International Journal of Science, Environment and Technology, Vol. 4, No 6, 2015, 1596 – 1602

ISSN 2278-3687 (O)
2277-663X (P)

NANOPHOTONICS –TECHNOLOGY FOR ACHIEVING EFFICIENT DESIGN APPLICATIONS

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Abstract: For any Interior architecture cool, pleasant and attractive lighting is the key and essential element. It influences the ambience and illustrates the frame of mind. Photonic technologies play an increasingly significant role in making it eco friendly. In addition to the direct eco-benefits photonics will also impact the product design and manufacturing processes employed. Higher integration and multifunctional enrichment is achieved with advancement in micro fabrication technologies. Nanophotonics merges nanotechnology methods with photonics and thus enables light transmission, manipulation and detection on a nanometer scale. This paper discusses few technical advances in the lighting applying nano-photonic structures and suited 3D printing of LED. Case study is focused on application of technology for sustainable design.
Keywords: Nanophotonics, Green energy, sustainable lighting, Nanostructures.

1. Introduction

Light is one among the vital element of design and also an attractive element which is highly influential in every aspect of life associated with it. Many papers discuss about the influence of light and the characterization of light for varied applications like neuro-psychology in health care sector [1], Lighting in classrooms [2], energy efficient lighting [3], lighting control strategies [4]. Replacement of traditional lighting with LEDs [5] and energy saving potential of LED by modulating spectral power distributions and wavelength control[6]were the few studies made in this LED lighting. With advent of nanotechnology, there prevails a smart shift of lighting industry from solid state lighting towards quantum dot structures and LED's [7] and colloidal quantum dots with luminophores [8] for designing various creative designs.

This paper discusses the methods to increase the efficiency of such quantum dot structures when applied for design technology. The spectral efficiency of quantum dots can be improved by amplification using nanostructures and such structures are discussed in this paper. This paper also extends an insight to 3D printing of LED's, an innovation in lighting technology with few case studies for the greener technology and sustainable environment.

*Received Oct 29, 2015 * Published Dec 2, 2015 * www.ijset.net*

2. Quantum dots

Current research in the semiconductor technology focuses on quantum dots which exhibit strongly size-dependent optical and electrical properties. Owing to its unique properties, it has become a promising material in the nanophotonic regime for varied applications. They also exist in colloidal nature facilitating various fabrications. The ability to join the dots into complex assemblies creates many opportunities for scientific discovery. Quantum-dot-based LEDs are characterized by pure and saturated emission colours with narrow bandwidth, and their emission wavelength is easily tuned by changing the size of the quantum dots[10].More advances in quantum dots for Nanophotonics and quantum information applications perceive. One such is in the industry of designing, where lighting is one of the basic elements. Quantum dot sources are integrated with nanophotonic structures to achieve modulation.

3. Nanostructures

Nanostructures range from 1 nm to 10 nm and are integrated in a single chip with the sources during lithographic processes Nano photonic structures are widely applied in all optical circuits for modulation of light. The structures are resonant in nature ranging from Fabry-perot, Ring resonators, disc resonators, micro toroids, micro spheres etc. In all these structures, confinement and multiple reflection of light occurs at nano-scale which in turn enhances the lighting effect. Disk structures have higher order Whispering Gallery modes (WGM) with low Fabry-Perot cavities, ring and disc structures can be fabricated with the silicon photonic technology attributing for the commercial platform with lower manufacturing costs and ease of integration with CMOS circuitry for processing. Interrogation of optical signal in 3 dimensional structures like disk and spheres are quite challenging due to inefficient and lossy coupling which involves optical fiber extrusion with nanometric precision and alignment. Ring structures are scalable and can be multiplexed for biomedical sensing applications.

Comparatively, ring structures with negligible insertion loss and high Q stands out as the prime candidate for most of the applications with silicon fabrication technology. Ring resonator at plasma level [11],wide tunable double ring resonator [12][13] suited for elemental design of structures at the foundation level. These nanostructures when integrated with the nanophotonic sources amplify the light and tunability is a feature available with these resonant structures.

Micro ring resonators can be fabricated from a variety of materials, including polymers, silicon oxide, silicon nitride and SOI. Signal is coupled with micro rings through linear waveguide both in vertical and horizontal direction. Below figure shows all the three types of micro resonators and the horizontal coupling with linear waveguide.

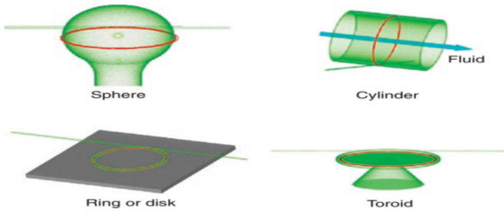

Figure 1: Structure shapes

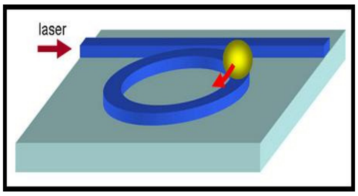

Figure 02: Ring structure

Multiple nanostructures together is called an array and will be much suited for linear and volumetric structures. Efficiency in lighting and tenability for different wavelengths, add /drop of light for designing are also possible for these nano structures. Ring structures are fabricated in arrays enabling multiplexed enabling channeling. Colloidal Quantum dots[14] are suited for volumetric owing to its nature.

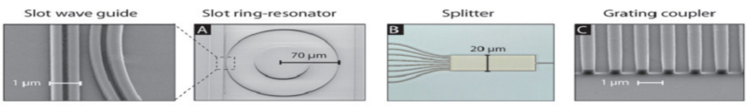

Figure 03: Resonator waveguide structure

4. 3D Printing of LEDs:

Another mile stone achieved within the lighting industry is the printing of such quantum LEDs. Fabrication has its own bottle necks; such can be made overcome with the printing technology.3D printing with optics technology started with printing of embedded optical elements. [15].Light is printed in its thinnest form as paper. The paper-thin Light paper is made by mixing ink with tiny LEDs printing on conductive layer sealed by two additional layers. When current passes through the paper, the tiny, randomly-dispersed diodes will light up.

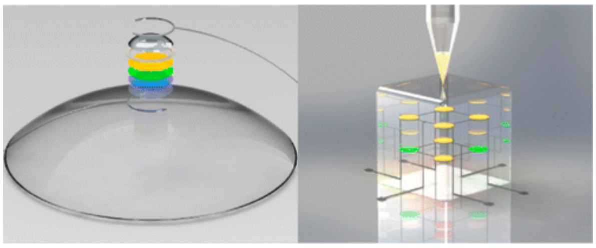

Figure 04: 3D Printing of LED's (Courtesy: 3Ders.org)

Though 3D printing is limited to specific plastics, passive conductors and few biological materials the research on smart interweaving multiple materials led to the path of 3D printing.[16] Novel architectures which are not easily accessed using micro fabrication technologies can be constructed with 3D printing technologies.

5. Case Study 01: GREEN TECHNOLOGY

Today's technological insights step beyond the applications towards the environmental impacts. As we all know, the move is meaningful if there stepping stone in every effort of technology. Light is used to illuminate the room. Same light can be used to transfer data packets in information technology. This conceptualization minimizes the negative environmental impact by enhancing efficiency and moderating the use of energy. Lighting control algorithm is developed with the ultimate goal of achieving energy efficiency and health aspects of occupants into consideration. [4] Most of the wireless information transfer is currently performed in the frequency domain. The drawback of this is the requirement of wireless nodes and power factor at these wireless nodes. Fiber optics recalls the application of light for wired communication .By applying the nanophotonic LED's the lighting distribution shall perform the information transfer by modulating the wavelength or intensity. Modulation of light can be achieved using the nanophotonic structures discussed above. On incorporation of detector modules for receiving, seamless communication can be established. The energy emitted by the nanophotonic LED's are harnessed in the form of Light to illuminate and the light to communicate. This electronic and photonic technology synergizes the Green Information technology.

6. Case Study 02: SUSTAINABILITY IN DESIGN STRUCTURES

Sustainable energy has been a challenge for the modern society. Any design considered, incorporates the mobile or immobile structures and patterns to add features about the concept. Efficient and effective use of lighting can reduce major energy costs. Thinking on the energy side, designing the art structures incorporating the solar cells adds the energy concept for design paving way for sustainable design. But moving further with nanotechnology, self aligning photovoltaic's when applied to such structures obviously increase the energy efficiency. This system overcomes the drawbacks of conventional systems like building orientation, installation plane and area, tilt angle ,surface temperature etc. Decorative organic solar panels are currently available in market and are printed for mass production. Such artistic panels can be placed any where light is available without carnaging the ambience of the environment. Self assembled structures for light trapping in solar cells improve the performance and reduce cost. Incorporating 3D printed LEDs and applying smart skin OLED structures on inside the roof aids illumination in rooms and artifacts. Future applications include colloidal quantum dots with printed photovoltaic's morphing the structure for aircrafts, automobiles for efficient energy conservation. Below figure illustrates the 3D printed LED lights for the automotives (fig 05)

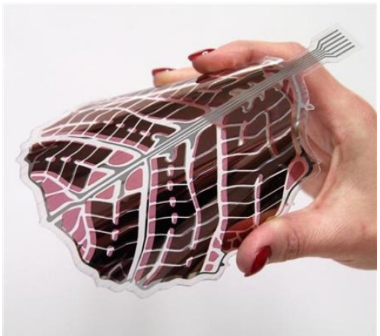

Figure 05. Decorative solar panels (Courtesy: Technical Research Centre of Finland (VTT))

Figure 06: Automobile lighting

7. Conclusion:

With these technologies, road map of design is redrawn with flexibility and energy efficiency, vital for any design structures. To achieve the objective of eco friendly, efficient and economical advantageous technology nanophotonics will play the vital role. Overall features of lighting design to be changed in the few years to come with Nanophotonic sources and structures. Much more complex, intricate and beautiful designs are to evolve with the implementation of nanophotonic technology.

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