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CHARACTERIZATION OF THE RADIATIVE HEATING CAPACITY OF AN INFRARED EMITTER FOR BIOMEDICAL PURPOSES

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ABSTRACT

Inadvertent perioperative hypothermia is a severe problem in surgical settings today. This work begins to explore the use of infrared emission from semiconductors for these purposes. Radiation from a commercial infrared LED used in telecommunications is applied to a temperature sensor at different distances under 7 mm. The mass of the encapsulated sensor is considered as the mass to be heated. The intensity of the current is constant throughout the measurement process. The obtained temperature data was manually processed to model the heating effect versus distance and 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 exponentially. We estimate the number of emitters for a hypothetical heating lamp. In this estimation, our team considered the minimum possible distance between a surgical patient and a lamp; besides, data related to skin weight was considered.t; the number of emitters for a hypothetical heating lamp is estimated. Due to the estimated number of emitters required, despite the power consumed, this technology is feasible for inclusion in a remote surgical warming system to decrease heat transfer from the patient's body to the environment.

INTRODUCTION

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

An infrared light-emitting diode is a semiconductor designed to produce light of a specific wavelength. This light, when in the infrared spectrum band, is capable of heating a target mass.

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

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 (9-11). 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 nearby area's heating.

This work examines the concept of heating the outermost layer of the skin by infrared light irradiation. Heating this layer will compensate for the colder environment's heat loss and decrease heat transfer from the patient's body core (13,14). As the first step in this research, we analyzed a standard low-power communications infrared LED. This paper reports the characterization of the IR333 infrared emitter's heating capacity due to exploring the use of optical semiconductors for biomedical temperature control purposes.

MATERIALS AND METHODS

Experiment details

The radiant power of the emitters is known from the manufacturer's datasheets. However, the objective is to measure the induction of heat generated by infrared radiation, which is essential for this work. There is a correlation between the irradiation power, the distance, and the mass of the target object.

Of course, other environmental factors and characteristics of the target object influence the heating capacity, but these are not the focus of this work.

A typical commercial infrared LED for telecommunications and remote controls was selected. It is the IR333 with a radiant power (15) of 85 mW/sr, a maximum current of 100 mA, and a maximum direct voltage of 1.4 V. For this power range; the experiment was performed in a millimetric scale. The distance was adjusted from 0 to 7 mm between the emitter and the target. The beam opening angle, according to the datasheet, is 20 degrees. As the distance increases, some of the radiation is wasted due to excessive beam opening, which is an additional reason not to go beyond 7mm away. The distance was adjusted in 0.5mm increments for each measurement using a precision screw holder, as shown in Figure 1.

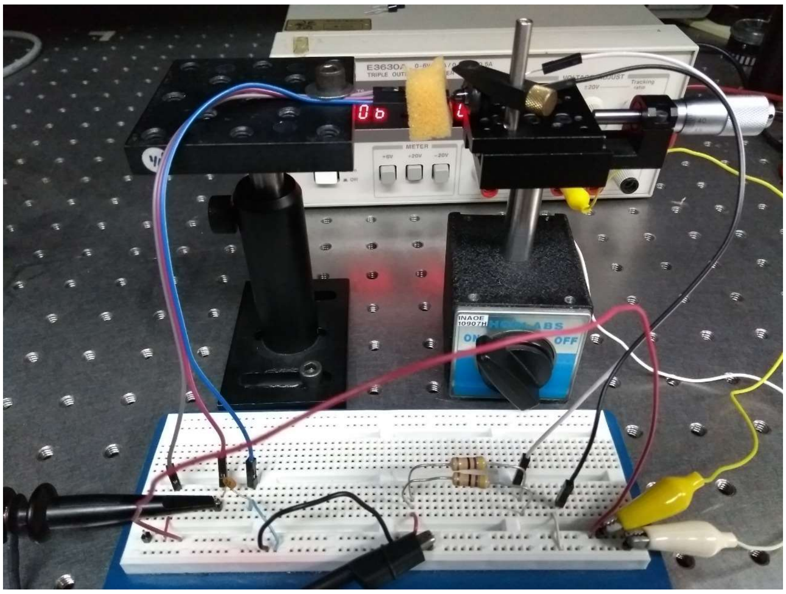

Figure 1: *Photo of the experimental array and the electrical circuit utilized in this work*

A well-known LM35 sensor integrated circuit was used to detect the temperature. A Styrofoam side cover was used to decrease the heat dissipation of the sensor package. This IC brings ten mV per degree Celsius. A Tektronix TDS 2022B oscilloscope was intended to display the sensor output signal. For this low power experiment, a small target mass was needed. It was decided to use the 0.1897 g temperature sensor package as the target mass. The power for the IC temperature sensor should be in the range of 4 to 20 V. A voltage of 5 V and a suitable resistance of 25 Ohm was used to have a direct current of 100 mA through the IR LED in an array shown in figure 1.

The sensor was irradiated for 200 seconds while the oscilloscope recorded the voltage fluctuation. Between each of these recordings, a cooling procedure (fresh air blowing) was run. Each of these 14 traces (0 to 7 mm, with distance increments of 0.5 mm) was photographed. Figure 2 shows a sample of these photographs. One set of temperature increment data was obtained from the photos manually for exposure times in 10 s increments; this means 20 data sets, including an obvious set of zero temperature increments for zero time. The photographed traces showed a noticeable noise that led the person to take the data to estimate the center of the value at the time point of observation on the traces.

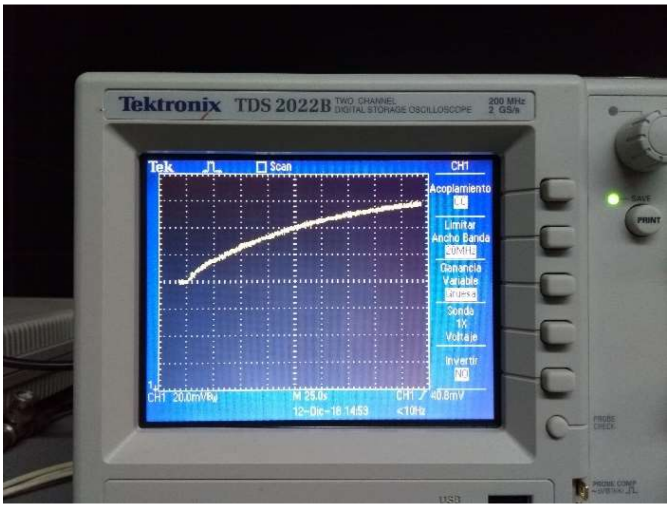

Figure 2: Sample of trace obtained from oscilloscop Tektronix TDS 2022B's screen showing the reaction of sensor

Modeling

Exponential regression of all the obtained curves was analyzed to obtain the expression that relates the distance, temperature, and time for the small mass used in the experiment, shown in formula 1.

$$y=51.849x^{-0.271} \qquad (1)$$

We infer that the accumulation of emitters could have a linear reaction. To check this inference, we experiment with this way:
Two emitters were pointed at a single sensor from directions 60 degrees apart from each other. Irradiation was first tested with only one emitter on at a time and with both emitters simultaneously. The trace obtained is shown in figure 3. This trace reveals an exact overlay effect. This effect is attributed to the increase caused by the two simultaneous emitters' temperature and is equivalent to the sum of both emitters.

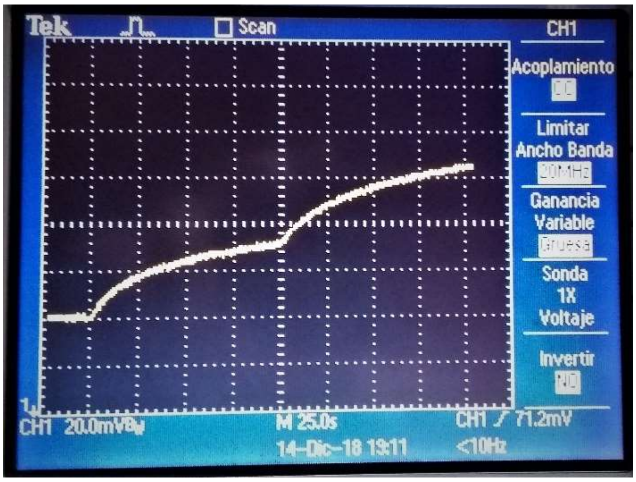

Figure 3: Trace of sensor voltage output, showing the superposition of effects with two emitters irradiating at once

RESULTS AND DISCUSSION

The curve obtained through the extraction of trace data from the oscilloscope is shown in Figure 4. It describes the effect of infrared irradiation on the target mass's temperature, depending on the distance and the exposure time. The ability to heat the target mass decreases with distance and increases with exposure time. A second-order regression was performed from these data to obtain an analytical model of the temperature increase over different distances.

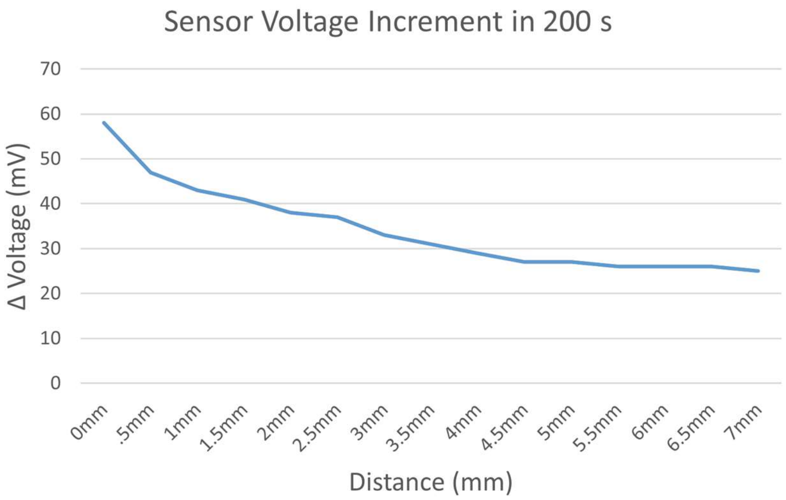

Figure 4: ***Effects of infrared irradiation depending on distance with exposure time of 200 s for a mass of 0.1897 g***

The graph obtained with this equation (figure 5) shows the extrapolation of the effect of infrared irradiation to much longer distances, this is, distances close to 800 mm. That is a distance expected in operating rooms from instruments and lamps hanging on the operating table, up to the patient's body. 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 (16). 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 and consequently to the environment.

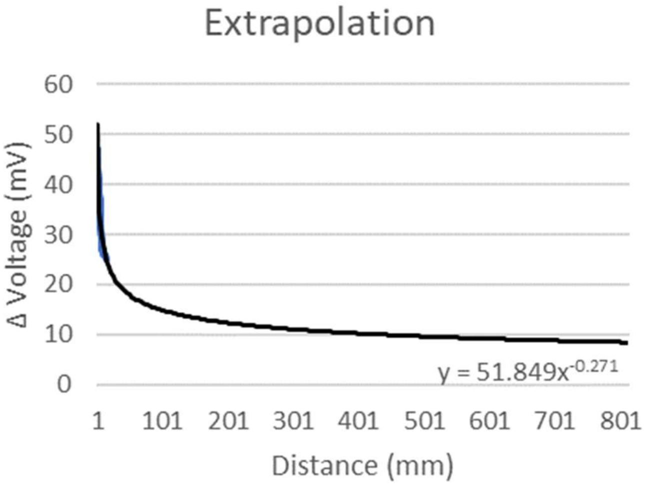

Figure 5: ***Extrapolating model for the temperature increment effect of infrared irradiation***

For estimation purposes only, alarming skin temperature of 34° Celsius was considered. Two degrees Celsius are set as the target for temperature increase. With these values, a quantity of 933 infrared LEDs (IR333) is required for a heating lamp's future design.

CONCLUSION

Almost a thousand LEDs required may seem like an excessive quantity, but the experiments for this work were done using a low-power communications LED. We consider that using a power LED with ten times the radiant power of the IR333, the required quantity of LEDs will be close to one hundred. One hundred is an acceptable quantity of electronic components. One hundred power LEDs will require a significant intensity of the electric current. Managing this power will be a matter of another work. Due to the estimated number of emitters required, despite the energy consumed, this technology is feasible to be included in a remote surgical warming system to decrease heat transfer from the patient's central body to the environment.

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