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Characterization of High Temperature Optocoupler for Power Electronic Systems

An undergraduate honors thesis submitted in partial
fulfilment of the requirements for the degree of Bachelor
of Science in Electrical Engineering

By

David Elias Gonzalez Castillo

May 2019

University of Arkansas

Abstract

High-temperature devices have been rapidly increas due to the implementation of new technologies like silicon carbide, high-temperature ceramic, and others. Functionality under elevated temperatures can reduce signal integrity reducing the reliability of power electronic systems. This study presents an ongoing research effort to develop a high-temperature package for optocouplers to operate at higher temperature compared with commercial devices. Low temperature co-fired ceramic (LTCC) was used as the substrate. Bare die commercial LED and photodetectors were attached to the substrate and tested for functionality. Preliminary results show enhanced performance at elevated temperatures compared to a commercial optocoupler device.

List of Contents

List of Figures 4

List of Tables 4

Acknowledgment 5

Introduction 6

Background 8

  Type of isolators 8

    Transformer or Inductive Coupling 8

    Optical Isolators 9

  Motivation 11

  Characterization of Commercial Devices 13

Design Process 16

  Design Consideration 16

    LTCC Process 18

  Design 1 19

  Design 2 21

  Design Complications 23

Experiment 25

  Test Setup 25

  Results 26

Discussion of Results 31

Future Work 33

  Design 3 33

Conclusion 35

References 36

List of Figures

Fig. 1. Isolation transformer functionality [8]. 9
Fig. 2. Cross section of an optocoupler [9]. 10
Fig. 3. Output waveform comparison: optocoupler vs pulse transformer [7]. 11
Fig. 4. Commercial devices tested to obtain electrical characteristics. a) IL300, linear optocoupler with high stability and wide bandwidth provided by VISHAY [14]. b) CNY17 phototransistor output with base connection provided by VISHAY [15]. c) 52458 Dual current to current opto-isolator provided by MICROPAC [16]. 14
Fig. 5. CREE-DA2432 InGaN LED [17]. 16
Fig. 6. OPC7000-21 AlGaAs [18]. 16
Fig. 7. MT41-011CH Si photodetector [19]. 17
Fig. 8. Optocouplers preliminary designs. a) Chip carrier model. b) Silicon based model. c) LTCC based model 17
Fig. 9. Production process for multilayer ceramics [20]. 18
Fig. 10. Cros section design 1. 20
Fig. 11. Deisgn 1 packages after fabrication. a) Shows LTCC panel after being fired. b) Individual package after dicing. c) Individual device after devices being assembled. 21
Fig. 12. LTCC Design 2. A) Solid-Work design before fabrication. B) LTCC Panel with the designs. C) LTCC model after fabrication and assemble front side. D) LTCC model after fabrication and assemble backside. 22
Fig. 13. Silicon detector test. 24
Fig. 14. Comparison of IL300 with LTCC sample. 26
Fig. 15. Temperature comparison between LTCC Sample and IL300. 27
Fig. 16. LTCC sample results at 25 °C. Stress under different input voltages 28
Fig. 17. LTCC results vs MICROPAC 25458 over temperature. 29
Fig. 18. LTCC results vs IL300 results over temperature. 30
Fig. 19. Design 3 drawings. a) Chip carrier for LEDs. b) 3D model of new optocoupler. c) 3D model of new optocoupler substrate transparent. 34

List of Tables

Table 1. Advantage of Optocouplers over Pulse Transformers [5]. 12
Table 2. Electrical Testing Results from Commercial Devices 14
Table 3. Electrical Characteristics for Commercial Devices According to Datasheet [13] [14] [15]. 15
Table 4. Design Constraints for Model 1. 19
Table 5. Design Constraints for Model 2. 22
Table 6. Elctrical Testing Results from Coomercial Devices and LTCC Devices [13] [14] [15]. 31
Table 7. New Leds dimmensions. 33

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Introduction

Development of advance power electronics with unprecedented functionality, efficiency, reliability, and reduced form factor are required in an increasingly electrified world economy. With the new developments on wide-bandgap semiconductor materials such as silicon carbide and gallium nitride, the range of functional application has increased. Metal-oxide-semiconductor field-effect transistors (MOSFETs) based on this materials are capable of high power at high switching frequencies with less switching and conduction losses. These devices also expanded the temperature limits of regular silicon devices, creating a temperature lack between this new technology and current commercial devices [1] [2]. The implementation of these semiconductor devices allowed power electronic applications to drive high voltages level that can induce massive current flows through the circuit. Having a poor control of the current flow can be catastrophic causing circuit damage or failure, personal injury, or even death [3]. In order to avoid this, isolation techniques or materials with high dielectric capabilities are implemented to reduce the flow of unwanted current through the system. The most common type of isolation used currently is galvanic isolation. Even though the term galvanic refers to metal and electrochemical process, galvanic isolation refers to the absence of conduction metal or conduction path [3]. This type of isolation reduces the current flow of the circuit by adding clearance, space or an isolation material.

Optocouplers are optical isolators that use galvanic isolation to control the flow of high current density on sensitive circuitries. The implementation of optoisolators has increased due to its convenient size and functionality [4]. Similar to optocouplers, pulse transformers are another form of galvanic isolation to protect the circuit. Pulse transformers reduce the efficiency of the integrated circuit since its volume is higher and the integrity of the signal is compromised due to the mutual inductance of the coils [5]. In contrast with pulse transformers, optocouplers have a reduced placement area and only have a forward directional structure, reducing the risk of altering signal integrity.

Most commercial optocouplers consist of a light emitted diode as emitter and a phototransistor as photodetector on silicon package. These commercial devices can be as basic as a pair, or they can include more components inside to amplify the signal that is being isolated before outputting to the rest of the circuit. Nonetheless, the reliability of these devices starts to be compromised after reaching temperatures higher than 100°C. Having temperature as the main constraint, there is only one commercial optocoupler that is rated to provide isolation at 200°C.

Low temperature co-fired ceramic (LTCC) has been found to be a suitable package solution for power electronic devices due to its thermal and chemical stability, hermiticity, simple 3D structure, and integration of electrical components inside the ceramic [5]. Previous research has shown that LTCC coefficient of thermal expansion is compatible for SiC power devices; and in comparison with commercial power substrate has better isolation characteristics [6]. Considering all these factors, implementation of LTCC as the substrate for optocouplers has the potential to be a promising solution for this application.

Background

Type of isolators

Regarding electrical isolation, signal isolation can be accomplished by a combination of physical separation, insulating material and/or combined with isolated signal transmission methods (magnetic, optical, or capacitive) [7]. Even though there are a variety of isolation techniques, the circuit design difficulties are latent when finding a specific isolator for different applications.

Transformer or Inductive Coupling

Pulse transformers are a common type of galvanic isolation. In this case, the transformer achieves complete isolation by utilizing the current induced magnetic fields around the coils. The primary and secondary coil do not share any type of electrical connection, and the signals are inductively coupled using a varying magnetic field [7]. Fig. 1 shows the basic functionality of a pulse transformer. The signal can travel to the load from the source without a physical electrical connection.

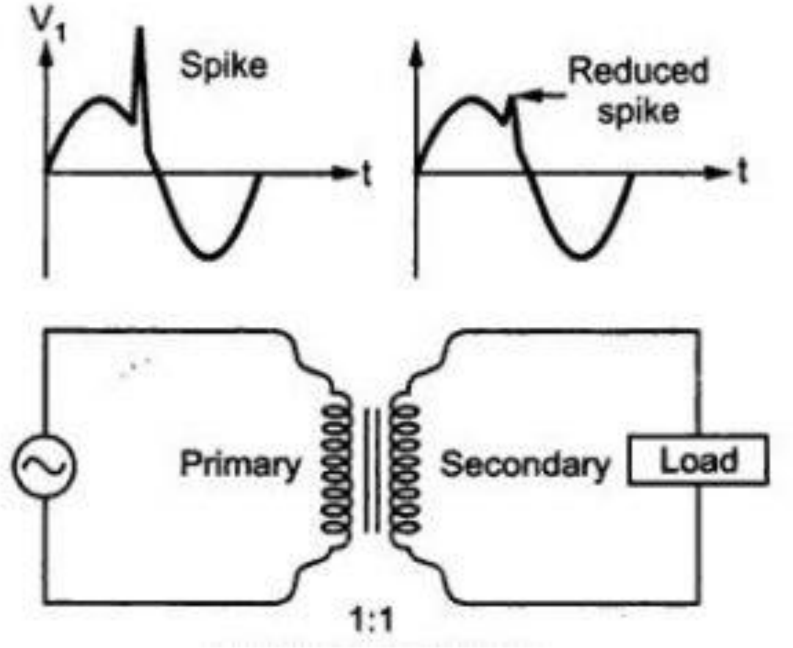

Fig. 1. Isolation transformer functionality [8].

One advantage of isolation transformers is they can also be used to buffer the voltage. Most importantly, they allow breaking ground loops from primary to secondary coils, preventing incorporation of noise and common mode rejection at the input. Even though pulse transformers have been well studied and provide great isolation, they are very susceptible to magnetic interference and can be a source of magnetic interference to the rest of the circuitry.

Optical Isolators

Optical isolation or optical coupling as well as pulse transformer use galvanic isolation. These devices transmit a differential signal by varying the intensity of light generated on the input side of the device and detecting a portion of that light on the output side.

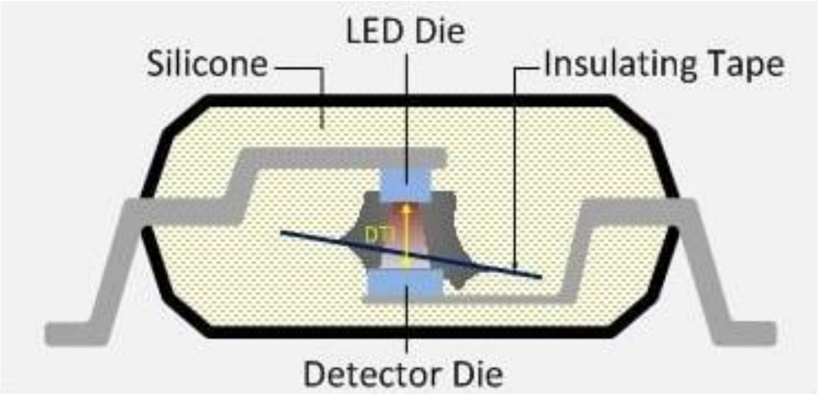

Fig. 2. Cross section of an optocoupler [9].

Fig. 2 shows the internal configuration of a regular optocoupler. The insulating material works as a barrier, providing additional isolation to the circuit. The LED die generates different light intensity depending on the input current to the device. The detector die senses the photonic current turning on the device and converting the photonic waves into an electrical signal [4]. Common architecture of optocouplers involves an aluminum gallium arsenide (AlGaAs) LED and either a phototransistor or a photodiode. More complex optocouplers may also include current amplifiers and other circuitry in order to improve performance, depending on the application. Optocouplers provide a major advantage over conventional isolation techniques due to their inherent immunity to EMI (Electro-Magnetic Interference or electrical and magnetic noise). However, optocouplers are more sensitive to temperature, and, depending on the materials used, they provide higher power dissipation [10]. A reliability study showed that failure of optocouplers is due to degradation of the LED which changes the intensity of light that is being emitted. This degradation directly affects the value of the current transfer ratio of the device. This failure increases significantly when the device is exposed to elevated temperature, resulting on reliability concerns for multiple industries [11].

Motivation

When achieving isolation in transient or continuous high voltages, rejecting extreme noise, and breaking ground loops, pulse transformers are the most commonly used [7]. However, some disadvantages include design complexity, noise sensitivity and some provide a larger overall volume compared to other components in the circuit and other optoisolators. In addition, these isolators are very sensitive to temperature adding external noise to the system.

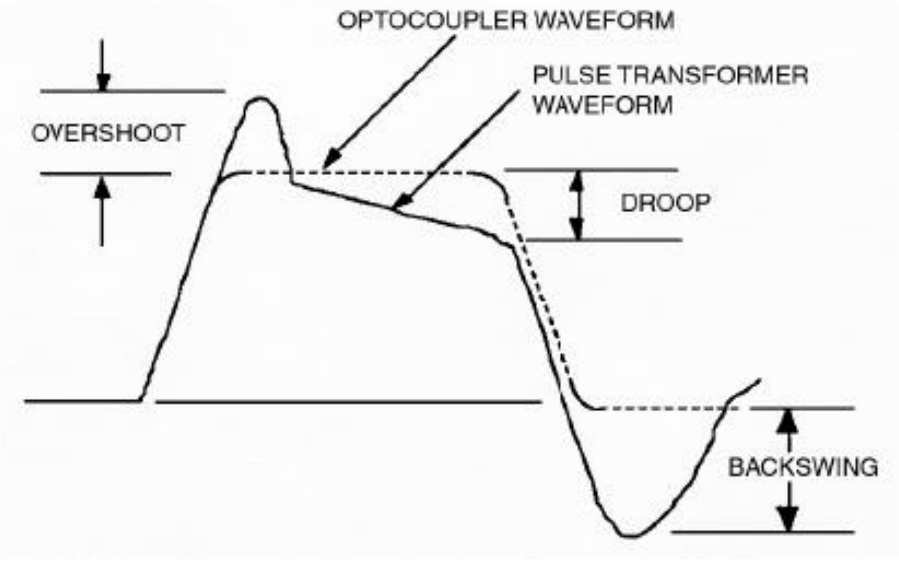

Fig. 3. Output waveform comparison: optocoupler vs pulse transformer [7].

Fig. 3 shows the results obtained from a study on a comparison of pulse transformers and optocouplers. Even though pulse transformers are well known for a fast response, they still provide a higher overshoot and backswing in comparison with the output signal of the optocoupler. This can provide false switching on the duty cycle of the device, causing reliability issues of the circuit as a whole.

Table 1 shows a direct comparison of pulse transformers with commercial optocouplers. In this study, it was concluded that regular commercial optocouplers present better isolation and switching conditions than pulse transformers; nonetheless, they have some temperature limitation that make them unreliable at temperatures above 100 °C.

Table 1. Advantage of Optocouplers over Pulse Transformers [7].

Characteristic	Pulse Transformer	Optocouplers
Waveform Fidelity: Droops	10 % per microseconds depending on duty cycle	No droop
Waveform Backswing	Relative high	No backswing
Primary to Secondary Turns Ratio	Output could be sensitive to magnetic effect due to mutual inductance	No ratio effects
Data Format Requirements	Complex	No need
Common Mode Transient Immunity (CMTI)	Fast and High	Higher without extra complexity
Size	High volume	Small size

In current power electronic designs, optocouplers are more common due to their easiness of design and beneficial size. In addition to this, optocouplers help maintain signal integrity of the circuit, help prevent false turn on, and changes on the duty cycle. However, the need to find high temperature reliable isolation to protect the circuit is still latent. Due to their electric characteristics, optocouplers are more favorable for wide-bandgap application but their temperature limitations make them unreliable at high temperatures. Having this temperature limit the motivation of this project is to develop an optoisolator that can have the same if not better electrical performance of commercially available products but also be able to operate efficiently at the elevated temperatures that wide bandgap devices are pushing. This packaging technique attempts to overcompensate the current limitations of commercial optocouplers and isolate power electronic systems with an appropriate efficiency range.

Characterization of Commercial Devices

Before developing a new package, several tests and studies were performed on commercially available optocouplers to have a better understanding of their failure mechanisms. These tests explained some of the common failures and established a standard test plan for testing all devices. Three devices were tested, two of them packaged with silicon materials (CNY17 from VISHAY, and IL300 from VISHAY), and the other was the high-temperature device (MICROPAC-52458). A variety of electrical characteristics were observed to determine degradation over temperature. Current transfer ratio (CTR), leakage current, current-voltage curve (I-V curve), and time response were the primary focus for this testing. These test conditions were obtained after literature review on optocouplers [12] [13] . These devices do not specify the type of materials that are being used for the LED or photodetector limiting the analysis to the electrical constraints mentioned before.

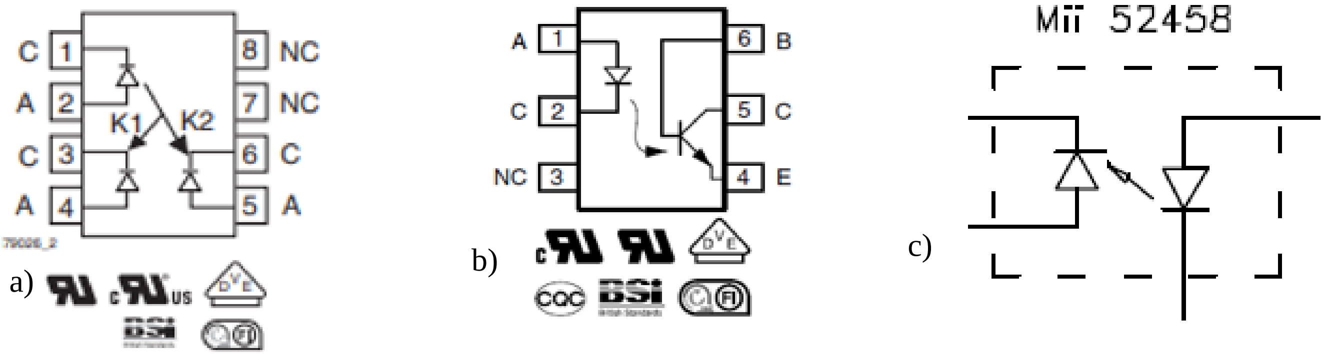

Fig. 4. Commercial devices tested to obtain electrical characteristics. a) IL300, linear optocoupler with high stability and wide bandwidth provided by VISHAY [14]. b) CNY17 phototransistor output with base connection provided by VISHAY [15]. c) 52458 Dual current to current opto-isolator provided by MICROPAC [16].

Fig. 4 shows the three commercial devices tested. Two of them (IL300 and 52458) having an inner structure of a LED and Photodiode as a detector. Devices IL300 and CNY17 have an operating temperature up to 110°C while 52458 has an operating temperature of 200 °C. All of these devices were temperature stressed to understand their behavior.

Table 2. Electrical Testing Results from Commercial Devices

Constrain	**CNY17**		**IL300**		**MICROPAC 25458**	
Temperature	25 °C	150 °C	25 °C	150 °C.	25 °C	275 °C
CTR (%)	141.82	69.32	168.4	100	41.44	20
Leakage Current (A)	91 n	27 µ	1.06µ	3.79µ	30.4 *p*	24.7 µ
Rise Time (µs)	3.272	5.715	11.48	27.20	2.7	2.7
Fall Time (µs)	4.032	91.1	156.0	142.0	6.4	6.4

Several samples from each device were tested, and Table 2 summarizes the average result obtained from the samples tested. When this results are compared to the estimated value according to their datasheet (Table 3), it can be seen that at room temperature there are some differences. These alterations are present due to internal error for the setup. The connections introduced extra capacitance that altered the testing result. When elevated temperature results are compared, it was clear that temperature was altering the results; and in a real application, these devices would have failed since they are experiencing a significant amount of thermal noise. Almost for all the devices tested, the leakage current increased significantly at high temperature. This rise of dark current could generate false responses and potentially complete failure of the module. In this sense, developing an electronic package able to mitigate thermal heat could potentially decrease the effect of thermal noise and enhance the efficiency of the devices.

Table 3. Electrical Characteristics for Commercial Devices According to Datasheet [14] [15] [16].

Constrain	CNY17	IL300	MICROPAC 25458
Temperature	25 °C	25 °C	25 °C
CTR (%)	100-200	175	200
Leakage Current (A)	100 n	1 µ	1 µ
Rise Time (µs)	2	1.75	0.130
Fall Time (µs)	2	1.75	0.090

Design Process

Design Consideration

The majority of commercially available optocouplers are rated for 125 °C or less. Wide bandgap semiconductor devices have the ability to operate at 200 °C and above. A packaging technique was developed to allow fabrication of optocouplers that are rate for 200 °C or above while maintaining the electrical performance of commercially availble products.

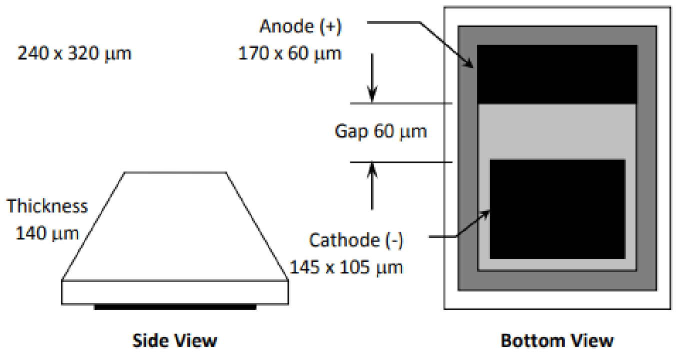

Fig. 5. CREE-DA2432 InGaN LED [17].

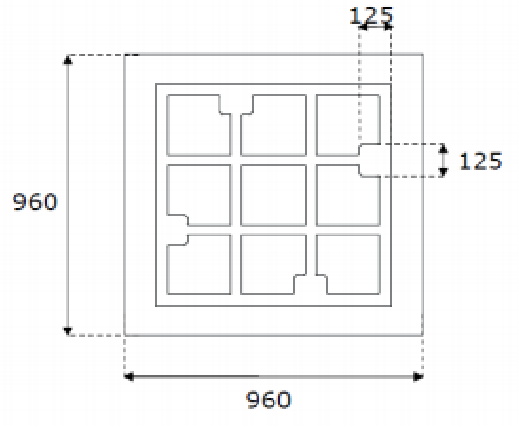

Fig. 6. OPC7000-21 AlGaAs [18].

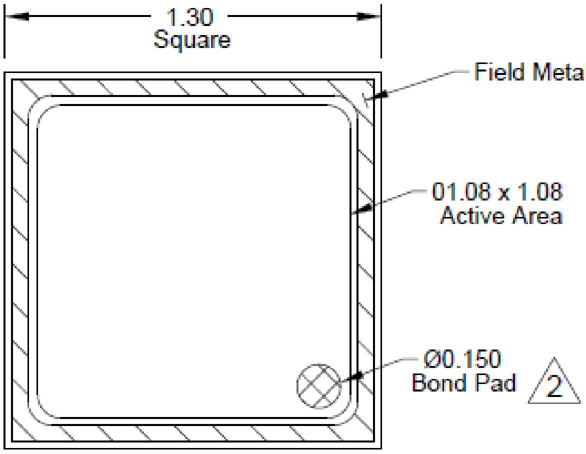

Fig. 7. MT41-011CH Si photodetector [19].

Commercial LEDs and detectors were obtained after being characterized at elevated temperatures and showed great performance. Fig. 5 – 7 show the different commercial LEDs and photodetector that were to be used for fabrication purposes of the high temperature package. These devices are to be paired differently (LED to LED, LED to Detector) to compare differences in functionality and electrical performance.

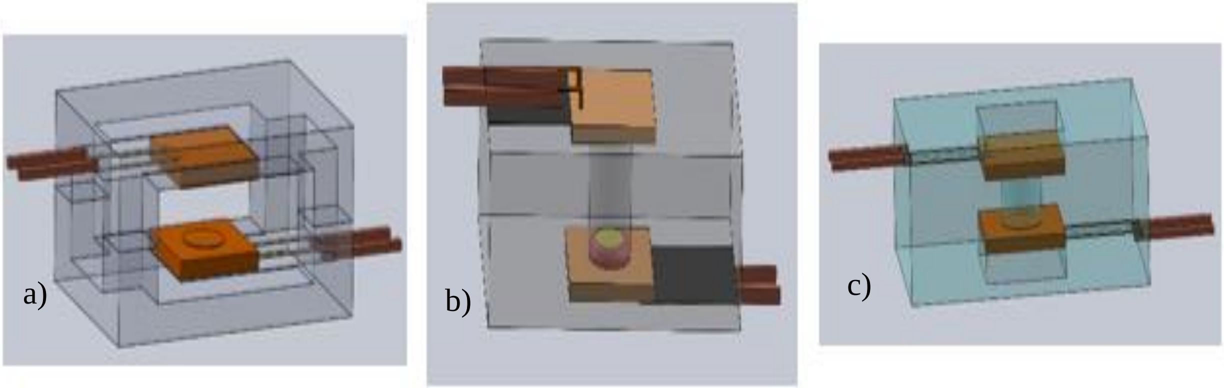

Fig. 8. Optocouplers preliminary designs. a) Chip carrier model. b) Silicon based model. c) LTCC based model

Fig. 8 shows the package models that were designed based on the LEDs and detectors discussed above. Fig. 8a shows a chip carrier design. With this design, the LEDs or detectors would be solder to a chip carrier that will be attached to each other. The top connection corresponds to the anode, which would require a gold wire bond for electrical connectivity. Fig. 8b shows a silicon substrate that would have a cavity to allow the light to travel from the LED to the detector surface. Internal routing is needed in order to connect the anode of the devices, this would be challenging in the silicon substrate. Fig. 8c shows a similar design to 8b, but in this case the material used is LTCC (Low Temperature Co-fired Ceramic). The chip carrier design and silicon-based model (Fig. 8a and 8b) were ruled out due to internal routing limitations. In addition, the chip carrier design would require insulation material to concentrate the light directly to the detector. The LTCC-based model was promising due to the intrinsic characteristics of the material and the flexibility for fabrication.

LTCC Process

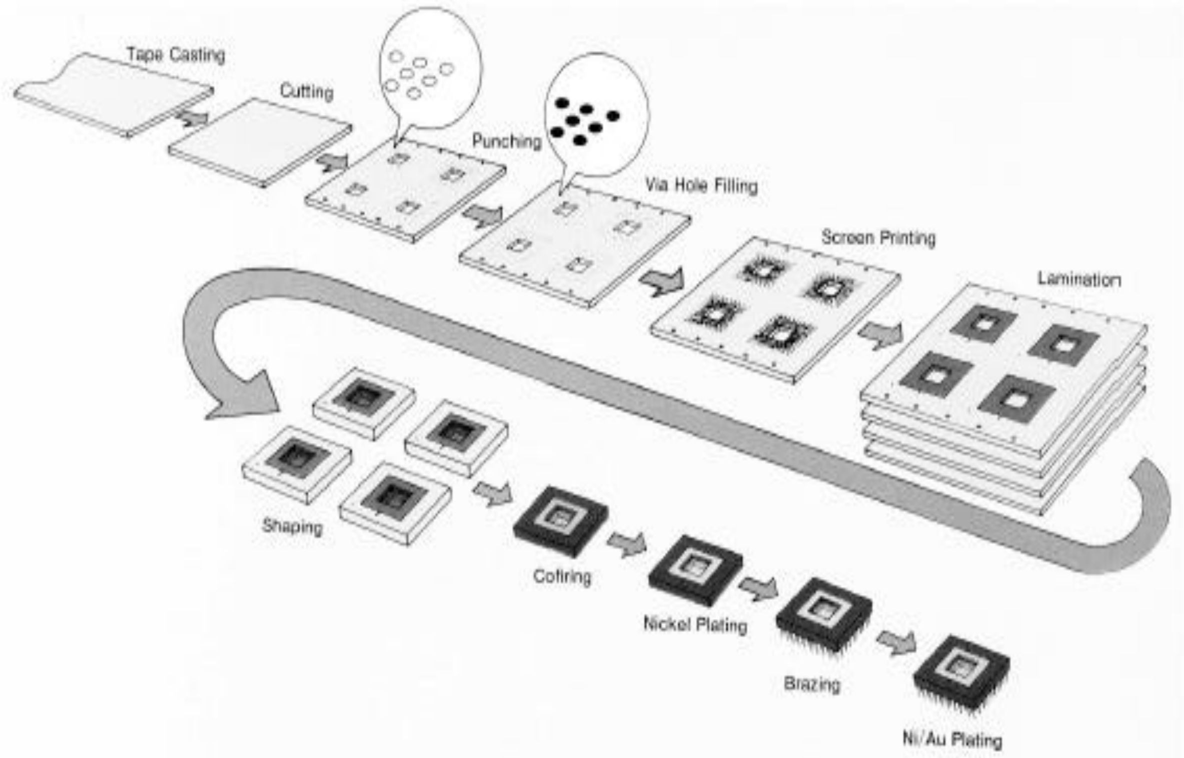

Fig. 9. Production process for multilayer ceramics [20].

Multilayer ceramics represent a number of technologies that are capable of producing high-density electronic substrate with highly desirable properties. Fig. 9 shows the common process for multilayer ceramics. This process may vary depending on the desired design. Low Temperature Co-fired Ceramic (LTCC) in particular resulted as an improvement of High Temperature Co-fired Ceramic (HTCC). Similar to HTCC, LTCC is fabricated making them convenient for different types of designs; however, LTCC provides superior electrical performance since it has a lower firing temperature and can implement other metal materials as conductor [20].

Design 1

The fabrication constraints of the LTCC process directly depends on the type of ceramic tape that is been used. For this project, all the packages were fabricated on 951 green tape since this required lower time for the firing profile. 951 green tape has a thickness of 10 mils (254 µm), limiting the via size to 10 mils (via size and tape thickness has a 1 to 1 ratio) [20]. In this first model, the design characteristics were made to meet the minimum values possible for the metal in the ceramic.

Table 4. Design Constraints for Model 1.

Constraints	Size
Via	10 mils
Traces (Width)	20 mils
Cavity	24X24 mils
Package	197x197x68 mils

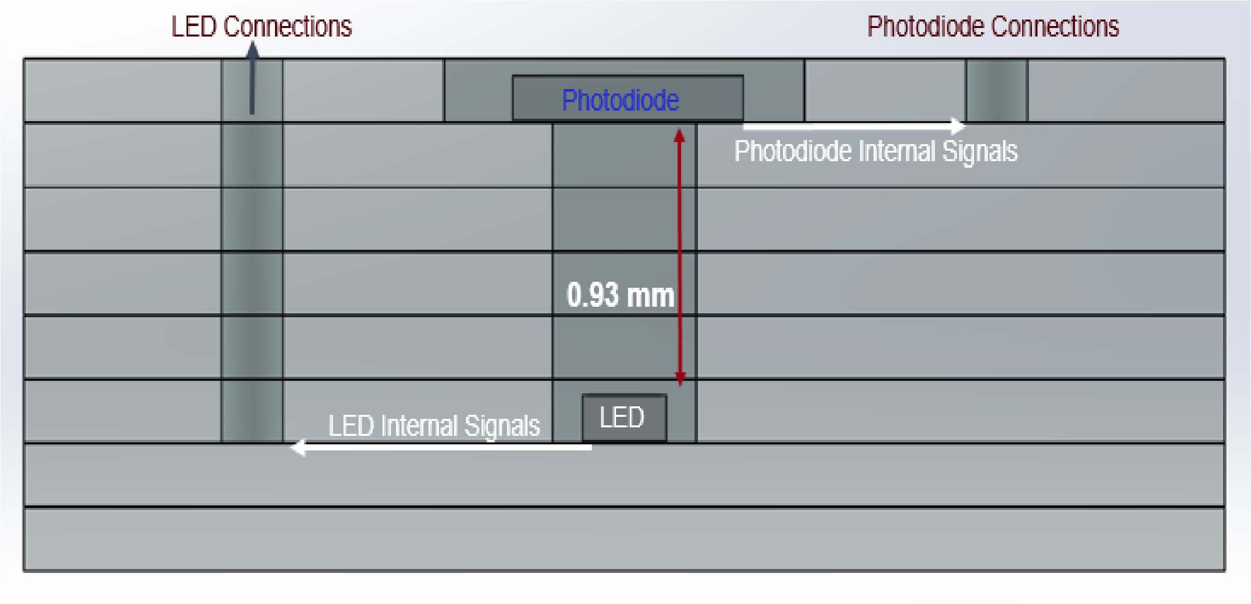

Fig. 10. Cros section design 1.

Table 4 shows the main characteristics for the first model designed. This first designed met the requirements to use the LED shown on Fig. 5 as emitter, and the LED shown on Fig. 6 as detector on reverse polarity. Fig. 10 shows a cross section image of design 1 where the LED was attached inside the cavity emitting light in the up direction, and the photo-diode was facing down to capture the light. The anode and cathode of the devices were connected through traces and vias that routed the signal up of the package.

a)

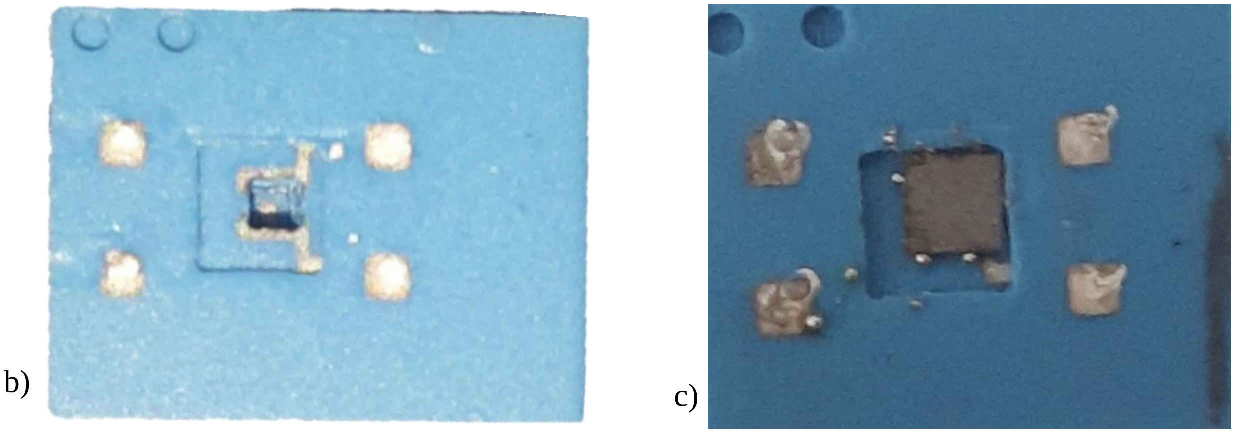

Fig. 11. Deisgn 1 packages after fabrication. a) Shows LTCC panel after being fired. b) Individual package after dicing. c) Individual device after devices being assembled.

Fig. 11 shows design 1 package after the fabrication process was completed. Out of this fabrication, there were two LTCC panels fabricated resulting in 200 potential packages to be assembled. Each individual package was tested for connectivity, and none of them showed short or open circuit. Fig. 11b shows the LTCC package without any device. In this picture it can be seen the traces that would provide a signal to the devices. In addition to this, in this picture it can be seen the traces inside the cavity for connectivity of the LED.

Design 2

A second model was designed utilizing LTCC. For this model, some of the design considerations for model 1 were used; nonetheless, some other constraints were varied for better performance. Table 5 shows the design constraints used for the fabrication of the second model. One of the main difference between this model and the first model is that the size for the vias and traces are bigger. The total area of the package was increased as well due to changes on the cavity size.

Table 5. Design Constraints for Model 2.

Constraints	Size
Via	20 mils
Traces (Width)	24 mils
Cavity	18x18 mils
	33x33 mils
	47x47 mils
Package	394x315x68 mils

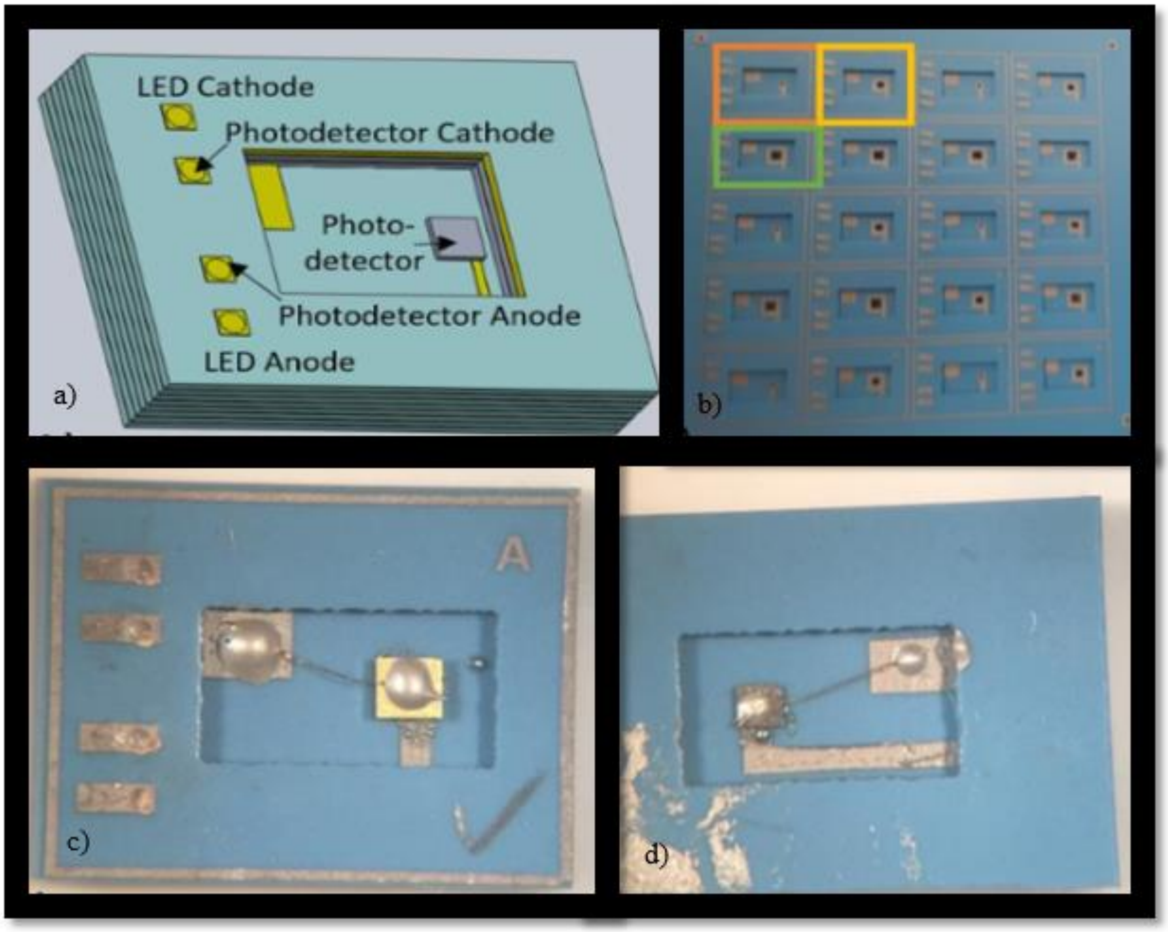

Fig. 12. LTCC Design 2. A) Solid-Work design before fabrication. B) LTCC Panel with the designs. C) LTCC model after fabrication and assemble front side. D) LTCC model after fabrication and assemble backside.

Fig. 12 shows LTCC packages for design 2. In this case, the design consisted on a small hole as cavity where the LED and the photo-diode would be assemble one on top and one on the bottom side of the package. Fig. 12a shows 3D model of how the traces, vias and device are in the package. Different from design 1, for this design there are three different cavity sizes. The cavity sizes are shown in table 5 while Fig. 12b shows the actual LTCC packages. These cavities were fabricated according to potential LEDs that would be used. Another major difference between design 1 and 2 is the number of LTCC layers between the LED and the photo-diode. On the design 1 there are five layers while design 2 only has two layers between the devices. The reason for this choice was to compare and obtain an optimal isolation distance.

Design Complications

Throughout the fabrication process, several complications were faced. While doing die attachment blue LED shown in Fig. 5, there was some misalignment when placing down the devices. This was due to the machine's camera not being able to record inside the cavity to place down the LED. FineTech is a pick and place machine used for die attachment. This machine has two cameras, one lateral and one on top of the part desired to attached; however, it was hardly impossible get a perfect alignment. In addition to this, the connection traces were too small, increasing the chances for misalignment. Several tries for die attachment were performed on design 1; nonetheless, only one was successful.

Ideally, design 2 was made to have an LED as emitter shown in Fig. 6, and a silicon detector shown in Fig. 7. Nevertheless, this was not achieved since the silicon detector cannot be attached to the substrate. On Fig. 7 it is shown that this silicon detector has a bond pad connector for the anode and the back side is the cathode for the device. However, the field metal in the top side of the device has an internal connection to the cathode.

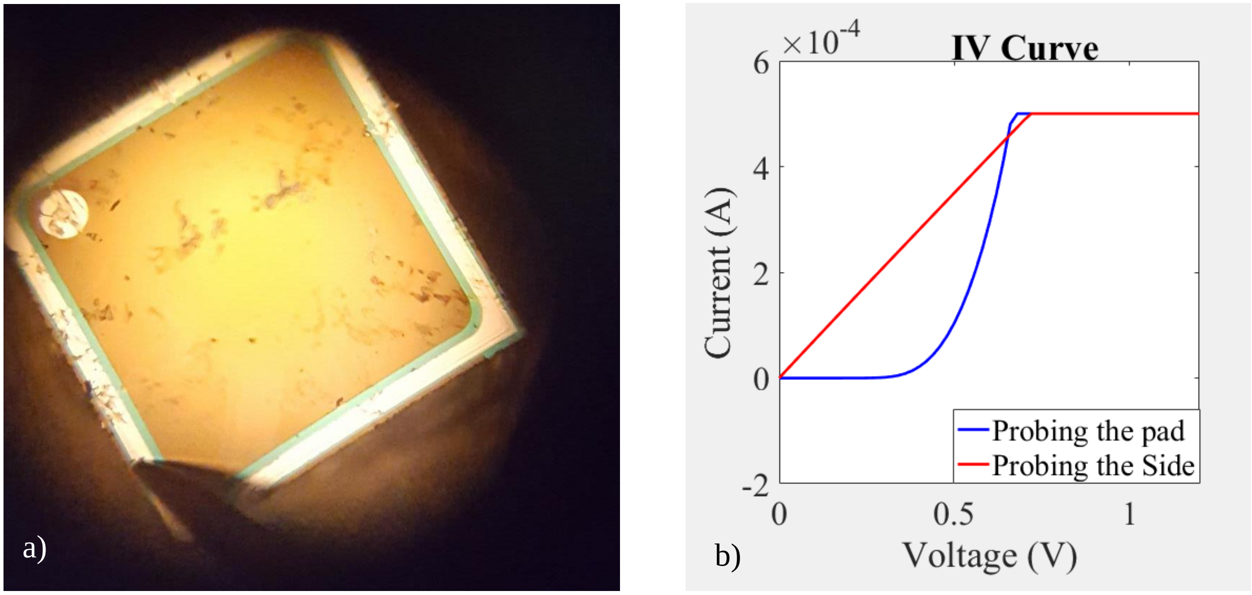

Fig. 13. Silicon detector test.

Fig. 13a shows a picture of the silicon detector being probe on metal field of the device. Fig. 13b shows the plot resulting from probing both the bond pad and the metal field. As the Fig. shows, the metal field makes a short circuit to the cathode, while probing the bond pad shows the detector is in perfect conditions. Whenever the device was attached to the LTCC substrate, the bond pad and the field metal made a short circuit creating malfunction on the device. Given this complication, design 2 was tested using two LEDs one as emitter and another one as detector in reverse bias.

Experiment

Test Setup

The standardized setup from the commercial device testing was developed according to the parameters on the device datasheet and for varying stress conditions. The test set up for the LTCC optocouplers was similar in development. It is important to mention that the stress conditions used were the same during testing, but the setups were different.

The commercial devices were connected to a PCB and tested inside an oven. This oven has wire connections out that were hooked up to a Keysight B1500 Semiconductor Analyzer. This piece of equipment was able to read the Current-Voltage measurements (I-V measurements). It also gave a preliminary plot to check for functionality. For time response test, the same oven was used, and a function generator was used to supply a square wave of 1 kHz to the input of the optocoupler. For the CNY17 device, there was a voltage bias of 5.0 V since it has a phototransistor as a detector. The other devices including LTCC optocoupler, were not biased on the output side since they utilize a photodiode as a detector. These measurements were saved and plotted later using MatLab and OriginPro.

LTCC optocouplers were tested a little different than the other devices. The LTCC packaged devices were tested using a probe station and heated chuck. This probe station has leads that were connected to the Keysight Semiconductor Analyzer to obtain I-V measurements. Literature on testing wide bandgap LEDs and photodiodes [21] was used to perform the electrical test over temperature on the LTCC optocouplers.

Results

LTCC optocouplers were tested and preliminary results seem to be very promising. Seven successful LTCC devices have been tested, one being from design 1 and the others from design 2. Same electrical characteristics as the commercial devices were used to perform a direct comparison between commercial devices and the LTCC devices.

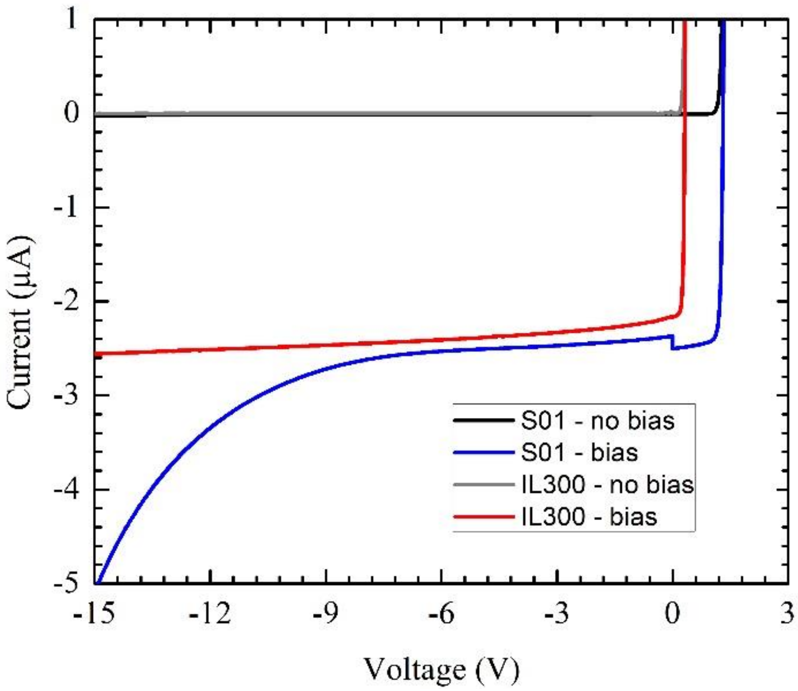

Fig. 14. Comparison of IL300 with LTCC sample.

Fig. 13 shows the I-V curve of the LTCC sample with and without bias (black and blue lines) and the I-V characteristics taken from the device IL300 (grey and red lines). Sample 01 (results shown on Fig. 13 and 14) is the only sample from design 1 that was successfully fabricated. As Fig. 13 shows, the LTCC sample shows a similar pattern as the commercial device. Even though the LTCC sample is not using a photodiode, the LED in reverse bias is able to detect as much light as the IL300 device. These results were taken at room temperatures with the same biasing conditions.

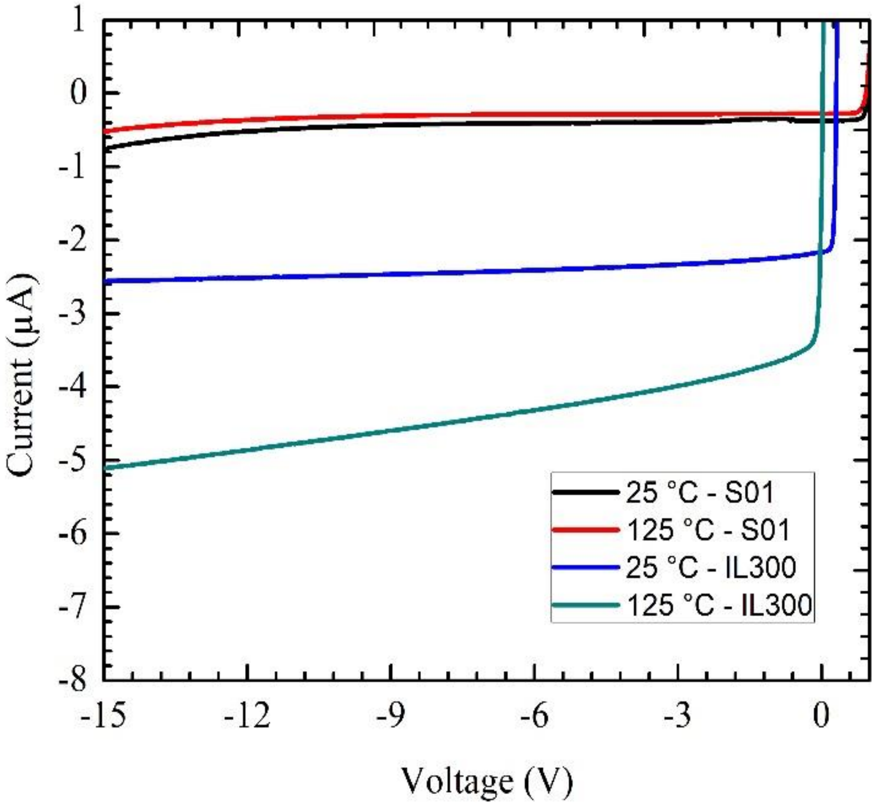

Fig. 15. Temperature comparison between LTCC Sample and IL300.

Fig. 15 directly compares the results obtained over the temperature of the LTCC sample (black and red lines) with the IL300 device (blue and light blue lines). On this graph, it can be seen that there is a small difference of about 0.15 µA due to thermal noise, for the LTCC packaged device. The IL300 device presents a difference of about 2.5 µA due to thermal noise. This directly shows that the designed package effectively helps mitigate thermal noise on the device, in comparison with silicon-based commercial optocouplers.

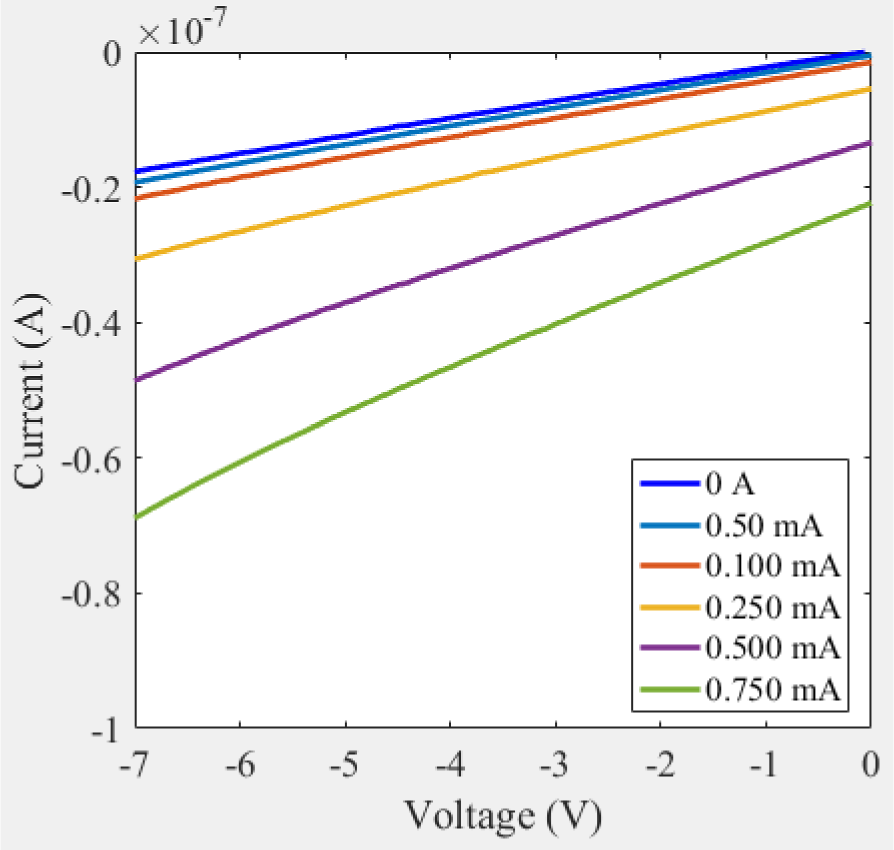

Fig. 16. LTCC sample results at 25 °C. Stress under different input voltages

Fig. 16 shows the result obtain from another test from design 2. In this case, the graph shows a comparison of the device being exposed to different bias condition. Low current input was used to keep the device under its limits as suggested following literature criteria [21], and datasheet parameters [16]. Even from small input current values, there is a notorious increased in the output current of the reverse bias LED.

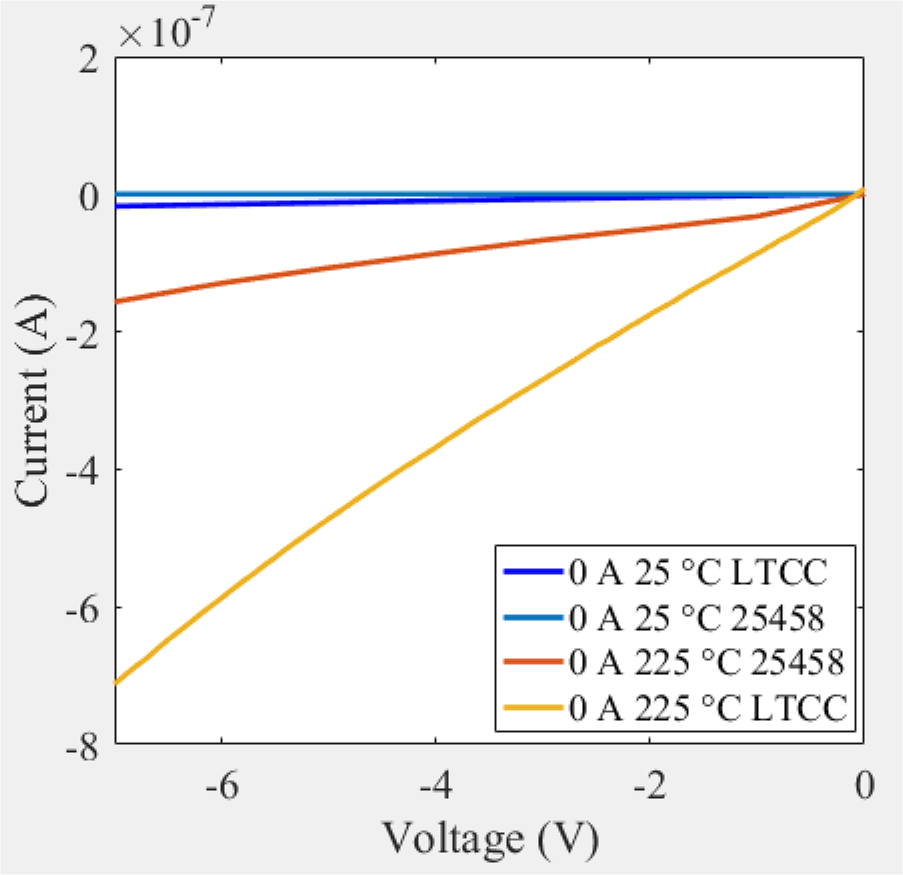

Fig. 17. LTCC results vs MICROPAC 25458 over temperature.

Fig. 17 shows a direct comparison of the LTCC optocouplers fabricated from design 2 against the results from testing the high temperature optocoupler from MICROPAC. The optocoupler 25458 is the only commercially available optocoupler rated for temperature up to 200 °C. In this graph, the commercial high temperature is compared to the LTCC based optocoupler fabricated with commercial LEDs. In the plot, it can be seen that the LTCC package shows higher thermal noise than the commercial high temperature device; however, the difference is still at an acceptable range. On the other hand, Fig. 17 shows a comparison between the same LTCC device against the commercial IL300 device. On this graph it can be seen that at 25 °C both devices show similar response; nonetheless, when they are exposed to temperature, the commercial device show an increase of 9 µA in comparison to the LTCC optocoupler.

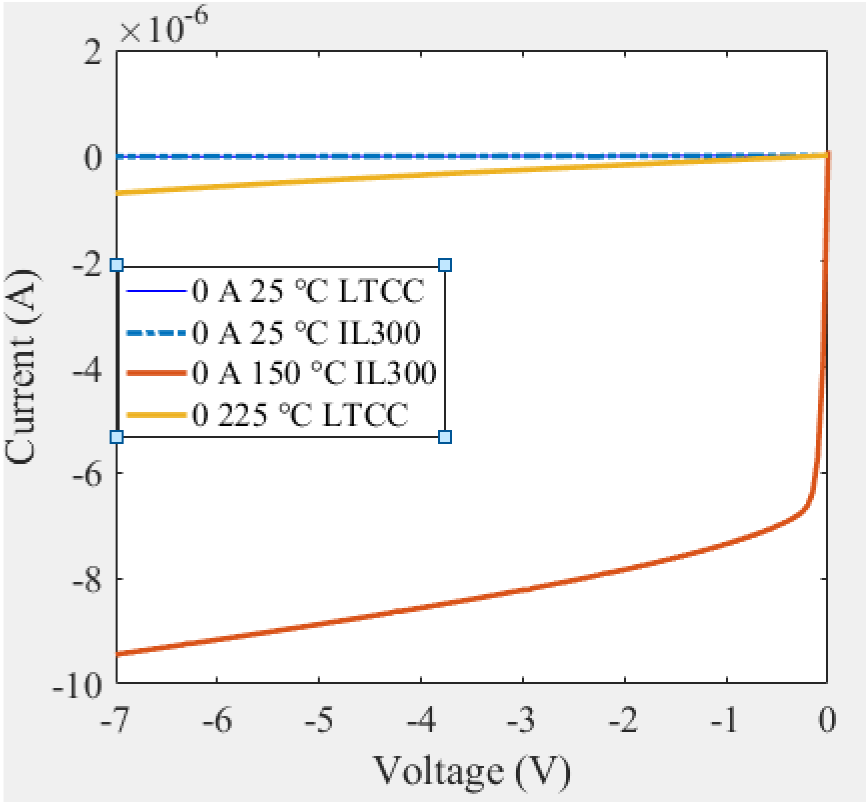

Fig. 18. LTCC results vs IL300 results over temperature.

Discussion of Results

Thermal noise increase could potentially generate a huge failure on real circuitry application since it may alter the duty cycle of the circuit and generates false turns on. LTCC package was not compared to the other devices regarding time response test due to time constraints. Future tests will involve a variety of LTCC packaged devices and more commercial devices.

Table 6. Elctrical Testing Results from Coomercial Devices and LTCC Devices [14] [15] [16].

Constrain	**CNY17**		**IL300**		**MICROPAC 25458**		**LTCC**	
Temperature	25 °C	150 °C	25 °C	150 °C	25 °C	275 °C	25 °C	275 °C
CTR (%)	141.82	69.32	168.4	100	41.44	20	6.85	5.50
Leakage Current (A)	91 n	27 μ	1.06μ	3.79μ	30.4 *p*	24.7 μ	0.843	0.952
Rise Time (μs)	3.272	5.715	11.48	27.20	2.7	2.7	These are ongoing tests that have not been completed yet.	
Fall Time (μs)	4.032	91.1	156.0	142.0	6.4	6.4		

Table 6, shows a summary of the electrical test performed this time including the LTCC optocouplers fabricated. This table states that the CTR on the LTCC devices is significantly less than in the commercial devices, but the drop at high temperature is less than on any of the other devices tested. Dark current also shows little increment in comparison with the other commercial devices that showed more than twice increment over temperature. As it says in the last section, time response has not been obtained yet for those devices limiting a comparison.

As the results showed, implementing LTCC technology as package for optocouplers helped mitigate thermal issues and improve device functionality under thermal stress. Even though there are tests to complete, and further research to be done, the current results seem to indicate that this packaging technique can enable optocoupler functionality at or above 200 °C.

Future Work

Continuing with the project, more thermal stress testing will be performed to confirm the preliminary results obtained. As well as time response test would be performed on the LTCC devices and the commercial high-temperature device. This will provide a better idea of the response time of the devices and its efficiency for fast switching modules. Once all of the electrical tests are completed and standardized, reliability testing will be performed. This will include vibration and humidity tests, as well as isolation and breakdown testing. These tests will help to provide an expected life expectancy of the devices and establish specific conditions for the devices. All of these tests will be performed following a designed guide paper for electronic devices [22] [23].

Design 3

A third design is in development. This third design is based on display LEDs that have been simulated and showed great performance at elevated temperatures. The LEDs have been tested as LED and detector, and they have shown an improvement in comparison to the current bare devices that were used for fabrication.

Table 7. New Leds dimmensions.

Color	Area	Cavity
Blue	0.8x1.35 mm	2.0x4.75 mm
Blue	0.215x0.280 mm	2.0x3.70 mm
Green	0.275x0.200 mm	2.0x3.6 mm
Red	0.315x0.3 mm	2.0x3.7 mm

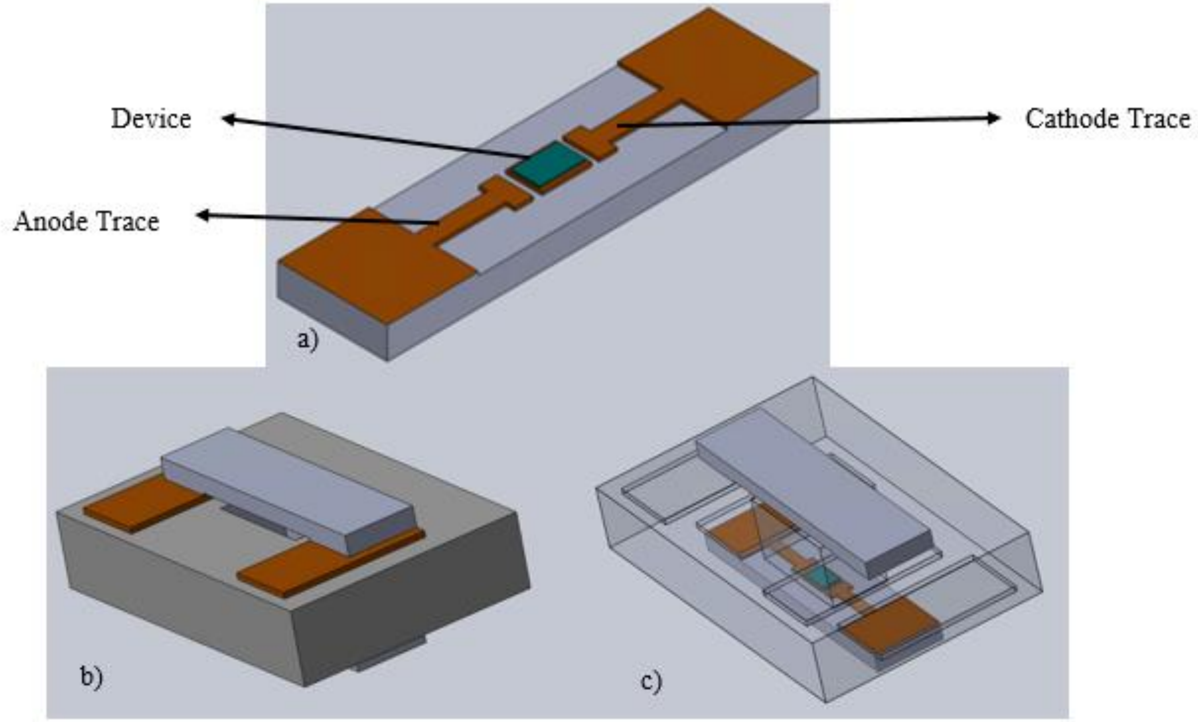

Fig. 19. Design 3 drawings. a) Chip carrier for LEDs. b) 3D model of new optocoupler. c) 3D model of new optocoupler substrate transparent.

Given the size of the new LEDs, the new package design involves a silicon chip carrier where the LEDs would be attached and then flip chipped onto a LTCC substrate. Fig. 19a shows a drawing of the silicon chip carrier with the device. Fig. 19b and 19c illustrates how the new package would look like on the LTCC substrate. In comparison with the previous design, the new design is more simple and does not involve any type of internal connection given that the leads on the top and bottom of the substrate can be solder to headers for routing. The implementation of these new devices intends to improve the current ratio obtained from the LTCC optocouplers.

Conclusion

The similarity of the LTCC optocouplers to the commercial devices at 25 °C shows that these devices are able to perform equally. However, when they are both stressed over temperature, LTCC devices show superior improvement helping mitigate thermal noise. As the operating temperature of the optocouplers increased, LTCC devices presented lower increment on dark current. This packaging technique seems to improve the functionality of optocouplers highly at elevated temperatures. Reduced leakage current and CTR drop are evidence that LTCC has the capability help mitigate thermal noise on optocouplers and increase the functionalities of the devices.

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