Global Health: Color Changing Imaging Surface For Prevention of Diabetic Foot Ulceration

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Abstract

- Diabetes is a growing problem in India and can lead to lead to formation of foot ulcers and even amputation of the feet
- An easy, inexpensive, at-home remedy is needed
- Measuring the temperature of feet can help to prevent ulcerations [1].
- Thermochromic liquid crystals can be used to create an imaging surface that will change color when stepped on so that patients can monitor foot temperature
- Significant temperature differences indicate ulceration

Problem Definition

Motivation

- Unchecked diabetes often leads to foot amputation
- Finding a preventative solution avoids ulceration and is cost effective for non-shoe wearers
- Providing a simple and affordable device to measure the temperature in the feet can allow patients to take control of their own health and make lifestyle changes when necessary.

Background

- Diabetes affects the regulation of blood glucose, so diabetic patients can develop hyperglycemia which leads to vascular damage and neuropathy [2]
- Overuse can cause skin to break down to form an ulcer
- A temperature difference of 2.2 degrees Celsius in symmetrical areas of the foot can indicate an ulcer [1]

Foot Ulcers

Figure 1 *- Diagram of diabetic foot ulcer [3]*

Design Specifications

- Must be low cost and easy to use
- Usable by patients that both use and don't use socks and sandals
- Thermochromic material must accommodate people of many different foot sizes and weights
- Must withstand multiple uses and still be accurate
- Should be able to output thermal images that can be incorporated into a machine learning algorithm
- Material used to collect temperature data and thermal maps must be safe to use

Fabrication and Testing

Color Changing Ability of Powders:

- TLC powders of different temperature ranges
- Mixed with two different acrylic bases
- 3 trials of swatches on both fabric and wood with each powder —> weak color changing ability
- Mixed all powders together —> zero color change

Figure 2 *- Image of swatches of TLC pigments on wood, resulting in very weak color change*

Combination of TLC Sheets

- Each color changing sheet has 5ºC range
- Desired range is 10-15ºC
- Average size of foot ulcer is 2.8 cm^2 [4]
- Layered strips of each sheet with ranges 20-25ºC, 25-30ºC, and 30-35ºC in order

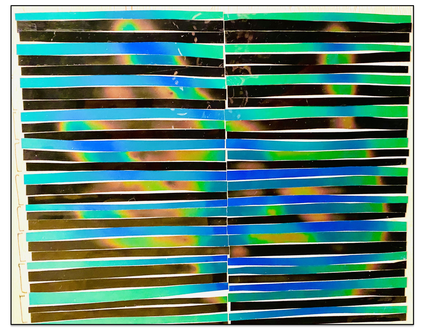


Figure 3 *- Image of Layered TLC Sheets showing a thermal image of a hand. The strips are layered in groups of 3, bracketed on the left.*

Temperature and Time Data

Table 1 - *Temperature data comparing actual and color estimated temperatures*

Trial	Estimate based on color shift (Celsius)	Actual (thermometer) (Celsius)	Difference
1	36	38.1	2.1
2	34	33.2	-0.8
3	27.5	28.4	0.9
4	24.5	23.2	-1.3
5	19	17.8	-1.2
6	27	29.5	2.5
7	29	28.9	-0.1
8	31.5	31.3	-0.2
Average	28.5625	28.8	1.1375
Standard deviation	5.4145	6.1542	

The t-value is -0.08195. The p-value is .935846. The result is not significant at p < .05.

Final Design and Prototype

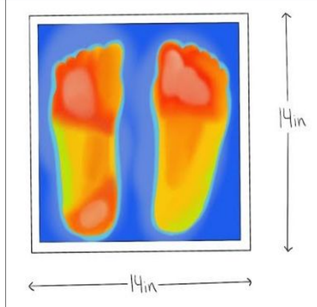
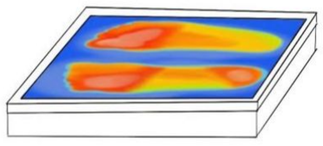


Figure 4 *- Drawing of proposed final design showing top and side view of thermal image of feet*



- Layered strips of TLC sheets of different temperature ranges
- Each section has three strips making up a total range of 20-35ºC
- Strips are labeled to indicate temperatures
- Any color change in highest range strip indicates higher-than-average foot temperature, meaning there is cause for concern about potential ulceration

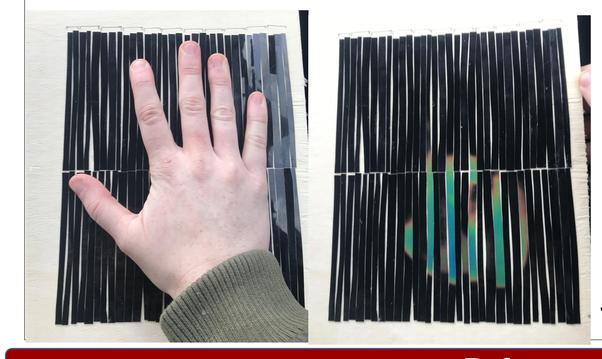
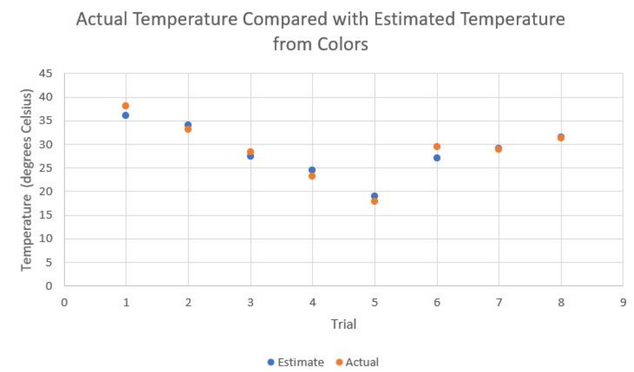


Figure 5 *- Image of final prototype showing a hand pressing onto the layered thermochromic liquid crystal surface and the thermal image produced*

Results

Figure 6 *- Graph of actual temperature and estimated temperature*



- Two Sample T test to determine if temperature from TLC imaging surface is significantly different from actual temperature measured with thermometer
- alpha = 0.05
- The t-value is -0.08195. The p-value is .935846. The result is not significant at p < .05.
- The color estimated temperature is not significantly different from the actual temperature
- The average difference was 1.14 ºC
- Thus, our device will yield accurate temperatures corresponding with colors that last for an average of 19.6 seconds in the 25-30 ºC range, and an average of 8.35 seconds in the 30-35 ºC range

Future Project Development

- Continue to modify the imaging surface to achieve more precision
- Collect more data on the long-term lifespan of the TLC materials under different conditions
- Use machine learning algorithm to identify temperature differences of 2.2ºC or more in symmetric areas of the feet
- Collect real-life data from patients stepping on the imaging surface to aid in programming of the ML algorithm

Acknowledgements

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References

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