nowadays energy rate consumption is approximately 4.1x1020 Joule/year, equaling to the continuous power consumption of 13 trillion watts. Even with dynamic conservation and energy efficiency measures, and increase in earth's population, accompanied by rapid technology development where economic growth worldwide is estimated to produce more than double the demand for energy up to 30 TW by 2050 and more than triple the demand up to 40 TW by end of century. As a result of increased worldwide energy demands the consequences results to deleterious effects of hydrocarbon-based power such as ozone depletion, acid precipitation, air pollution, global warming, and forest destruction. In order reduce these effects, the dependence on the fossil fuels is needed, and the search for clean and renewable alternative energy resources is one of the most urgent challenges to the sustainable development of human civilization. The most important source of clean and abundant energy is sun. About 120,000TW of radiations from sun reach earth's surface far exceeding human needs. Conversion of solar energy to electricity using photovoltaic cell is most common as shown in Figure 1. These photovoltaic cells are nothing but traditional pn junction cells. The basic physics of energy absorption and carrier generation are a function of the materials characteristics and corresponding electrical properties (i.e. band gap). A photon need to have greater energy than that of the band gap in order to excite an electron from the valence band into the conduction band. Earth is composed of photons with energies greater than the band gap of silicon. These higher energy photons will be absorbed by the solar cell, but the difference in energy between these photons and the silicon band gap is converted into heat (via lattice vibrations — called phonons) rather than into usable electrical energy. For a single-junction cell this sets an upper efficiency of ~20%. The current research path of implementing complex, multi junction PV designs to overcome efficiency limitations does not appear to be a cost-effective solution. Another drawback of PV-based technologies is the fact of being strongly dependent on daylight, which in turn makes them sensitive to the weather conditions.

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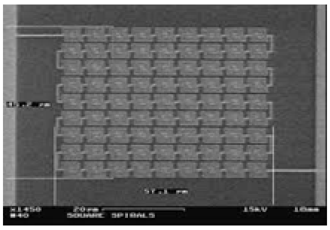

Fig. 1. Architecture of Nano Antenna

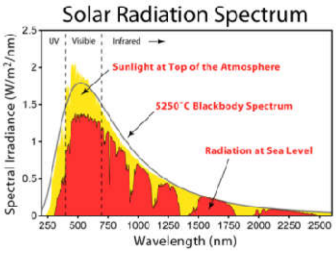

Fig. 2. Solar Radiation Spectrum

An energy harvesting approach based on n antennas is an alternative to PV Cells. In contrast to PV, which are quantum devices and limited by material band gaps, antennas rely on natural resonance and bandwidth of operation as a function of physical antenna geometries. Efficient collection of the incident radiation is dependent upon proper design of antenna resonance and antenna impedance matching. Recent advances in nanotechnology have provided a pathway for large-scale fabrication of nano-antennas.

Software and Simulation

Various softwares used for simulation of nano-antenna are:

Comsol Multiphysics

COMSOL RF module is used to model optical nano-antenna arrays and a related sensing system. Optical nano-antennas have been of great interest recently due to their ability to support a highly efficient, localized surface plasmon resonance and produce significantly enhanced and highly confined electromagnetic fields.

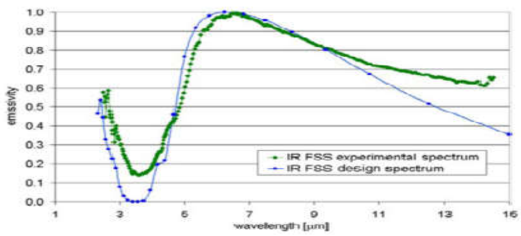

Fig. 3. Intensity vs. Wavelength Graph

Such enhanced local fields have many applications such as biosensors, near-field scanning optical microscopy (NSOM), quantum optical information processing, enhanced Raman scattering as well as other optical processes.

Nano-antennas simulation with cst microwave studio®

Nano-antennas are a large interest for researchers due to possible large field enhancement in the nearfield of the device. This strong field enhancement might be used for single molecule detection and spectroscopy (SERS). The main quantities of interest are the field distribution and field enhancement inside the small gap. This rather simple geometry might still offer some challenges for electromagnetic field solvers because of the large aspect ratio of the small gap compared to the wavelengths of interest and the strong dispersive behavior of gold at optical frequencies. The paper will demonstrate how both general purpose solvers of CST MICROWAVE STUDIO® can be used to simulate such a device. The simulation results agree with the reference solution.

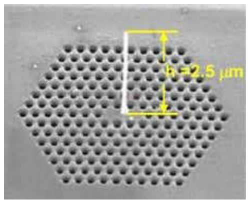

Fig. 4. Simulation of Nano Grids

Antenna magus software

Antenna Magus is a software tool can help accelerate the nano-antenna design and modeling process. It increases efficiency by helping the engineer to make a more informed choice of antenna element, providing a good starting design. Validated antenna models can be exported to CST MICROWAVE STUDIO® from a huge antenna database which means that the engineer can get to the customization phase of an antenna design quickly and reliably. Antenna Magus has proven to be an invaluable aid to nano-antenna design engineers and anyone who requires nano-antenna models for antenna placement and/or electromagnetic interference studies.

Fabrication

Fabrication is the action or process of manufacturing or inventing. Nano-antenna or nantenna farication can be explained as: Nanoantennas combined with rectifying diodes have been proposed as new devices for light harvesting in the visible and infrared. Metallic nanostructures act as antennae to concentrate electric fields at nanogaps and enable the conversion of light into an electrical signal through asymmetric tunneling across metal-vacuum-metal junctions. Electro-optical conversion occurs when surface-plasmon induced charge oscillations are converted into unidirectional electrical current flow.

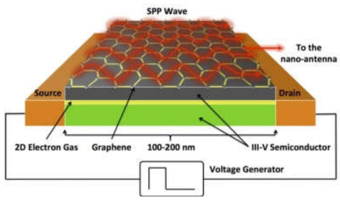

Fig. 5. Nano Antenna Fabrication

The proposed devices would accomplish the electro-optical conversion without the need for semiconductor materials. The nanofabrication of antenna-coupled tunnel diodes is extremely challenging, and requires sub-nm precision for tuning tunnel junction resistance. Atomic layer deposition is one of the few methods available with the necessary precision to accomplish this. In this work, we investigate selective-area atomic layer deposition of copper to modify lithographically-defined antenna structures and form arrays of geometrically- asymmetric tunnel diodes. Finite-difference time-domain simulations and optical characterization measurements are used to guide antenna design, including shape, polarization dependence, and wavelength response. Simulations show the electric-field enhancement in the gap to increase significantly with decreasing gap distance; moreover, antenna size and morphology allows for tuning of the peak wavelength response over the infrared to visible range. Nucleation is found to be a critical factor for tuning the electrical and geometric properties of the tunnel junctions. Whereas conformal, epitaxial growth is desired, actual growth is sensitive to surface preparation and seed-layer properties. Analysis of copper growth on palladium seed layers using in-situ spectroscopic ellipsometry reveals a surface chemistry mechanism different than previously understood. Contrary to expectations, palladiumhydrogen complexes are found to be the stable intermediates during growth cycles, and their sensitivity to surface structure may explain non-epitaxial growth. Nanofabrication methods are essential elements in the field of nano-manufacturing, which remains the essential bridge between the discoveries of the nano-sciences and real-world nanotechnology products. Advancing nanotechnology from the laboratory into high-volume production ultimately requires careful study of manufacturing system issues including product design, reliability and quality, process design and control, shop floor operations and supply chain management. Nanomanufacturing is the controllable manipulation of materials structures, components, devices, and systems at the nanoscale (1 to 100 nanometers) in one, two, and three dimensions for large-scale reproducibility of value-added components and devices. Nanofabrication methodologies encompass bottom-up directed assembly, top-down high resolution processing, molecular systems engineering, and hierarchical integration with larger scale systems.

As dimensional scales of materials and molecular systems approach the nanoscale, the conventional rules governing the behavior and properties of these components, devices, and systems change significantly. As such, the behavior of the final product is enabled by the collective performance of the nanoscale building blocks. Roll-to-roll (R2R) processing is a broadly defined terminology encompassing a range of processes wherein a substrate is transferred between two moving rolls during which the processes are applied to the substrate. As such, the processes have both a time and spatial occurrence, requiring specific customization to achieve the desired process outcomes. Inherently, R2R processes require flexible substrates, which generally entail plastic or polymer materials, and in limited cases, can also include thin-form glass, metal, or ceramic substrates. Manufacturing processes possible in R2R platforms include the full range of additive and subtractive processes, including vacuum-, thermal-, and solution-based methods. Notwithstanding the range and types of processes possible on R2R platforms, the inherent advantage for many product applications requiring high-rate and low-cost is the economy of scale offered by solution-based processes. R2R manufacturing has transitioned from paper and textiles to advanced multi-layer coatings as exemplified by products from companies such as Polaroid and Kodak for imaging and film products and applications. More recently, new industries with applications in printed electronics have emerged. Initially, these have been in the area of semiconductor integrated circuit packaging and printed circuit board replacement, and are now being considered for a range of integrated device and system applications requiring higher levels of functionality and performance printed directly on the flexible substrate. The printed electronics industry has expanded into a broad range of market applications including flexible electronics, displays, touch screens, sensors, and energy harvesting and storage. This demonstrates the use of femtosecond direct laser writing lithography for a fast and homogeneous large-area fabrication of plasmonic nano antennas on a substrate by creating a patterned polymer as an etch mask on a metal layer. Subsequent argon ion beam etching provides plasmonic nanoantennas with feature sizes below the diffraction limit of the laser light. They exhibit tunable high-quality plasmon resonances in the mid-infrared spectral range, which are ideally suited for surface-enhanced infrared absorption (SEIRA). In the present work, we demonstrate reliable, fast, and low-cost fabrication of a wide variety of antenna arrays and examine particularly the influence of plasmonic coupling between neighboring antennas on the SEIRA enhancement effect. Specifically, we measure the enhanced infrared vibrational bands of a 5 nm thick 4,4′-bis(*N*-carbazolyl)-1,1′-biphenyl layer evaporated on arrays with different longitudinal and transversal spacings between antennas. An optimum SEIRA enhancement per antenna of 4 orders of magnitude is found close to the collective plasmon excitation in the nanoantenna array, rather than at the highest antenna density. Our method establishes a low-cost replacement technique for electron beam lithography. Simple, fast, and straightforward fabrication of optimized SEIRA antenna arrays with cm^2 areas, enhanced infrared absorption (SEIRA). In the present work, we demonstrate reliable, fast, and low-cost fabrication of a wide variety of antenna arrays and examine particularly the influence of plasmonic coupling between neighboring antennas on the SEIRA enhancement effect. Specifically, we measure the enhanced infrared vibrational bands of a 5 nm thick 4,4′-bis(*N*-carbazolyl)-1,1′-biphenyl layer evaporated on arrays with different longitudinal and transversal spacings between antennas. An optimum SEIRA enhancement per antenna of 4 orders of magnitude is found close to the collective plasmon excitation in the nanoantenna array, rather than at the highest antenna density. Our method establishes a low-cost replacement technique for electron beam lithography. Simple, fast, and straightforward fabrication of optimized SEIRA antenna arrays with cm^2 areas, which can be used in real-world applications such as chemical and biological vibrational sensing, is now possible.

Recently new technologies and nano materials have been developed to allow the fabrication of patch antennas. One of the technologies is to deposit required amount of conductive patch material on the dielectric substrate using nanotechnology tools like Physical (PVD) or chemical vapor deposition (CVD) method, instead of removing the unwanted metal from a fully covered dielectric substrate which uses conventional lithography. F. Urbani, D.W. Stollberg, and A. Verma have developed and demonstrated an aperture coupled microstrip patch antenna (ACMPA) that uses nano film as radiating patch. Their demonstration clearly indicates the potential use of nano material as radiating patch for improving bandwidth of an MPA. Although their antenna demonstrates outstanding performance in terms of ultra wide band width (UWB), it has some disadvantages like very small coupling circular slot between ground plane and patch, high cost of substrates (RT Duroid and Silicon substrate), and ACMPA offers low bandwidth compared to PCMPA.

Conclusion

Currently, the largest problem is not with the antenna device, but with the rectifier. As previously stated, present-day diodes are unable to efficiently rectify at frequencies which correspond to high-infrared and visible light. Therefore, a rectifier must be designed that can properly turn the absorbed light into usable energy. Researchers currently hope to create a rectifier which can convert around 50% of the antenna's absorption into energy. Another focus of research will be how to properly upscale the process to mass-market production. New materials will need to be chosen and tested that will easily comply with a roll-to-roll manufacturing process.

REFERENCES

Corkish, R., Green, M.A. and Puzzer, T. (December 2002). "Solar energy collection by antennas". Solar Energy 73 (6): 395–401. doi:10.1016/S0038-092X(03) 00033-1. ISSN 0038-092X.

Novack, Steven D., et al. 2009. “Solar Nantenna Electromagnetic Collectors.” American Society of Mechanical Engineers (Aug. 2008): 1–7. Idaho National Laboratory. 15 Feb. 2009

Berland, B. 2009. “Photovoltaic Technologies Beyond the Horizon: Optical Rectenna Solar Cell.” National Renewable Energy Laboratory. National Renewable Energy Laboratory. 13 Apr. 2009

Lin, Guang, H., Reyimjan Abdu, John O'M. Bockris (1996-07-01). "Investigation of resonance light absorption and rectification by subnanostructures". *Journal of Applied Physics* 80(1): 565–568

Robinson, Keith. Spectroscopy: The Key to the Stars. New York: Springer, 2007. Springer Link. University of Illinois Urbana-Champaign. 20 Apr. 2009

“Nanoheating”, 2009. Talk of the Nation. National Public Radio. 22 Aug. 2008. Transcript. NPR. 15 Feb. 2009.

Green, Hank. “Nano-Antennas for Solar, Lighting, and Climate Control”, Ecogeek. 7 Feb. 2008. 15 Feb. 2009.

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