EAI Endorsed Transactions
on Internet of Things
Research Article
EAI.EU

UV Disinfection Robot with Automatic Switching on Human Detection

A.Vyshnavi[1,*], A. Naga Sri Manasa[1], Ch. Sesha Sai Hamsika[1] and P. Shalini[1]

[1]Department of ECE, V R Siddhartha Engineering College, Vijayawada, India.

Abstract

Ultra violet (UV) light is used for the purpose of disinfection or sterilization of rooms and surfaces. UV-C is employed as it has germicidal properties, in particular - bacteria and viruses, but it is detrimental to human-beings as well. So, for the purpose of disinfection without human interference, a UV Robot has been designed and implemented that follows a pre-defined path. It was equipped with three 20W UV lamps which radiates light in all directions. Given that UV light can be dangerous to humans, an embedded system based on Arduino along with PIR sensors are employed on top of the robot that detects human or animal's motion and presence. So, one of the effective ways to avoid getting infected with SARS-COV-2 (Corona virus) is by sterilizing rooms using UV robot.

Keywords: UV light, Disinfection, Sterilization, Robot, SARS-COV-2

Received on 05 August 2020, accepted on 19 September 2020, published on 25 September 2020

doi: 10.4108/eai.25-9-2020.166364

*Corresponding author. Email:vyshnavi99.alla21@gmail.com

1. Introduction

The ultimate aim of disinfection and sterilization is to inactivate or eliminate microorganisms in order to avoid the spread of airborne diseases and infections. Contaminated surfaces increase the threat of disease transmission through the spread of pathogens either by contact or through air. Proper disinfection and sterilization aids in reduced probability of disease transmission. Surface disinfection plays a vital role in disease prevention and transmission. Effective and frequent disinfection of surroundings ensures a safe life. For the purpose of disinfection, UV light is one of the best possible solutions. The disinfection of surfaces in hospitals or in any places is a very prominent example of ultraviolet germicidal irradiation (UVGI) [6]. UV-C light has a diverse range of applications in the fields of disinfection and sanitization [20]. One of the salient applications of UV light is sterilization of surgical instruments and medical equipment. Low pressure mercury lamps which are a cheaper way to generate disinfecting UV light, can also be used for this purpose [7]. However, it is economical and environment-friendly to use UV light due to it's high replacement cycle. UV radiation spectrum is divided into three regions called UV-A, UV-B, UV-C. Nevertheless, UV-C radiation is used for the process of sterilization as it has a wavelength of 100-280nm and the energy is large enough to destroy the bacteria [19]. As UV-C light has significant use in the field of sterilization, it can be used as a key element to fight the novel Corona virus [8].

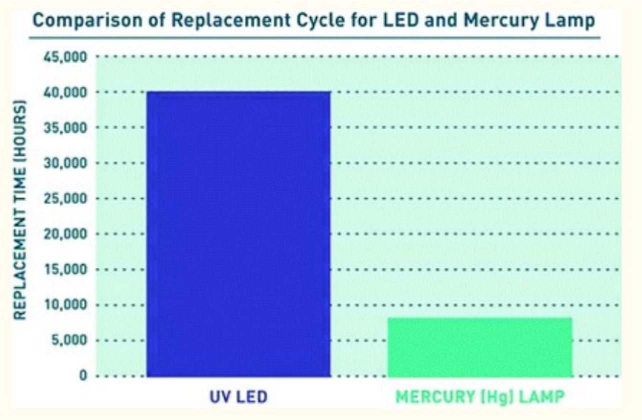

Figure 1. Comparison of UV LED and Mercury lamp

Till now, fixed UV sterilization system has been employed [27]. But there are few limitations in using fixed UV sterilization system. That is, due to their bulky size it is difficult to navigate crowded spaces and reach shadowy areas. A cost efficient and effective UV robot has been designed to limit the spread of bacteria and viruses, which goes along the given path [11, 16] and has the capacity to reach the inaccessible areas for effective disinfection.

Extreme subjection to Ultraviolet rays from either naturally available sources or fabricated sources has threatening effects on humans. When skin is exposed to Ultraviolet rays, the skin cells get damaged by absorbing the Ultraviolet rays and result in skin reddening, itching and skin peeling. Subjection of skin to Ultra Violet radiation also results in cell damage, tissue damage, DNA damage and skin cancers [9, 10]. Ultraviolet rays on eye causes many eye problems such as Photokeratitis, Photo conjunctivitis, Cataract and may also result in eye cancers and blindness. Ultra violet radiation not only affects skin and eye but also immune system [10]. So, in order to avoid the above stated disadvantages, our robot is equipped with (motion sensor) PIR sensors which are mainly used in burglar alarms and security systems to detect human motion. [14, 15]. These PIR sensors are mounted on the top of the robot to sense any movement (human/animal) so that it turns OFF the UV light by itself. The robot is designed in such a way that it follows a pre-defined path [12, 13].

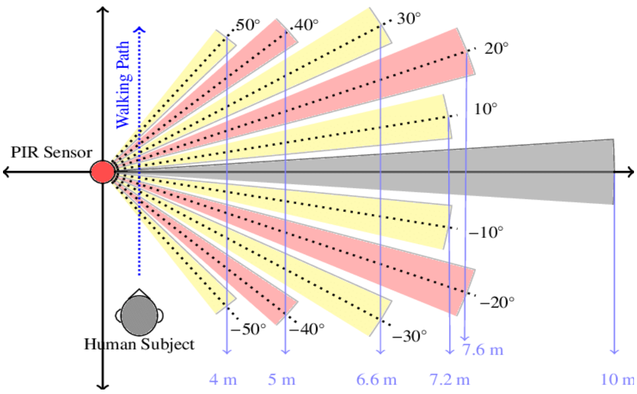

Figure 2. Field of view of PIR sensor

2. Background

A. Ultra Violet Disinfection

By 1930s, UV light has come into common use throughout the hospitals for air and water treatment and anywhere where microbial contamination was a major concern. UV light gained significance in the 1950s for helping to eradicate TB. The UV-C light which is effective in the process of disinfection ruptures the DNA of the bacteria thereby killing the ability of the organism to reproduce, can be considered as dead as it cannot multiply it's number any further. UV-C is absorbed by the DNA and RNA bases leading to molecular structure damage through a process called as photo dimerization [17, 19]. The direct exposure of UV-C radiation to human skin or eyes leads to cancers. The effectiveness depends upon the exposure time and the distance of the source from the object which is being sterilized.

The direct exposure of UV-C can be dangerous to humans but upon passing through glass or transparent plastic casing, just like the UV rays from Sun passing through Ozone layer, the light that comes of it is just the blue light, excluding the UV-C radiation.

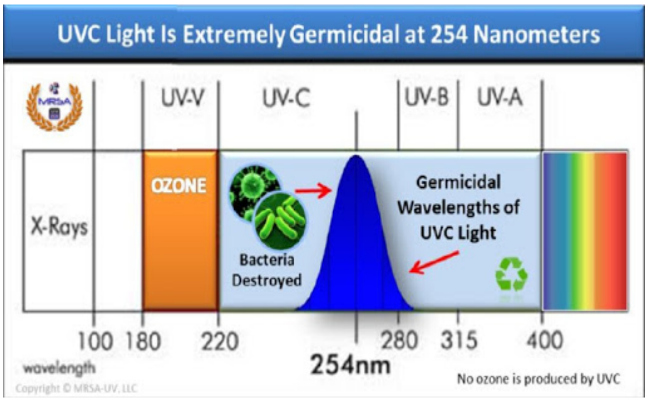

Figure 3. Electromagnetic Spectrum of UV (www.mrsa-uv.com/clinics.html)

B. Exposure Time Required for Inactivation of Coronavirus:

In order to calculate the exposure time for coronavirus inactivation, it is necessary to measure the amount of UV energy. The unit of brightness or intensity is expressed as microwatt per centimetre square($\mu W/cm^2$), which is energy per area in a given time. UV disinfection dosage is a function of total intensity of UV-C light and length of exposure and is given by (i). From this, the time required for UV sterilization (i.e. for inactivation of Coronavirus) is directly proportional to the amount of UV dose per brightness as described below (ii).

$$\text{Brightness} = \frac{\text{Luminosity(w)}}{4\pi\text{distance}\ \hat{}2(\text{cm}\hat{}2)} \quad \text{----------- (i)}$$

$$\text{Time} = \frac{\text{UV dose (uW.sec/cm}\hat{}2)}{Brightness(\frac{uW}{cm^2})} \quad \text{--------------(ii)}$$

3. Literature Survey

An extensive overview of the literature is mentioned in this section. Aladin Begic proposed the service disinfectant robots which are simple and effective in disinfection in medical institutions [1]. These are semi-automated systems that reduce the heterotrophic bacteria and MRSA on high-touch surfaces in rooms vacated by MRSA patients. Implementation includes training personnel to operate the robots and the device should run when the room is empty.

PacharawanChanprakon, Tapparat Sae-oung, TreesukonTreebupachatsakul, PimkhuanHannanta-anan, WiboolPiyawattanametha have developed an Ultra-violet sterilization robot for disinfection [2]. This robot makes use of ultrasonic sensors and webcam camera to avoid collision with obstacles. The signals from these sensors and webcam are used to navigate the robot. This robot uses 3 UV lamps to cover an angle of *360°* for the purpose of disinfection. The movement, speed of this robot and UV lamp switching on-off can be controlled by the user via website with the same Wi-Fi network connected.

Noriyuki YAGI, et al. have proposed Sterilization using 365nm UV-LED. This paper examines the sterilization effects of UV-LED and proves that UV-LED is capable of sterilizing morbific bacteria [3]. This paper postulates that UV-LED is smaller and brighter than low-pressure mercury lamp, so UV-LED can be used for the purpose of sterilization effectively

Thomas Rubaek, et al. have developed a UV-Disinfection robot to reduce the outspread of diseases and Hospital-Acquired Infections (HAIs) [4]. This robot is used to disinfect predetermined places in hospital and other environments. This robot is designed as an addition to the existing cleaning cycle. The test results of the designed robot are that the robot is able to destroy different types of bacteria.

Jui - HsuanYang, et al. have implemented the Hyper Light Disinfection Robot that was successful in killing a number of multidrug-resistant bacteria and fungi that are commonly present in hospital [5]. The effectiveness of the Hyper Light Disinfection Robot was very less on shadowed sites. This UV-C device may not be feasible to use in double or triple room because other patients who are admitted or present in the same room will get harm from UV exposure. This device cannot be used in crowded wards or large open spaces due to the consideration of safety measures.

4. Methodology

The UV sterilization robot has a small form factor and can be turned ON/OFF automatically when human or animal is detected so that no damage is done. Key components of the robot are three PIR sensors, three UV lamps, controller box, power source (which is free of electrical wires) – battery, Arduino, two IR sensors. The height of the robot is about 123 centimeters.

4.1. Methodology

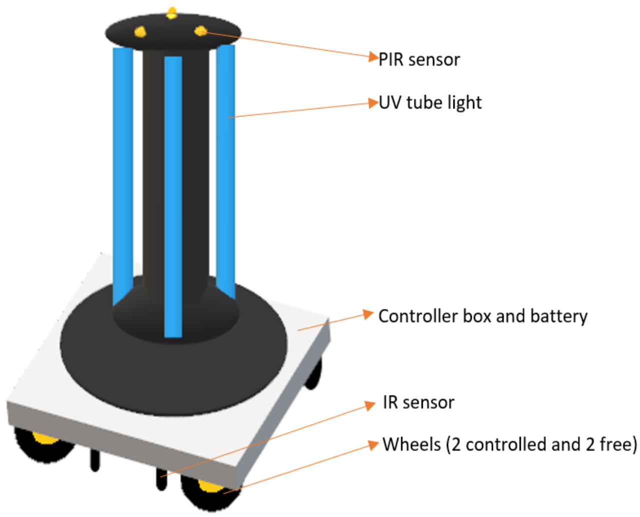

Figure 4. Design of UV robot

The main command center of the robot is the microcontroller. It is programmed to detect human beings /animals with the help of three PIR sensors or IR motion sensors which are mounted on top of the robot to cover a total angle of 360° [18]. If a person is detected while disinfection process is going on, the robot comes to a halt and the UV light gets turned OFF [21]. Once the person leaves the room or operating area, the UV lights which were OFF gets turned ON automatically and the disinfection process goes on until the process is complete [22]. The robot has two IR sensors at the bottom of the base to follow the predefined path. The microcontroller controls the wheels of the robot by motor drivers in the path [23, 24].

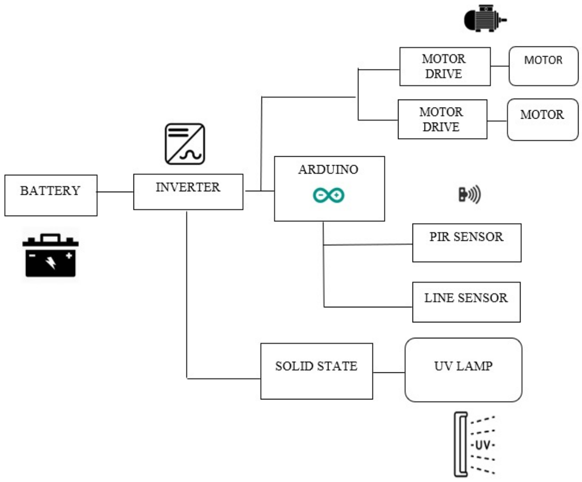

Figure 5. Block Diagram of Controlling System

4.2. Calculated Time for Disinfection

As a matter of fact, all virus species of comparable kind have a similar structure and a similar RNA strand length. UV light experiments conducted in the past were used to determine the UV radiation dose required for 90% virus reduction (i.e., the log-reduction dose). Dosages for a 90% destruction of most bacteria and viruses range from 2000 to 12000 $\mu W/cm^2$ [28]. The robot utilizes 3 UV lamps in a circular pattern to cover 360° and maximize the efficiency. Each lamp has a 20-watt output power (as listed in the UV lamp datasheet). The amount of brightness for a distance of 2.5feet away can be calculated as:

$$\text{Brightness} = \frac{20*3(W)}{4*\pi*(158.49)2(cm2)}$$

$=0.00018886 W/cm^2$

$=188.86\ \mu W/cm^2$.

A UV dose of 10,600 $\mu W.sec/cm^2$ is required for 90% virus reduction which can be considered as upper limit of log-reduction median dose (in low absorbance media) [28]. Hence, the time required to eliminate germs is expressed as:

$$\text{Time} = \frac{10{,}600(\mu W.sec/cm2)}{188.86(\mu W/cm2)}$$

$=56.12$ sec.

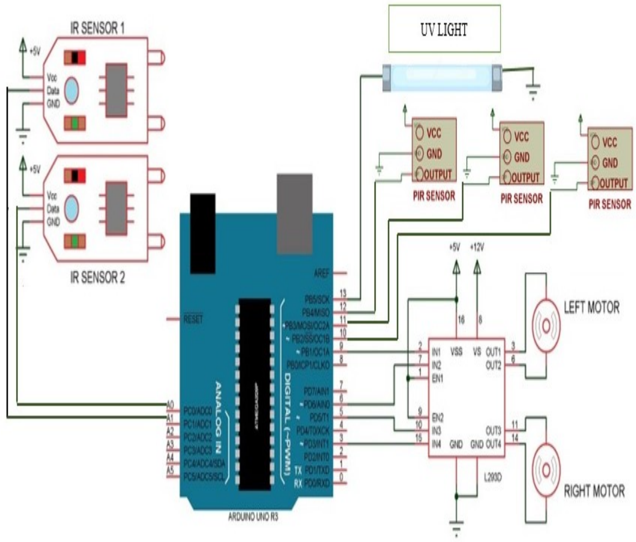

Figure 6. Circuit Diagram

4.3. Working

Disinfection starts the moment the robot is turned ON. After the disinfection of a particular place is complete, the robot moves to the next directed position by following the line marked [25]. This process continues till the disinfection of the entire room or place is complete. During the disinfection process, if a human or an animal approaches the operating area, then a command is sent to turn OFF the UV lights automatically. The data sensed by the PIR sensors is processed by the microcontroller and a message is sent to the robot. The robot remains in the same position if disinfection is not completed. After a delay of few seconds, the PIR sensors checks for the presence of human, in general, detects infrared radiation from surrounding area of specific range [26]. As soon as the PIR sensors detects that there is no person or an animal in its range, robot resumes-- which means the UV light gets turned ON automatically and finishes the process. After the complete disinfection of a room or a place, the robot can be scheduled for disinfecting another room or can be turned off.

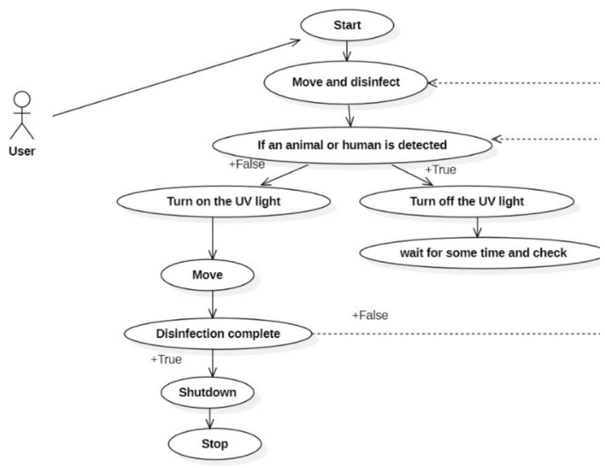

Figure 7. Use Case Diagram

5. Result

The height of the robot designed is 123 centimetres. The weight of it is about 6.5 kilograms.

Figure 8. UV Sterilization Robot

The robot that was designed and constructed is used for the purpose of surface disinfection. We have tested the efficiency of our robot considering a 12X12 feet room and 15x15 feet room. The time taken by our robot to disinfect a 12X12 feet room without any obstacles and human or animal detection is 10 minutes. The time taken for disinfection of a 15x15 feet room is 16min 49sec. In case of human or animal is detection, the robot takes much more time to disinfect as the disinfection process pauses during their presence. The time depends on the relative distance between the robot and the person, the speed with which the person is walking.

Table 1. Disinfection time in rooms of different sizes.

Conditions	Time taken to disinfect 12x12 feet room	Time taken to disinfect 15x15 feet room
Without any human detection	10min	16min 49sec
With human detection	>10min	>16min 49sec

Unfortunately, there are few limitations. The first critical consideration is that UV light does not penetrate through furniture, laminated glass or other objects. The second one is regarding distance, farther the robot lesser the disinfection and the robot can disinfect only up to some height, the area above its height is not disinfected.

6. Conclusion and Future Scope

In this paper, design and implementation of a fully autonomous and cost-effective UV disinfection robot is presented which has huge potential to guard people from coronavirus by sterilizing surfaces with the help of 20W UV lamps. The disinfection is done along a pre-defined path without human intervention as UV is deadly and dangerous to all living beings along with microbes. The UV robot requires at least 57 seconds for the inactivation of coronavirus present on the surface. The robot will be able to move around the room and on detecting humans or animals with the help of IR motion sensors, it turns OFF the UV lights automatically making it safer and feasible to operate everywhere and from anywhere by scheduling the period of disinfection.

The UV robot often works in peopled surroundings. Therefore, this robot should not only clean efficiently but also harmoniously integrate with humans. Hence, cognitive abilities can be added to this robot by very simple and efficient theoretical approaches. The cleaning efficiency of the robot can be greatly improved by understanding the environment along with the safety enhancement. To make it more environment friendly, the robot can be made to run on a renewable power source such as solar energy.

References

[1] Aladin Begic, "Application Of Service Robots For Disinfection In Medical Institutions", Advanced Technologies, Systems, and Applications II. 2018; 28: 1056–1065.

[2] Pacharawan Chanprakon, Tapparat Sae-Oung, TreesukonTreebupachatsakul, PimkhuanHannanta-anan, WiboolPiyawattanametha,, "An Ultra-Violet Sterilization Robot For Disinfection", 2019 IEEE.

[3] noriyuki yagi, mirei mori, akiko hamamoto, masayuki nakano, masatake akutagawa, souko tachibana, akira takahashi, toshitaka ikehara, yohsuke kinouchi, "Sterilization Using 365 Nm Uv-Led", 29th Annual International Conference of the IEEE EMBS Cité Internationale, 2007.

[4] Thomas Rubaek, Merima Cikotic, Simon Falden, "Evaluation Of The Uv-Disinfection Robot", 2016.

[5] Jui-HsuanYang, Un-InWu[a]Huei-MinTai, Wang-HueiSheng, "Effectiveness Of An Ultraviolet-C Disinfection System For Reduction Of Healthcare-Associated Pathogens", Journal of Microbiology, Immunology and Infection , Volume 52, Issue 3, June 2019, Pages 487-493.

[6] G Katara, N Hemvani, S Chitnis, V Chitnis, "Surface Disinfection By Exposure To Germicidal Uv Light", Indian Journal of Medical Microbiology (2008)26(3):241-42.

[7] A.I. Al-Shamma'a, I. Pandithas, J. Lucas, "Low Pressure Microwave Plasma Uv Lamp For Water Purification And Ozone Production"; IEEE Conference Record - Abstracts. PPPS-2001 Pulsed Power Plasma Science 2001. 28th IEEE International Conference on Plasma Science and 13th IEEE International Pulsed Power Conference (Cat. No.01CH37)

[8] DISINFECTION OF AIRBORNE VIRUSES USING UV https://spectrum.ieee.org/tech-talk/biomedical/devices/ultraviolet-revolution-could-faruv-light-provide-widespread-safe-disinfection-of-airborne-viruses

[9] RuchikaThukral, Gulshan, Ashwani Kumar and A.S. Arora, "Effects Of Different Radiations Of Electromagnetic Spectrum On Human Health.", IEEE, (2020).

[10] World Health Organization: Health Effects of UV Radiation. https://www.who.int/uv/health/uv_health2/en/

[11]M.S Islam, M. A Rahman, "Design And Fabrication Of Line Follower Robot", Asian Journal of Applied Science and Engineering, Vol 2, No 2, ISSN 2305-915X

[12] RabiulHossen Rafi, Shuva Das, Nowsher Ahmed, Iftekhar Hossain, SM Taslim Reza, "Design And Implementation Of Line Following Robot", IEEE, 19th International Conference on Computer and Information Technology, 2016.

[13] Hasan U. Zaman, Md. Majidul Haque Bhuiyan, Montashir Ahmed, SM Tarek Aziz, "A Novel Design Of Line Following Robot With Multifarious Function Ability", 2016 IEEE.

[14] Yogesh Pawar, Abhay Chopde, Mandar Nandre, "Motion Detection Using Pir Sensor", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 04 | Apr-2018.

[15] Ajay Kumar Tiwari, Prince Raj, Justice Kumar, Mr. Ashish Tiwary, "Motion Detection Using Pir Sensor", International Journal of Scientific Development and Research (IJSDR), May 2016 IJSDR | Volume 1, Issue 5.

[16] AichaMoulay, Fatima Laoufi, TarakBenslimane, "Fpga-Based Car-Like Robot Path Follower With Obstacle Avoidance", 2020 International Conference on Mathematics and Information Technology, IEEE.

[17] E.C. Friedberg, G.C. Walker, W.Siede, R.D. Wood, R.A. Schultz, T. Ellenberger, "DNA REPAIR AND MUTAGENESIS,"ASN Press, Washington, 2006.

[18] AnshikaChaturvedi, Praveen Kumar, Seema Rawat, "Proposed Noval Security System Based On Passive Infrared Sensor", 2016 International Conference on Information Technology (InCITe).

[19]https://spectrum.ieee.org/tech-talk/semiconductors/optoelectronics/ultravioletled-maker-demonstrates-30second-coronavirus-kill

[20] I. Kano,D. Darbouret and S. Mabic, "Uv Technologies In Water Purification Systems", The R&D Notebook 9A publication of the Lab Water Division of EMD Millipore,2012,pp.5

[21] O. Urfaliglu, Emin B. Soyer, B. UgurToreyin, A. Enis Cetin, "Pir-Sensor Based Human Motion Event Classification", 2008 IEEE 16th Signal Processing, Communication and Applications Conference.

[22] Jaeseok Yun and Sang-Shin Lee, "Human Movement Detection And Identification Using Pyroelectric Infrared Sensors", Embedded Software Convergence Research Center, Korea Electronics Technology Institute, 25 Saenari-ro, Bundang-gu, Seongnam 463070, Korea, 5 May 2014.

[23]https://www.researchgate.net/publication/327965269_Line_Follower_Robot_For_Industrial_Manufacturing_Process

[25] Kazi Mahmud Hasan, Abdullah-Al-Nahid, Abdullah Al Mamun, "Implementation Of Autonomous Line Follower Robot For Various Purposes ", 2013 IEEE.

[26]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4063065/

[27] Michael S. Shur, RemisGaska, "Deep-Ultraviolet Light-Emitting Diodes", IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL .57, NO.1, JANUARY 2010.

[28]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7273323/