SKIN COLOR MONITOR

Final Design Report

December 12, 2008

THE UNIVERSITY *of* WISCONSIN
MADISON

Team:
Amy Lenz, Vincent Mi, Brooke Sampone, Grant Smith

Advisor:
Walter F. Block, Ph.D.

Client:
John G. Webster Ph.D.

TABLE OF CONTENTS

SKIN COLOR MONITOR

Final Design Report

Abstract

Menopausal women commonly experience discomfort due to hot flashes. The objective was to develop a device that detects hot flashes by measuring changes in skin redness. The prototype uses a 525 nm LED to illuminate the skin and a photodiode in photovoltaic mode to detect the reflected light. The output signal from the photodiode is amplified through an inverting amplifier with a low pass filter. As expected, the device observes decreasing skin reflectance with increasing skin flushness. The device consistently output a decrease of 5-10 mV between flushed and normal skin. This semester's work focused on minimizing the size and weight of the device through a complete re-fabrication of the LED/photodiode housing as well as a semi-permanent soldered circuit.

Problem Statement

The goal is to improve upon an already existing skin color monitor. The device uses a colored LED and a photodiode to detect color changes in women's skin color due to hot flashes. The purpose of the device is to record sudden color changes resulting from hot flashes for analysis during research and testing of pharmaceutical menopausal drugs. Compliance with FDA standards is also important, because the device is meant to be worn continuously to optimize the amount of data that can be recorded. As a result, the device needs to be small and aesthetically pleasing or to be concealed under clothing. Continuous use requires the device to run on a battery that will last for at least one day while readings are recorded every ten seconds. To properly detect hot flashes, the device needs to be worn on the chest or upper arm region where significant blushing has been frequently observed (James et al., 2004). Overall, the device needs to be compact (less than 6 cm x 6 cm x 1 cm), comfortable and inexpensive (less than two-hundred dollars to manufacture, disposable parts are desired to cost under seven dollars).

Motivation

Middle-aged women commonly experience hot flashes as a symptom of menopause. Hot flashes are characterized by a sudden onset of warmth, skin redness, and sweating. During menopause, the depletion of primary oocytes cause follicle stimulating hormone (FSH) to respond to the cease of ovarian and uterine cycles. Consequently, lowered levels of estrogen and progesterone confuse the hypothalamus, causing the body to register at a higher temperature than normal (Martini, 2006). To compensate for this illusion of high body temperature, the heart increases blood flow and blood vessels dilate to allow saturation of capillary beds. The elevated blood flow in epidermal capillary beds causes the visually observed flushness. As a result, heat is lost from the surface of the skin which is meant to lower the body temperature.

Over fifty percent of women in Western cultures experience hot flashes during menopause. In contrast, Eastern cultures such as China, Japan and Pakistan have hot flash occurrence rates below twenty percent. The significant decrease is thought to be due to the presence of dietary phytoestrogens, which are found in soy and mimic the chemical properties of estrogen. (WebMD Health, 2000)

A device to help monitor hot flash occurrence would help in diagnosing hot flashes as well as quantifying the effectiveness of any drug treatments. Current methods of logging hot flash occurrence are qualitative, unreliable, and prone to human error. This new device aims to provide a reliable quantitative solution to this problem. This will allow for quantitative analysis of hot flash frequency, intensity, and duration. Identification of these factors allows for a better understanding of hot flashes and treatments.

What Already Exists

CURRENT DEVICES

Several existing devices are used to monitor hot flashes. Physicians currently rely on patients' documentation of physical symptoms through a journal. Although this is a simple and cost effective way to monitor hot flashes, several problems are associated with this system. This data is unreliable as it is completely subjective and highly prone to human error.

Figure 1. The BIOLOG can be programmed to specifically monitor hot flashes in several different ways. (Hot Flash, 2007)

Produced by UFI, BIOLOG is a device currently on the market with the potential to monitor hot flashes (Figure 1). This multipurpose device can be programmed to monitor hot flashes by measuring various physiological properties. However, this device lacks many desired qualities. The market price of the device is about $2200 and the software required for analysis is an additional $2000. Also, the device is too large and bulky, weighing approximately 200 grams. These factors make the BIOLOG undesirable for the given application.

The client has already developed a device to monitor hot flashes through skin conductance (Figure 2). This device employs electrodes attached to the skin to measure conductance. When the subject sweats, changes in the conductivity of her skin are measured and recorded. The subject is also asked to make note of hot flashes by manually swiping a magnetic indicator over the device. Although this device can accurately measure hot flashes, the client hopes to monitor hot flashes through a different variable: skin color.

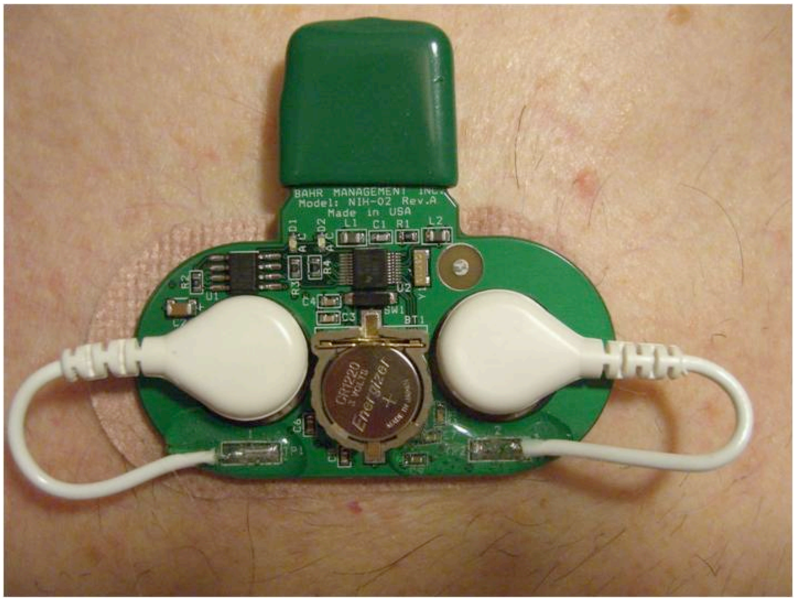


Figure 2. The skin conductance device is used to measure the change in conductivity of the skin while a woman experiences a hot flash. (J. G. Webster, personal communication, 2008)

PREVIOUS SEMESTERS' WORK

This project is in its third semester of work. The first semester team designed the basic housing and setup of the skin color monitor. The housing was made of rigid, black polycarbonate (Figure 3). The cylindrical polycarbonate housing measured 3.8 x 3.8 x 1.4 cm and contained two small holes at 45° angles from skin's surface for the LED and the phototransistor. An acrylic shield was placed on the bottom of the device to prevent the movement of the skin in relationship to the LED and phototransistor. The team spoke with Kevin Eliceiri, Director of Laboratory for Optical and Computational Instrumentation at the University of Wisconsin – Madison, who suggested the use of blue LEDs, noting that the wavelength is least absorbed by the skin. Testing also indicated that reflectance of blue light varied more widely than that of red light in response to different colors of construction paper (Ginter, Ho, Kurkiewicz, & Yuen, 2007). Basic circuitry was used to power the LED and monitor the output of the phototransistor on a digital multimeter.

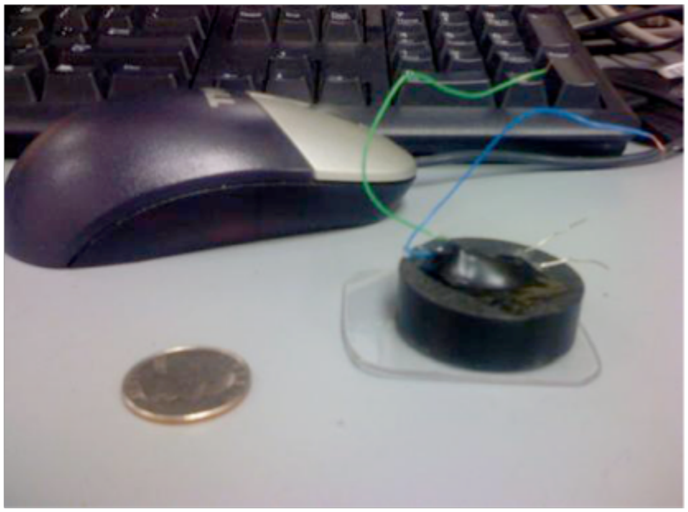


Figure 3. Image of the sensor and housing design developed by the fall 2007 design team. (Ginter, Ho, Kurkiewicz, & Yuen, 2007).

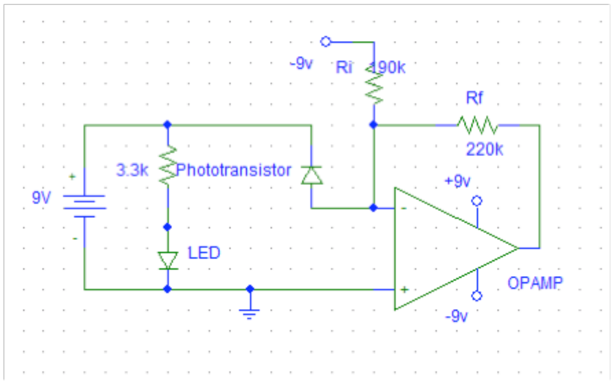


Figure 4. Circuitry designed by the spring 2008 design team. (Mosher, Offutt, & Vasys, 2008).

The spring 2008 team worked to improve the circuitry and modify the housing. They attempted to make the housing more ergonomic and durable. Their final prototype housing measured 3.65 x 3.65 x 1.59 cm. The team also minimized spectral reflection by placing the LED at an angle perpendicular to the base of the housing and the phototransistor at a 45° angle from the skin's surface. An inverting amplifier was added to magnify the output voltage so the device better distinguished skin color changes. The team used a phototransistor because testing shows that it is more sensitive to light than a photocell (Mosher, Offutt, & Vasys, 2008).

Design Criteria

The client's objective was to create a skin color monitor for recording color changes due to hot flashes in menopausal women. The design team narrowed the project focus to determine if an FDA approved monitor could track skin color changes reliably for under $200. The client stated this was his primary objective.

The client provided numerous design constraints. First, the device must record skin color every ten seconds by measuring voltages proportional to the light detected by a photodiode. The device's output needs to facilitate repeatable measurements within a 1 mV tolerance for a constant, known sample. This allows for detection of the baseline skin tone and ensures that background noise is not included in the signal. Also, the output value when detecting induced skin color changes needs to have a difference of at least 5 mV from an individual's baseline reading. The resulting signal to noise ratio will allow for substantial confirmation of skin color changes. The LED and photodiode should be powered by a 3 V battery since this size battery is common and could fit inside a commercially designed prototype. Minimizing the amount of light that does not interact with the skin before reaching the detector is also of value. A full description of product design specifications is listed in Appendix A.

Other design expectations were less important for answering the client's main question but still relevant to the project. Many complex issues will need to be resolved via data interpretation software; these problems were not of primary concern to the client who expressed that he wanted mainly to provide a definitive answer to the question of whether or not hot flashes could be detected by monitoring changes in skin color. The housing unit needs to be capable of remaining attached to a subject's chest indefinitely, except during activities where water might hamper the device such as showering or swimming. The attachment did not appear to be of primary concern to the client, and thus, was not a primary focus of the design team's work. The device needs to be constructed without sharp edges in order to prevent irritation and injury. The volume of the device must be smaller than 6 cm x 6 cm x 1 cm and it must weigh less than 50 grams. The preferred size of the device's housing is 3 cm x 4 cm x 0.5 cm. The criteria regarding the housing size and ergonomics are important for insuring the patient's safety. These things would need to be finalized in a working prototype in order to accomplish further testing.

Design Alternatives

LIGHT SOURCES

Three light sources were considered for the device: a laser, an LED, and a fiber optic cable. Lasers are intense and directional and would thus increase the ease of detection and reduce the internal reflection of the light; unfortunately, they were not within the desired price range. Fiber optic cables have similar benefits, but they are also too expensive. Additionally, they are relatively sharp and thin and can produce discomfort when in direct contact with the skin. LEDs were the most logical option sine they are cheap and effective. Light between the wavelengths of 500 and 600 nm is the most sensitive to changes in the blood saturation of the skin (Figure 5). For this reason, the final design uses an LED with peak wavelength of 525 nm. (See appendix for data sheet)

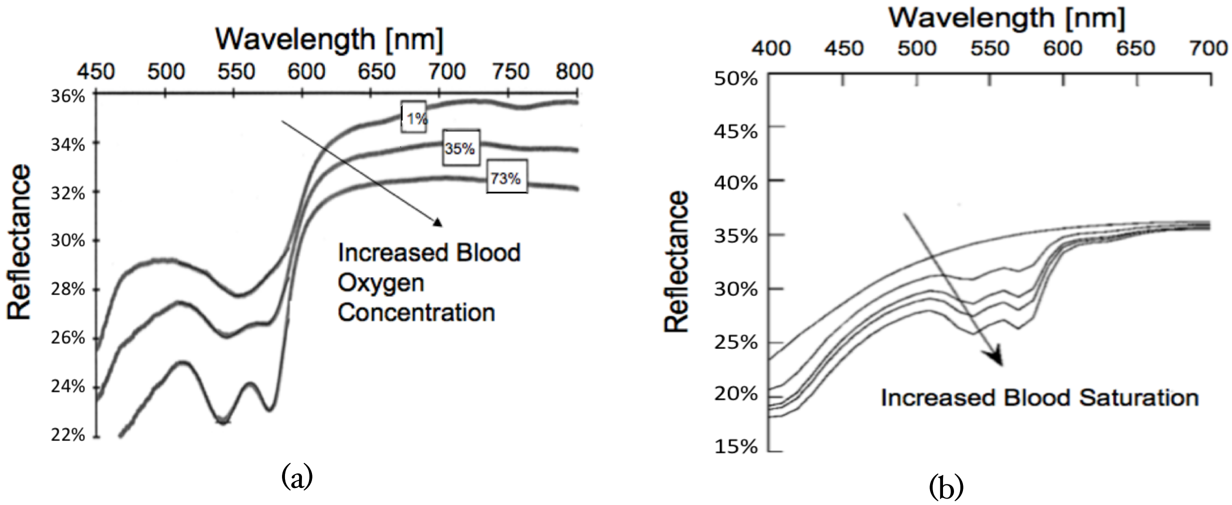


Figure 5. Plots of skin reflectance at various wavelengths in reaction to changes in blood saturation (a) and blood oxygen concentration (b). According to these graphs, skin reflectance is most sensitive to changes in both blood saturation of the skin and oxygen saturation of the blood between 500 and 600 nm wavelengths.(Sratonnikov)

A green LED with a wavelength of 525nm was chosen to optimally detect skin color changes due to hot flashes. This coincides with research showing that skin reflectance due to increased blood flow varies the most between 500 nm and 600 nm wavelengths (Figure 5). Testing from the previous semester provides corroborating evidence (Mosher, Offutt, & Vasys, 2008).

LIGHT DETECTORS

Three types of light detection systems were considered: photodiodes, phototransistors, and diffraction gratings. All methods are sensitive enough to meet the client's needs; thus, the ability to produce repeatable and accurate results became our main concern. Previous semesters used phototransistors, but during testing, it was noted that raising the temperature of the device using a blow dryer caused voltage outputs to fluctuate by up to 20%. It is not unreasonable to think that the device's temperature will be subjected to similar temperature ranges, and therefore, a phototransistor would be inappropriate. While slightly more expensive, photodiodes also accurately measure reflectance changes on the skin's surface when tested in our device, but temperature does not affect them. Diffraction gratings could be used to filter out all but one wavelength; however, given the small amount of light reaching the detector and the reflectance spectrum of the skin, this seems unnecessary. Hence, a photodiode is used in the final design.

A photodiode (OP906) from OPTEK was used as opposed to the infrared detecting phototransistor that was used in past semesters. Advisor Wally Block stated, "While this is a PIN diode, the performance plots show that you get about 80% of the current out of them at zero bias that you would at a reverse bias. The performance curves show that you can get current from .05 to 5 mW/c^2." (See appendix for data sheet of OP906) Considering the improved responsiveness while hooked up in zero biased, or photovoltaic mode, the design team chose this method. Additionally, this prevents the power supply from having to provide the input voltage for the photodiode. An operational amplifier was included to magnify the observations of skin reflectance as detected by the photodiode. The low pass filter was added to remove background electronic noise and improve the signal to noise ratio. In combination, the output adequately represents the changes in reflectance caused by skin color changes.

HOUSING CONSIDERATIONS

Previous semesters' testing determined that 45º between the photosensor and the LED was an optimal angle for minimizing the signal with respect to background reflection from within the device itself. The design team noticed that light might enter the acrylic shielding in the previous semesters' designs, so the acrylic was sunken into the black housing for further optical insulation. Since the reflectance measurements are sensitive to changes in the pressure and curvature of the skin, the current design tries to minimize those fluctuations. The client suggested a design where the acrylic was removed to eliminate internal spectral reflection and the viewing hole made very small to prevent curvature changes in the skin. This idea was not tested as it poses a mechanical risk to the patient's epidermis and would be very sensitive to pressure changes. Another design was tested in which the LED and photodiode were in distinct, separate cavities within the housing; this eliminates spectral reflection while maintaining the safeguards against pressure and curvature changes of the skin. Unfortunately, this limited the amount of light reaching the detector and no measurements were attainable.

The housing needed to be revamped to minimize size, which was considered only briefly in past semesters. Hand calculations along with Pro/Engineer 3D models provided the required data to achieve these design requirements using the established sizes of the LED and photodiode. The housing is flat black in order to minimize reflection within the optical cavities. Previous semesters have incorporated an acrylic shield to prevent movement into the device's optical cavity. This semester, the team sunk the acrylic shield into the housing to optically insulate the device. In accordance with previous semester's research and design, the hole cut for the photodiode in the new housing is angled at 45° from the LED.

CIRCUIT CONSIDERATIONS

When the current design team began to reconstruct a circuit according to the previous semester's circuit diagrams, they could not produce a functional circuit. The design team explored new options including various combinations of the following circuit elements: amplifiers, filters, offsets, and power sources. Decisions regarding overall circuit structure and quantitative parameters of circuit elements depend on the choices of light emitter, light detector, power source, and desired output. In the final design, the team chose to use two 3 V batteries to power an LED and a low pass filter coupled with an inverting amplifier. A zero biased photodiode provides the input to the amplifier. These explorations aimed to improve the functional range in which to detect skin color changes.

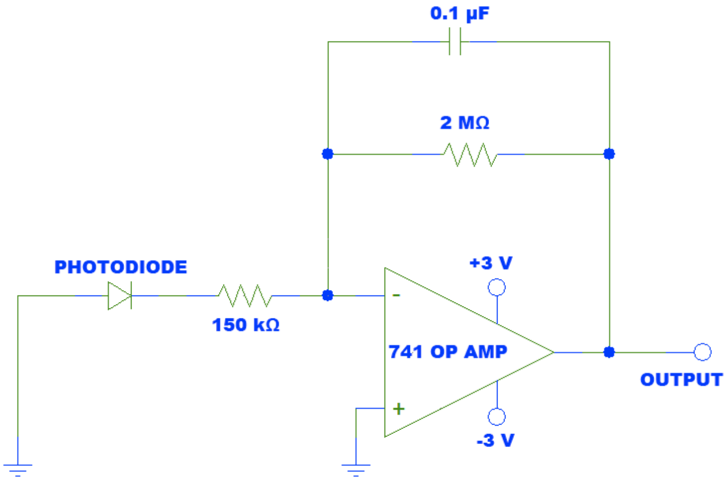


Figure 6. Current semester's circuit diagram including zero biased photodiode, inverting amplifier with gain of 13.3, and low pass filter with cutoff frequency of 0.8 Hz.

To streamline further progress, a circuit was constructed on a small piece of circuit board, making the device constant for future testing. A gain of 13.3 can be calculated for the final device, and no offset was used. This can be easily adjusted in the future in response the individual being tested. By providing more varied and precise quantitative measurements, a greater gain will allow for more qualitative correlation assessments. A low pass filter was added to the circuit and has a cutoff frequency of 0.8 Hz. This combination of elements results in a signal to noise ratio that is high enough to detect any changes in skin color and low enough eliminate background noise. The output of the device needs to facilitate repeatable measurements within plus or minus 1 mV for a given sample. This was tested by measuring several paint swatches.

Final Prototype

FINAL DESIGN

The final delivered product consists of the newly miniaturized housing and accompanying circuit with correctly optimized gain and filter. The housing measures 1.0" x 1.0" x 0.55" (2.5 cm x 2.6 cm x 1.4 cm) with a .238" hole cut for the LED and .156" hole for the photodiode. Additional countersink holes were drilled to accommodate the extended lip of both diodes. The acrylic shield for protection against skin pressure and curvature changes was sunk into the housing to optically insulate the internal cavities. A 3D CAD model of the housing is shown in Figure 7 (a), and a photo is also included in Figure 7(b). The circuit was constructed on a small piece of silicon as outlined with photodiode, LED, operational amplifier and resistors (Figure 6). A makeshift battery pack was included, and the entire testing apparatus is now portable (testable with a voltmeter attached to the output and ground). Preliminary testing indicates that the device can reproduce outputs that meet the design specifications.

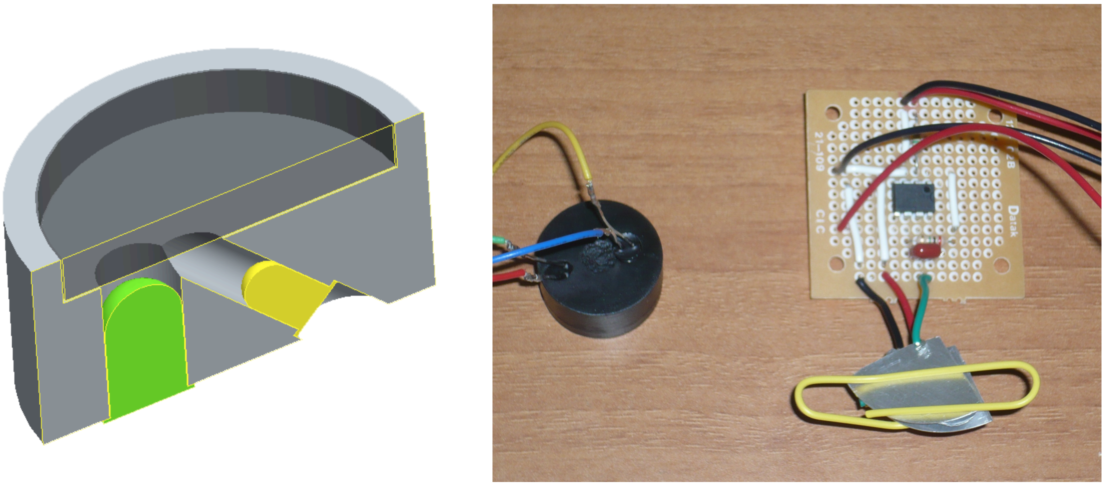


Figure 7. (a) Pro/Engineer model showing cross-section of new housing with LED and photodiode. (b) Photograph of new housing and soldered semi-permanent circuit.

COST ANALYSIS

- Green LED - $0.49
- Photodiode - $1.02
- 3 Volt Battery (2) - $8.98
- Resistors – donated
- Capacitor – donated
- Circuit Board – donated
- Wires – donated
- Plastic Casing – donated
- Plexiglass – donated
- Black Paint - $3.99

TESTING

Two different pallets were analyzed and gave similar results (Table 1). The slight variability between the three colors in each scenario consistently showed a decrease of approximately 11 mV.

TAN PALLET	VOLTAGE OUTPUT (MV)
Salmon White	148
Sugar bush	137
Soft Cinnamon	121
BLUSH PAINT PALLET	**VOLTAGE OUTPUT (MV)**
Apple Blush	136
Rose Marble	127
Sanibel Sunset	116

Table 1. Observed outputs of testing on paint swatches

The output also needs to facilitate the detection of color changes by a magnitude of at least 5 mV from the baseline value of a given individual. This was tested by measuring the skin in a given area before and after redness was induced (Table 2). The average voltage difference of the eight trials was 6.5 mV and is consistent with the goal of at least 5 mV of variation from a baseline value.

RED ARM (MV)	PALE ARM (MV)	VOLTAGE DIFFERENCE (MV)
87	95	8
83	88	5
87	92	5
84	92	8
84	90	6
77	84	7
87	93	6
85	92	7
AVERAGE VOLTAGE DIFFERENCE (MV):		6.5

Table 2. Testing on 8 different subjects shows a significant and consistent voltage difference between blushed and normal skin.

Although the device effectively measures skin color changes, these changes may provide only a limited, inconsistent measurement of hot flash occurrence. A generalization can be made: skin color changes as a result of hot flashes are not universal among the population or within the individual, and in some cases, they do not occur at all. It has been experimentally proven that women of Eastern cultures do not experience hot flashes (and thus, flushness) with the same prevalence as women of Western cultures (WebMD Health, 2000). Further research of hot flash pathophysiology is needed to test whether changes in skin color consistently and quantitatively reflect hot flash occurrence. Overall, this device would only be useful for monitoring women who express consistent redness during hot flashes.

Future Work

Although several improvements were made this semester, there are several minor aspects that the client wants modified and tested before he is willing to fund testing of a useful prototype. Primarily, he would like more concrete testing done over extended periods of time in a lab. These continuous measurements must indicate consistent observations regarding color change detection. First, the device requires further testing on various skin tones, in particular individuals with especially dark skin, to ensure minimal performance impact. Currently, a gain of 13.3 can be calculated for the final device, and no offset was used. This can be easily adjusted in the future if desired.

First, a method for attaching the device to the skin needs to be implemented. Although some form of adhesive will be necessary, the method of attachment should minimize skin irritation. Additional support may come from an elastic band surrounding the chest. Manufacturing a functional prototype will require incorporation of the electrical components into the housing. It may be worth revisiting the design in which the LED and photodiode are in separate optical cavities; for example, the angle and relative positioning of the cavities may be varied to attain measurable results.

In the future, software will need to be designed to analyze the collected data. For example, the device's accuracy could be further optimized for individuals' baseline skin tone by adding software to calibrate potentiometers; the potentiometers would modify the op amp's gain and offset to better indicate skin color changes by effectively amplifying the dynamic output range. Additionally, skin color changes due to hot flashes occur on the order of seconds and minutes. In exercise, changes in cellular metabolic rates effect the concentrations of oxygen and carbon dioxide carriers in the blood. Eventually, the energy expenditure causes elevated body temperature. To lower body temperature, capillary beds in the epidermis are dilated increasing blood flow to the region. The observable effect is redness or flushness of the skin. The same redness when induced by a hot flash is caused by steroid hormones which propagate throughout the body much faster, and thus, the rate and intensity of change in skin color becomes a distinguishing factor in recognizing hot flashes. Another unsolved problem is the change in output due to pressure increases in the epidermis as these also occur on the order of seconds and cannot be filtered out. An obvious example presents itself when sleeping: a patient will often be shifting pressure onto and away from the device. At present, there is no realistic way to accommodate for external positioning or pressure changes in the physical design; perhaps, the accompanying software can adequately address the issue. The software analysis of this data is probably the most difficult aspect of the project and requires complex analysis of a living system's output signal.

BIBLIOGRAPHY

Ginter, B., Ho, J., Kurkiewicz, P., & Yuen, J. (2007). *Skin Color Monitor.*

Hot flash. Retrieved October 9, 2008 from http://www.ufiservingscience.com/HFMon1.html

James, G. D., Sievert, L. L., & Flanagan, E. (2004). Ambulatory blood pressure and heart rate in relation to hot flash experience among women of menopausal age. Annals of Human Biology, 31(1; 1), 49-58.

Martini, F. H. (2006). *Fundamentals of Anatomy and Physiology.* San Francisco: Pearson Education Inc., Benjamin Cummings, p. 1061 & 1066.

Mosher, R., Offutt, S., & Vasys, V. (2008). *Skin Color Monitor.*

Shimada M., *et al.* 2001. Melanin and blood concentration in human skin studied by multiple regression analysis: experiments. *Physics in Medicine and Biology.* 46: 2385-2395.

Sratonnikov, Alexander A. and Loschenov, Victor B. Evaluation of blood oxygen saturation in vivo from diffuse reflectance spectra. *Journal of Biomedical Optic*s 6.4: 457-467.

Webb, Sarah. (September 18, 2007). Hormone Replacement Therapy Linked to Breast Cancer. *Discover.* October 21, 2008, from http://discovermagazine.com/2008/jan/hormone-replacement-therapy-linked-to-breast-cancer

WedMD Health. (February 9, 2000). Natural Alternatives to Hormone Therapy. *Medscape.* October 21, 2008 from http://www.medscape.com/viewarticle/517977

APPENDIX

Product Design Specifications

Function:

A skin color monitor that records color changes that occur during hot flashes, which could be used to provide the objective measurement needed for therapeutic drug testing for menopausal women. The device is to be capable of discerning color changes while remaining small and at a low cost. The device adheres to the skin in the upper chest region. An LED will shine light onto the skin and a photodiode will register the change and that will affect the output voltage. The changes in the voltage are recorded every 10 seconds.

Client Requirements:

Small size, Maximum of 6 cm x 6 cm x 1cm, ideally 3 cm x 4 cm x 0.5 cm.

Aesthetically pleasing, smooth design.

Elimination of specular reflection.

Design Requirements:

Physical and Operational Characteristics

<u>Performance requirements:</u> The device must record "skin color" every 10 s by displaying voltage proportional to light detected by photodiode, which will vary according to skin color.

<u>Safety:</u> The device must be FDA approved for humans. The LED and photodiode will be powered with a 3 V battery input and low duty cycle which will not overheat the skin, making the device safe for continual use. The method of attachment must not irritate skin.

<u>Accuracy and Reliability:</u> The output voltage must be recorded at least every 10 s. Changes in normal pattern will be flagged and measured to determine the intensity of skin color change. Accuracy will be improved by building a circuit in order to provide larger voltage differences with skin color change. Multiple persons of different ethnicities must be tested in order to find the accuracy of the device when applied to varying skin colors at normal body temperature.

<u>Life in Service:</u> The device must survive the minimum duration of an overnight recording and retrieval of data before recharging battery. There will be an On/off switch to preserve power when recording is not needed. It is designed to be a reusable device.

<u>Shelf Life:</u> The device must have a shelf life of at least one year when stored in original packaging.

<u>Operating Environment:</u> The device will be attached to the wearer's chest daily at home and work, and during sleep. The device should be taken off during daily activities such as during

shower in order to prevent damage to device. When unattached, the device should be stored and safe from outside exposure.

Ergonomics: The device will be fabricated with no sharp edges in order to prevent irritation or possible injury of the wearer. The on/off button will be contoured with the smooth casing of the device.

Size: The device will be a maximum of 6 cm x 6 cm x 1 cm including all possible attachments. The preferred size of the device by itself would be 3 cm x 4 cm x .5 cm

Weight: The device must be lighter than 50 g.

Materials: The device must not be fabricated with materials that would irritate or otherwise harm human skin. It should be soft and smooth to be comfortable while attached to wearer.

Aesthetics, Appearance, and Finish: The device must be small, smooth, and comfortable in order to avoid obvious detection and to provide the wearer optimal comfort. The LED within the device will also act as an “on” signal.

Production Characteristics

Quantity: Although we will only be making one prototype, if it is a successful design it may be produced in the thousands or hundreds of thousands.

Target Product Cost: We need to make a prototype that costs less than $200.

Miscellaneous

Standards and Specifications: FDA approval is required for this device

Customer: The customer requires a device that is comfortable to wear and is able to be concealed under clothing. If these specifications are not met, the motivation for the customers to wear the device (and thus the utility of the device) will be negatively affected.

Patient-related concerns: Depending on the method of attachment to the skin, adhesive may need to be cleaned off the skin after each use, and an adhesive may need to be re-applied to the device before subsequent uses. Hot flash occurrence data will be stored in the device, which may need to be safeguarded for the patient’s confidentiality.

Competition: There are other skin color monitors available, but due to their large sizes, heavy weights, and high costs, are not able to monitor a person constantly during their normal, everyday activities without being obtrusive and very expensive. There are several small hot flash monitors being designed and tested that measure hot flashes by changes in skin resistance due to sweating. Although these monitors have similar size and weight requirements as our design project, the method of detecting hot flashes is different.

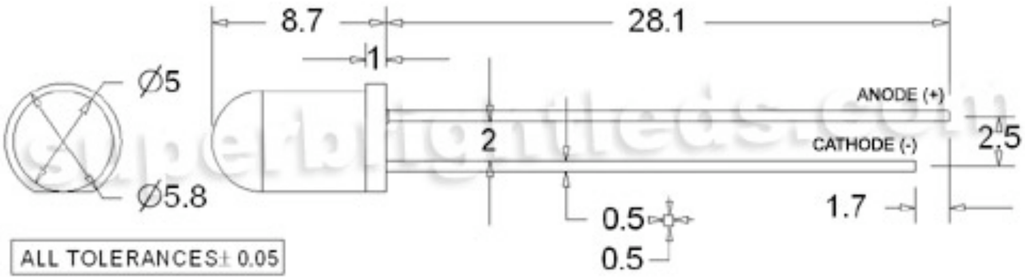
Part Number: RL5-G5023 - Super-Green LED (GaInN/GaN)

absolute maximum ratings: (TA=25°C)

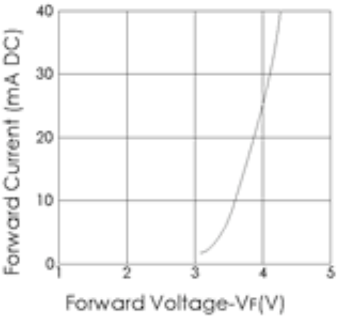
PARAMETER	SYMBOL	RATING	UNIT
Power Dissipation	PD	120	mW
Continuous Forward Current	IF	30	mA
Peak Forward Current (1/10th duty cycle, 0.1ms pulse width)	IFP	70	mA
Reverse Voltage	VR	5.0	V
Operating Temperature	TA	-25~+80	°C
Storage Temperature	TSTG	-30~+100	°C
Reverse Current (VR=5V)	IR	100	μa
Lead Soldering Temperature (3mm from body) 260C (for 3 seconds)			

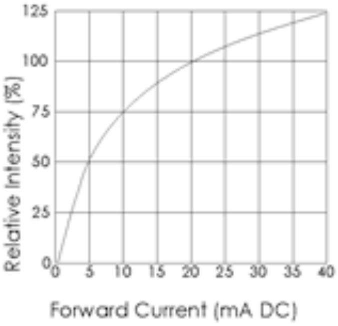
optoelectric characteristics:

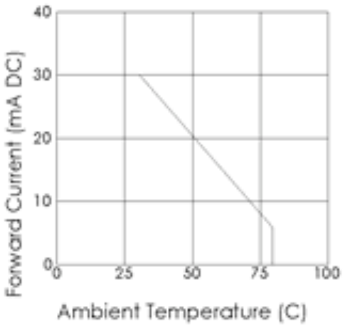
PARAMETER	SYMBOL	MAX	TYP	UNIT	TEST
View Angle of Half Power	2ø1/2	±3deg	23	Degree	
Forward Voltage	VF	4.0	3.5	V	IF=20mA
Peak Emission Wavelength	ÿ P		524	nm	IF=20mA
Dominant Emission Wavelength	ÿ D	±3nm	525	nm	IF=20mA
Spectral Line Half Width	Dl		35	nm	IF=20mA
Luminous Intensity	IV	±20%	5000	mcd	IF=20mA



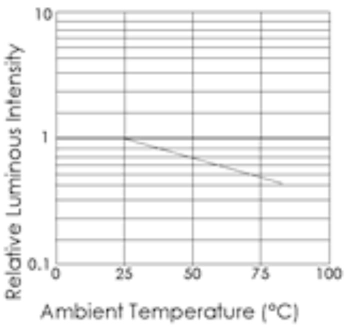
all measurements in millimeters



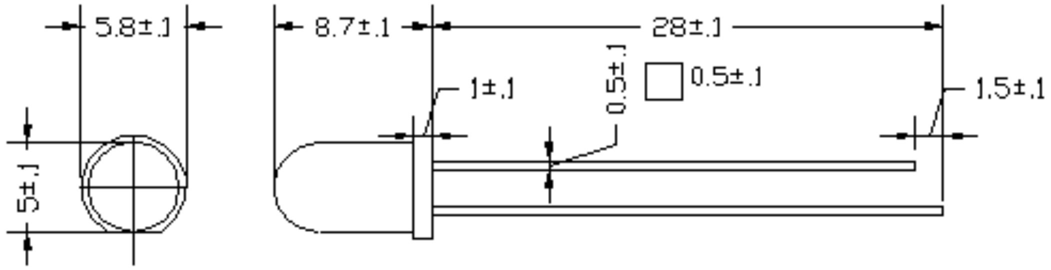




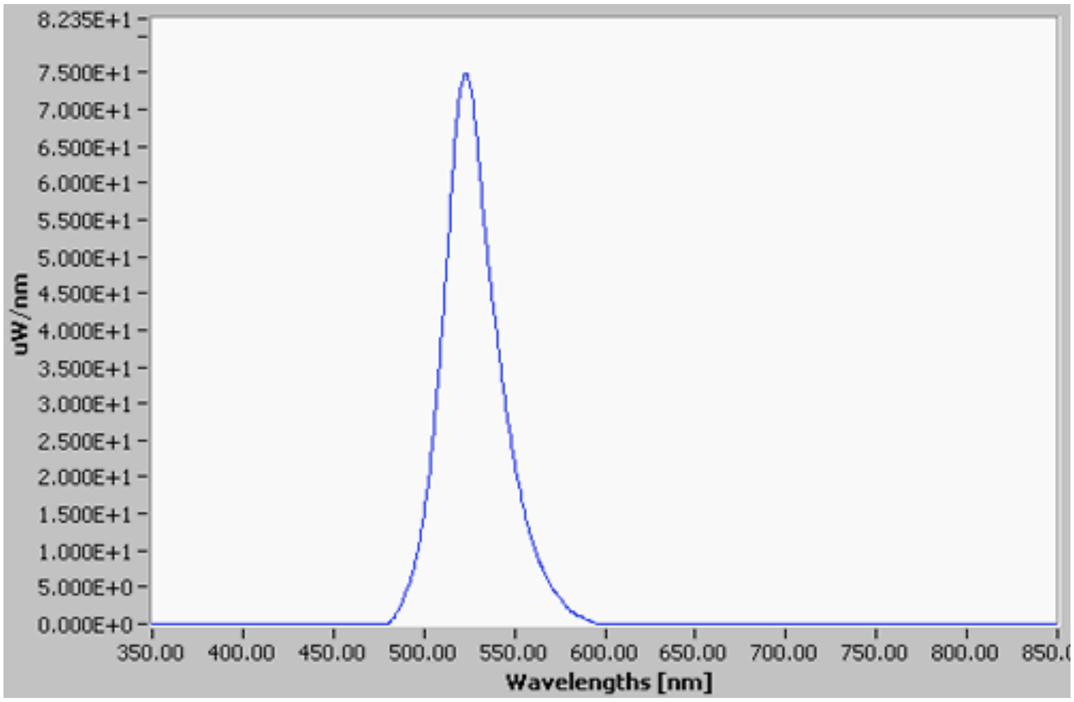
Forward Current (mA DC)
40
30
20
10
0
0
25
50
75
100
Ambient Temperature (C)



Relative Luminous Intensity
10
1
0.1
0
25
50
75
100
Ambient Temperature (°C)



5.8±.1
8.7±.1
28±.1
1±.1
0.5±.1
0.5±.1
1.5±.1
5±.1

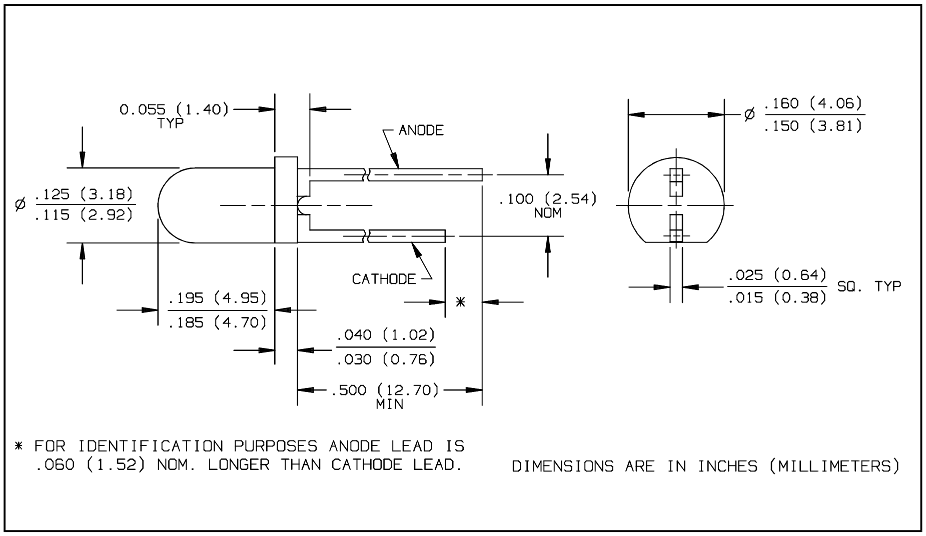


8.235E+1
7.500E+1
7.000E+1
6.500E+1
6.000E+1
5.500E+1
5.000E+1
4.500E+1
4.000E+1
3.500E+1
3.000E+1
2.500E+1
2.000E+1
1.500E+1
1.000E+1
5.000E+0
0.000E+0
uW/nm
350.00
400.00
450.00
500.00
550.00
600.00
650.00
700.00
750.00
800.00
850.0
Wavelengths [nm]

OPTEK

Product Bulletin OP906
June 1996

PIN Silicon Photodiode
Type OP906



Features

- Narrow receiving angle
- Linear response vs irradiance
- Fast switching time
- T-1 package style
- Small package ideal for space limited applications

Description

The OP906 device consists of a PIN silicon photodiode molded in a clear epoxy package which allows spectral response from visible to infrared light wavelengths. The narrow receiving angle provides excellent on-axis coupling. These devices are 100% production tested using infrared light for close correlation with Optek's GaAs and GaAlAs emitters. Lead spacing is 0.100 inch (2.54 mm).

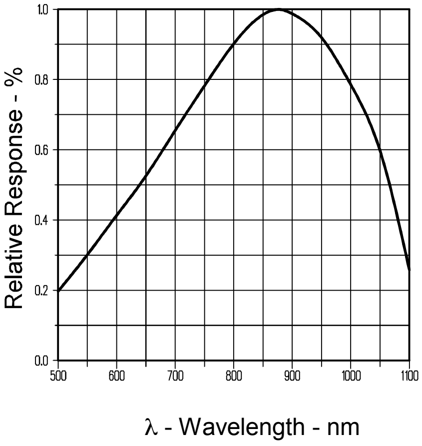
Absolute Maximum Ratings ($T_A = 25^o$ C unless otherwise noted)

Reverse Breakdown Voltage. . . . . 60 V
Storage and Operating Temperature Range . . . . -40° C to +100° C
Lead Soldering Temperature [1/16 inch (1.6 mm) from case for 5 sec. with soldering iron] . . . . 260° C(1)
Power Dissipation . . . . 100 mW(2)

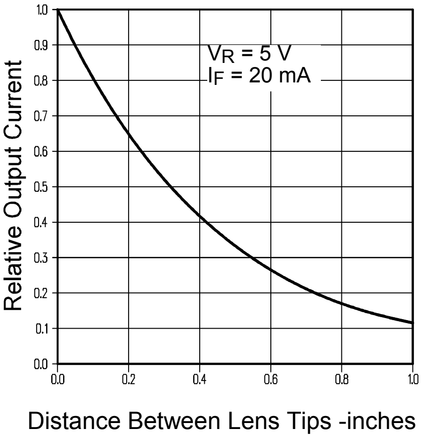
Notes:
(1) RMA flux is recommended. Duration can be extended to 10 sec. max. when flow soldering. Max. 20 grams force may be applied to leads when soldering.
(2) Derate linearly 1.67 mW/° C above 25° C.
(3) Light source is an unfiltered GaAs LED with a peak emission wavelength of 935nm and a radiometric intensity level which varies less than 10% over the entire lens surface of the photodiode being tested.
(4) To calculate typical dark current in nA, use the formula $I_D = 10^{(0.042\,T_A - 1.5)}$ where T_A is ambient temperature in ° C.

Typical Performance Curves

Relative Response vs. Wavelength



Coupling Characteristics OP906 and OP266



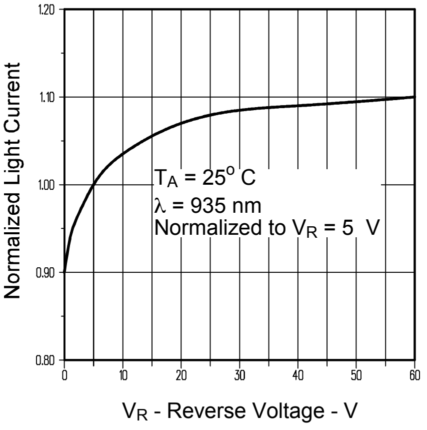
Type OP906

Electrical Characteristics ($T_A = 25^o$ C unless otherwise noted)

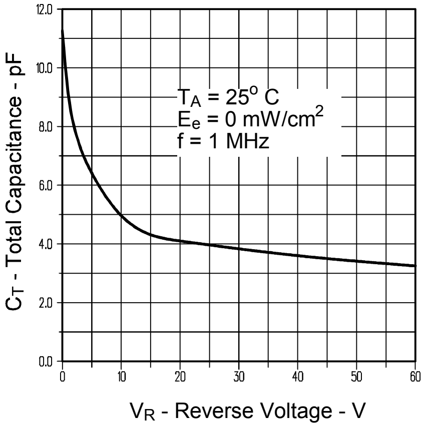
SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS	TEST CONDITIONS
I_L	Reverse Light Current	16		35	μA	V_R = 5 V, E_e = 0.50 mW/cm$^{2(3)}$
I_D	Reverse Dark Current		1	60	nA	V_R = 30 V, E_e = 0
$V_{(BR)R}$	Reverse Breakdown Voltage	60			V	I_R = 100 μA
V_F	Forward Voltage			1.2	V	I_F = 1 mA
C_T	Total Capacitance		4		pF	V_R = 20 V, E_e = 0, f = 1.0 MHz
t_r, t_f	Rise Time, Fall Time		5		ns	V_R = 20 V, λ = 850 nm, R_L = 50 Ω

Typical Performance Curves

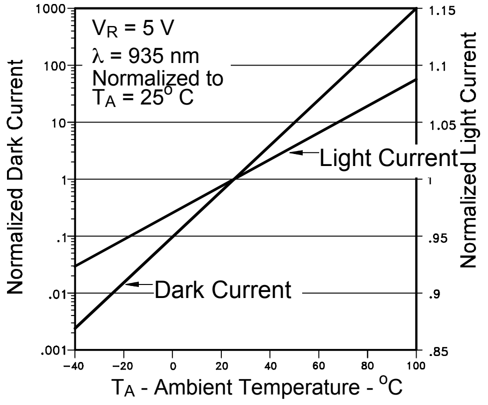
Normalized Light Current vs Reverse Voltage



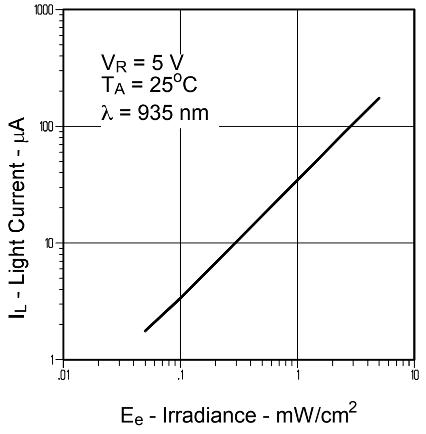
Total Capacitance vs Reverse Voltage



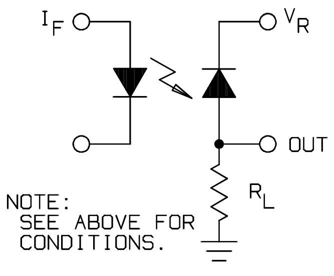
Normalized Light and Dark Current vs Ambient Temperature



Light Current vs. Irradiance



Switching Time Test Circuit



Light Current vs. Angular Displacement