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### HEATING CAPACITY OF POWER SEMICONDUCTOR INFRARED EMITTERS FOR MEDICAL APPLICATIONS

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#### ABSTRACT

Nowadays, inadvertent perioperative hypothermia is a serious problem in surgical settings. There are several methods to help maintain the patient's body temperature such as passive insulation, electrical resistance, forced air, and water circulation. This work continues to explore the use of infrared emission from semiconductors for these purposes. Radiation from a set of commercial infrared LEDs used for night photography is applied to a temperature sensor at different distances from 15 to 75 mm in 0.5 mm intervals. The mass of a polymer board with the encapsulated sensor included, is considered as the mass to be heated. The intensity of the current is constant throughout the measurement process. The irradiation duration was 120 s for each distance. The obtained temperature data was digitally processed to model the heating effect versus distance, over the target mass to be heated. The traces from the oscilloscope clearly shows a remote heating capacity from the infrared emitter. The speed of temperature increment gets reduced with the distance between the emitter and the sensor in an exponential way. Considering the minimum possible distance between a surgical patient and a lamp, and the data related to the weight of the skin, a quantity of emitters for a hypothetical heating lamp is estimated. Due to the estimated number of emitters required, we confirm that this technology would be feasible for inclusion in a remote surgical warming system to decrease heat transfer from the patient's body to the environment.

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#### INTRODUCTION

The human body naturally has a thermoregulatory system. Hyperthermia causes vasodilation, flushing, and sweating, while hypothermia causes vasoconstriction and chills. These reactions cause a gradual recovery of temperature homeostasis and the maintenance of normothermia (1). Anesthesia impairs the thermoregulatory system (2). According to studies, hypothermia in patients about to undergo surgery has a prevalence of more than 50% (3).

The strategies to avoid or reduce involuntary hypothermia can be divided into two categories: active and passive methods (4). Passive methods include blankets, foil, and drapes. Active methods include forced air devices, electrical resistive blankets, and water circulation mattresses (5) (6) (7).

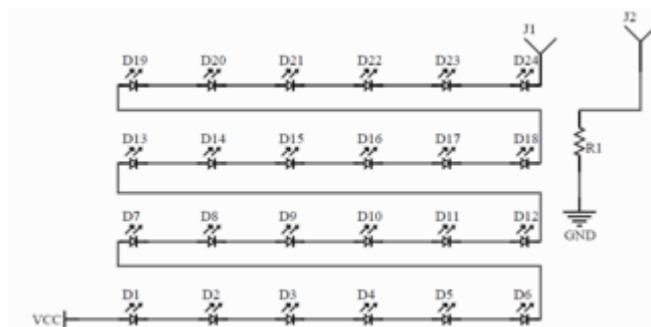
According to Moola (8), the most effective way to warm a patient between several active and passive options, including radiant devices, is forced air heating (9) (10) (11). The typical radiant device for the mentioned purpose is an infrared incandescent lamp (12). Such a lamp reaches a high temperature at the radiation source, which is undesirable due to the heating of the nearby area.

A light emitting diode is a semiconductor designed to produce light of a specific wavelength. This light, when in the infrared spectrum band, can heat a target mass.

This work examines an infrared emitter that can be considered in the concept of heating the outermost layer of the skin by infrared light irradiation. Heating this layer will compensate the heat loss caused by the colder environment and decrease heat transfer from the patient's body core (13) (14). In this work, we analyze the heating capacity of high-power LED designed for infrared photography. This paper reports the characterization of the heating capacity of the SFH 4780S infrared emitter, due to explore the possible use of semiconductors for temperature control in medical care.

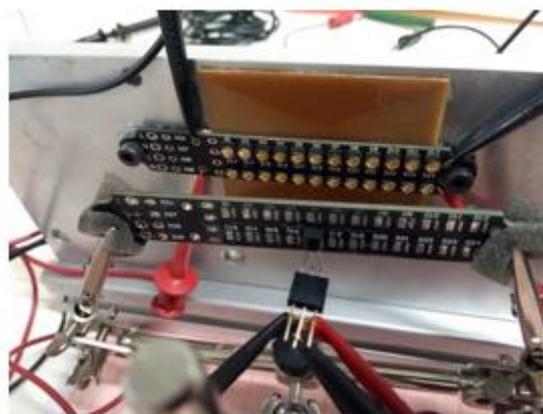
**METHODS**

The infrared emitter SFH 4780S used to elaborate this work, supports 500 milliamperes of direct current (15). The current applied for each one of the tests was a constant with a magnitude of 250 mA (16). A printed circuit board (PCB) was designed with 24 serial connected emitters and a pair of jumpers with the purpose of placing the appropriate resistance to achieve the mentioned current intensity. This can be seen in the electrical diagram shown in Figure 1.



*Figure 1. Electrical diagram of the infrared semiconductor array.*

The distance between the emitter and the target to be heated was maintained on a millimeter scale adjusted from 15 to 75mm with increments of 5 mm, in a set shown in Figure 2.



*Figure 2. Picture of the experiment set of this work.*

An integrated temperature sensor LM35 attached to a non-functional PCB (polymer board) was used as the target to heat, where the total mass is 4.8311 g. To decrease the temperature, to be ready for the next test, a fan was used on the target until it reached the laboratory air temperature. The results were observed on a Tektronix MDO3022 digital oscilloscope.

The target to be heated was irradiated for 120 seconds while the oscilloscope collected the information obtained, as shown in Figure 3. Nine tests were performed, each one with the same number of seconds at a different distance, increasing 5 mm each of the eight first tests, and the last test with a distance of 75 mm.



Figure 3. Trace obtained from the Tektronix MDO3022 oscilloscope for distance of 5 mm

The Tektronix MDO3022 oscilloscope can generate data files. Each file contains several samples of the input voltage signal. The number of samples per second depends on the timescale set on the oscilloscope. For this experiment with slow change input signal, the amount of voltage samples was enough.

The signal of the LM35 temperate sensor showed noise of relatively high frequency and amplitude less than 2% of the maximum measured value. To minimize the effect of this noise, calculations were made based on the average of all available voltage samples in each data file. In this way, compensation is expected to occur over the time that the signal lasts.

To obtain the data of the temperature reached after each irradiation, we obtained the average of the voltage samples from the time 119.0 s to the time 120.0 s, this is approximately 300 samples. With this, the voltages corresponding to the distances of the experiment, from 15 to 75 mm were obtained. These results are shown in Figure 4. Subsequently these voltage data will be expressed as temperature. To achieve this conversion (voltage to temperature) the LM35 sensor is considered to provide a calibrated output of 10 millivolt per degree Celsius, as its datasheet says.

From the analyzed data, an equation was obtained from the exponential regression of the set of values. See equation 1. This equation was used to obtained Figure 5 which shows the temperature increase versus distance and shows an extrapolation up to 1050 mm also.

$$y = 0.7597x^{-0.179} \quad (1)$$

## RESULTS

Figure 4 shows the curve obtained form the data provided by the Tektronix MDO3022 oscilloscope, already processed and integrated in one data set. This curve shows how the array of SFH 4780S emitters affects the voltage output of the sensor depending on the distance of the target after 120 s of infrared irradiation. In a previous work (17) it was demonstrated that the coincidence of two emitters radiating on a single target, causes the heating effect to accumulate (superposition principle).

Figure 5 shows the extrapolation of the effect of infrared irradiation at a greater distance. The expected distance between lamps hanging over the operating table, and the patient's body in operating rooms is 800 mm. The area of the body skin to be heated in a patient can be considered 400 square cm, which represents 2.21% of the total body surface. The average weight of the skin in a human body is 3,393 g (18). Therefore, the mass of the skin to be heated is 75 g. The underlying concept of this work is to heat the outermost layer of the skin, decreasing heat transfer from the core of the body to the skin surface.

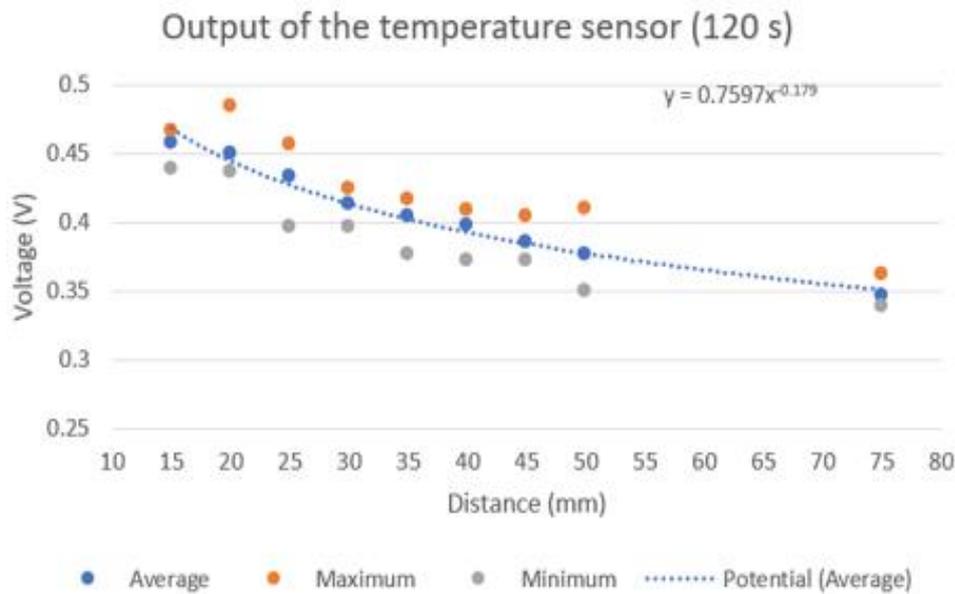


Figure 4. Output of the temperature sensor on a target with a mass of 4.8311 g after a 120 s irradiation.

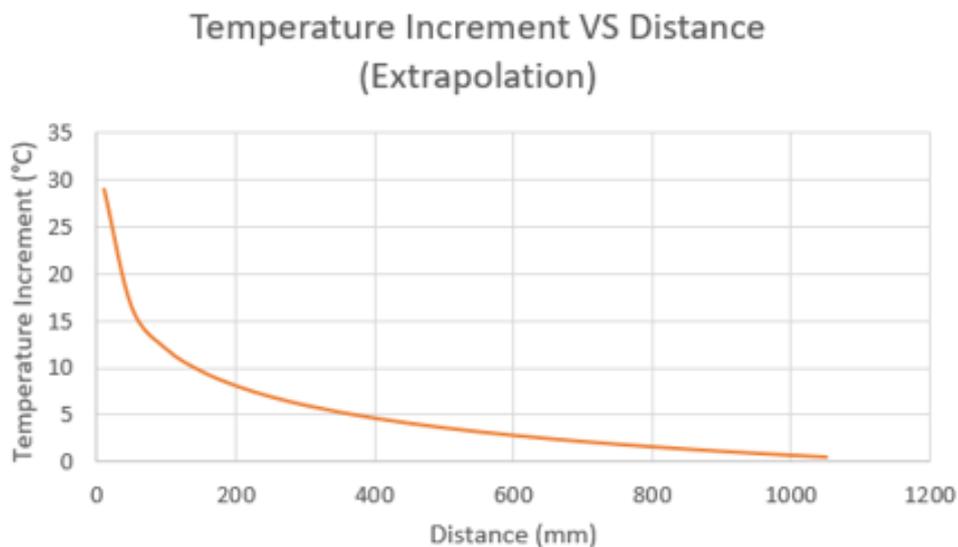


Figure 5. Extrapolation of temperature increment VS distance.

A health risk skin temperature of 34° Celsius was considered for estimation purposes only. We decided that two degrees Celsius is the goal for temperature increment. The emitter module designed and constructed for this work, produces a temperature increment of 1.66 °C at 800 mm after 120 s. This is 1.2048 emitter modules to reach the goal of two °C in a target mass of 4.831 g. Then, for a mass of 75 g to heat, a quantity of 19 emitter modules is needed (consider a rounding of 18.7).

**CONCLUSIONS**

There are successful methods to keep the patient’s body temperature in an acceptable range, such as electrical resistance, forced air and water circulation. Light-emitting semiconductors in the infrared spectrum could be used for this purpose because they provide energy to the object on which their light falls, in this case, the patient’s skin.



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To contribute to the exploration of this application of IR LED technology, it was possible to characterize the heating capacity of a power infrared light emitter.

All results of this work were calculated from an experiment using a constant current of 250 mA. Current can be incremented safely up to 400 mA with the appropriate heat dissipation system. With such a current intensity and the expected radiation power increment, the quantity of IR semiconductor emitters will be reduced in 30% at least. Given the estimated number of emitters required, this technology is feasible to be included in a surgical remote heating system with the purpose of decreasing the transfer of heat from inside the patient's body to the environment. It is planned to continue characterization of semiconductor emitters on body parts, as well as heating capacity experiments with interrupted patterns of energy.

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