

# Ultraviolet Radiation effects on the electrical resistivity of some La(Ca/Sr)MnO materials

William Raziano\*, Jermain Franklin#, Larry Henry, PhD&

\*REU student SUBR, BRCC, Baton Rouge, LA

#REU student SUBR, LSU, Baton Rouge, LA

&Mentor SUBR, Baton Rouge, LA

## Abstract:

The study investigated the effects of ultraviolet (UV) radiation<sup>3,10,11</sup> exposure on the electrical properties of some La(Ca/Sr)MnO (perovskite crystal structure<sup>11</sup>) compounds. The hypothesis was that if the UV radiation impacted the material then there should be an effect seen in the electrical resistance when the sample is exposed to the radiation. In order to test the hypothesis, it was necessary to calibrate the UV radiation sources. The calibration process required measurement of the UV intensity of the light source(s). Photodiodes were used to detect the UV light. The detection of UV radiation by the photodiodes is caused by the photoelectric effect. The project involved measuring the electrical resistance of the La(Ca/Sr)MnO samples under normal (i.e., no UV exposure) conditions, and then again while under exposure to UV radiation, while looking for any changes in the electrical properties of the samples. Our results did not show any changes; thus, our conclusion did not support our hypothesis.

**Keywords:** Ultraviolet Radiation, UV radiation, UVR, LaMnO, La(Sr/Ca)MnO, perovskite structure

## Introduction:

The reemergence of interest in materials exhibiting the perovskite<sup>12</sup> crystal structure, such as Lanthanum Manganite based compounds, is rapidly becoming widespread<sup>4</sup>. Applications in photovoltaics and fuel cell technology demonstrate that the use of these materials has great potential importance to industrial use.

### *Hypothesis:*

The irradiation of the La(Ca/Sr)MnO materials with UV light will cause a net movement of charge carriers, due to the photoelectric effect, at least on the surface. Moreover, this will affect the electromagnetic properties of the material and be manifested in a measureable way, specifically the resistance (resistivity) of the material.

There are numerous indications that UV radiation can impact the structure of many substances and compounds at the atomic level<sup>13,14</sup>. The exposure of LaMnO based materials to UV radiation may produce some unexpected outcomes on its physical properties. Many research groups report experimentation involving both thin/thick films and bulk material for this type of experiment<sup>5,6,15,16</sup>. The research project at hand, depending on the outcome, could also suggest the possible future applications of this material, or even impact the material synthesis technique.

## Experimental:

The use of UV radiation in this experiment justified the need for a/some UV radiation source(s), so two lamps of differing composition and energy output were used. The radiation sources were commercially obtained: One compact fluorescent “black light” as a source of UV-a and UV-b radiation, and one shrouded sanitizing lamp as a source of UV-c light. Initially, there was thought of using a microprocessor in the calibration and data collection process. This system would be capable of processing and storing or transferring data to a computer for analysis. Filtration mediums were employed to isolate certain wavelengths of UV light in order to test the apparent threshold of photoelectric reactivity<sup>14</sup>.

The LaMnO materials that were used in the experiment were synthesized by a solid state reaction process by the co-investigator. Details about the synthesis process are described elsewhere<sup>1</sup>. Initially, a sample from previous experimentation<sup>10</sup> was used to get preliminary results and to confirm that the experimental setup was operational. All tests confirmed that the system was functioning as desired.

The calibration process to determine the relative intensity<sup>9</sup> of the light source requires that the UV light source be placed at a measured distance from the photodiode array. In order to collect the data, the output of the photodiode array is connected to the microprocessor.

The experimentation process involved using the LaMnO based samples that the co-investigator synthesized as the materials on which to experiment. The LaMnO samples and the UV light source were placed inside a container to eliminate the effects of outside light sources. A four-probe resistance measurement method was employed to measure electrical resistance. In this method, a known electrical current (100mA) is applied to opposite ends of the sample and the

voltage is measured between two points along the length of the sample. The following diagrams (fig. 1a & 1b) display the experimental setups:

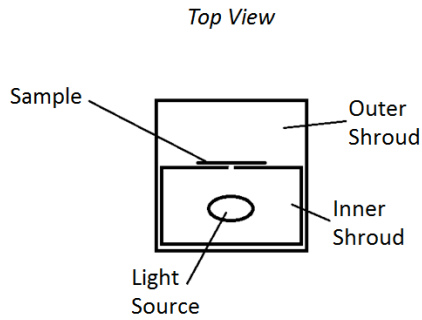


Figure 1a.

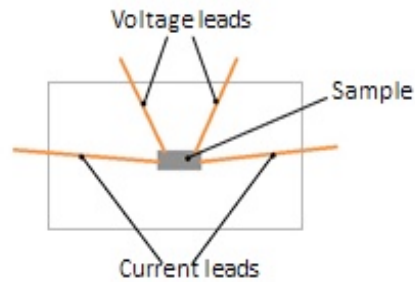


Figure 1b.

An additional step was taken to ensure that the UVR only illuminates the sample, and not the copper wire leads attached to the probes or the contacts at the sample. This involved making a cover with an aperture slit, and necessitated the consideration of diffraction<sup>8</sup> of electromagnetic radiation through the slit. Upon completion of this step, we found that the cover and aperture could be placed directly on the sample, which would effectively diminish the diffraction of electromagnetic radiation effect to a negligible factor.

The dimensions of the materials used for experimentation were measured several times, and an average of those measurements established<sup>1</sup> in order to calculate electrical resistivity. Electrical resistivity is an intrinsic property of the opposition to the movement of electric charge in the material<sup>7</sup>.

#### Data Analysis/Results:

The use of the microprocessor and amplifier boards proved to be unsuitable for use in the experiment, mostly due to excess electrical noise generated in the electronic circuitry. However, it was found that the photodiodes' output voltage could be effectively measured using a voltmeter of high sensitivity (Keithley Model 182 Digital Voltmeter). Consequently, the microprocessor and amplifier boards were not used, and the photodiode output voltages were measured by attaching the voltmeter leads directly to the photodiodes leads. This simple change in technique yielded a large enough output so that data could be collected to quantify the relative intensity of the UV lamps' outputs. This method did not give the actual frequency or wavelength of the output of the UV lamps. However this did not negate application of the intensity formula to determine the ideal distance of relative intensities of UVR emitted from the lamps.

Initially it was assumed that the two lamps produced UV radiation in different parts of the UV range. One lamp was a compact fluorescent "black light" lamp, so the assumption was that the light emitted was mainly in the UV-a range with some UV-b. The other lamp was a shrouded sanitizing lamp, and was believed to emit light mainly in the UV-c light range (This assumption was based on the fact that as a water purifier its radiation should be mostly geared to microbe destruction hence it should be rich in UV-c compared to UV-a and UV-b.). However, our measurements disproved these assumptions, and there was almost no difference between the frequencies of the radiation produced by each of them. Hence, we found that both lamps utilized for this experiment had very similar radiation output compositions. For the photodiodes, there was some crossover in the sensitivities to the various wavelength ranges. Using optical filters (some commercially obtained, and some homemade ones using sunscreen lotions sandwiched between glass slides), we determined that the actual composition wavelengths of the lamps could not be isolated enough to change the resultant composition wavelengths obtained by using the methods we employed. While this was a minor stumbling block for the research, it did not rule out the assumptions, but pointed to the need for other possible methods and equipment for isolation of resultant wavelength compositions. Utilization of a clear vacuum chamber filled with ozone gas would effectively filter out all UV-c radiation, and most UV-b radiation. The use of pure forms of more energetic UV radiation (i.e., the UV-c range and beyond) would require other equipment, but may yield more concrete results.

After calibration of the light sources, and upon determining the ideal distance to place the samples from the light source (the optimum distance was determined to be 10cm from the center of the lamp) for irradiation. This was determined through the formula we used for intensity; as the distance from the lamp increases beyond 0.1m (10cm), the denominator of the power to area ratio increases; thus, the intensity decreases. As intensity is measured from the center of the light source, using a lamp at a closer distance would complicate the calculation of intensity unnecessarily. A four-probe resistance measurement method was employed to measure electrical resistance. In this method, a known electrical current (100mA) is applied to opposite ends of the sample and the voltage is measured between two points along the length of the sample.

As mentioned previously, several measurements of the dimensions of the samples were made in order to determine averages of their lengths and cross-sectional areas<sup>1</sup>. These averages along with the experimentally determined electrical resistance from the four probe measurements were used to obtain estimates of the electrical resistivities of the samples.

The electrical resistivity determination was made during two sets of conditions: (a) while the samples were illuminated by UV light, and (b) while no illumination of UV light took place. Our results indicated that there were no differences in the electrical resistivity of the samples with UV irradiation or without UV irradiation. Any changes, if they occurred at all, were too miniscule to determine with any degree of certainty.

The two samples used for this experiment had different chemical compositions, based on the ratios of doping chemicals Calcium and Strontium. This minor change in the chemical composition yielded some interesting findings in the stoichiometry of the materials<sup>1</sup>. The chemical compositions of the LaMnO samples, based on the dopants Calcium and Strontium, was completed and outlined in this table (table 1):

Base Chemical Equation ↓	Dopant Variance (x value) →	x = 0.3 (Sample Number 270614A)	x = 0.4 (Sample Number 010714A)
$\text{La}_{0.5}\text{Ca}_{0.5-x}\text{Sr}_x\text{MnO}_3$		$\text{La}_{0.5}\text{Ca}_{0.2}\text{Sr}_{0.3}\text{MnO}_3$	$\text{La}_{0.5}\text{Ca}_{0.1}\text{Sr}_{0.4}\text{MnO}_3$

Table 1.

The electrical resistance of the samples was measured before testing in order to calculate electrical resistivity, and to ascertain any property changes while they were exposed to the UVR. Using the four probe method, and changing the locations of the probes to find an average, the electrical resistance at room temperature for the samples was found. With the formula for electrical resistivity  $\rho$ , we were able to calculate  $\rho$  ( $\Omega\text{m}$ ) for the samples. The following table (table 2) outlines the baseline measurements and calculations for the La(Ca/Sr)MnO samples:

Sample Number ↓	Properties Found →	h (height)	w (width)	l (length)	R (electrical resistance)	$\rho$ (electrical resistivity)
270614A		2.11 mm	3.34 mm	4.425mm	$5.6375 \times 10^{-2} \Omega$	$8.978 \times 10^{-2} \Omega\text{m}$
010714A		1.788 mm	3.86 mm	4.89 mm	$7.8675 \times 10^{-3} \Omega$	$1.1101 \times 10^{-3} \Omega\text{m}$

Table 2.

When the samples (270614A and 010714A) were irradiated with the ultraviolet lamps, no discernable changes in electrical resistance were found. The samples were also tested for changes in voltage while an applied current was passed through them, and UVR was applied. It was found that there were no discernable changes in voltage of the samples as the ultraviolet light was introduced.

**Conclusion/Future direction:**

Based upon our hypothesis, we concluded that there were no discernable electrical property changes in the LaMnO samples using Ultraviolet Radiation in the UV-a, UV-b, and UV-c ranges as a catalyst at room temperature. However; this finding does raise additional questions about the sample materials. Based on previous findings<sup>2,5,6,10,15,16</sup>, and our electrical resistivity testing<sup>1</sup>, the material behaves in unpredictable ways at differing temperatures. It has been found that the conductivity of substances similar to the samples utilized in our experimentation will increase its temperature decreases<sup>2</sup>. The effects of doping the materials with Calcium and Strontium does cause marked differences in atomic stoichiometry; therefore, variations in temperature should be introduced to samples of similar structure in the future. This does point towards the utilization of the same experimentation processes while introducing new independent variables, such as temperature variances. Given the perovskite<sup>12</sup> structure of the samples, and the fact that the electromagnetic properties of these materials can change greatly by applying heat or cold implies that further experimentation on them is warranted.

Another aspect of the experimentation that has not been mentioned is the fact that the materials utilized had very little surface area (approximately  $2\text{mm}^2$ ) which was exposed to the UVR. The possibility does exist that the reduced surface area of the materials experimented on may have shown an effect so miniscule that it could not be measured using the devices we employed. Because the photoelectric effect occurs at the surface of a material, if the same amount of material was created exploiting the maximum surface area possible, then a determinate effect may occur in the presence of UVR using the same measuring equipment. The use of thin films of La(Ca/Sr)MnO materials may yet yield a measureable electrical property change when UVR is used as a catalyst, and this avenue of investigation should be taken in future experimentations.

The use of a spectrometer to ascertain the precise composition wavelengths of the light sources would give future investigators the measurements necessary to yield further information about our samples' behavior under UV radiation.

This methodology may point to using more energetic forms of UV light (i.e., shorter wavelengths) to elicit a photoelectric effect; however, this methodology would require a suitable source of highly energetic UV light, and a clear vacuum chamber would be advantageous in order to isolate that light from any atmospheric occlusions that may occur. The use of said vacuum chamber may also be useful if filled with a filtering gas, such as ozone.

### **Acknowledgments:**

We would like to express our gratitude to the following individuals and organizations for their unceasing support and knowledge sharing, without which this learning and growing experience would have been impossible:

Dr. Larry Henry, for his dissemination of conceptual and mathematical materials which facilitated the process of this investigation and research paper, he is truly a boon to the research world.

Mr. Jermain Franklin, for his assistance in conceptual understanding, mathematical understanding and application, and measurement collaboration, it was a great honor that we had the opportunity to work with him.

To Dr. Ken Ford, for challenging our thinking processes on numerous subjects, and increasing our critical thinking skills to a new level.

To Dr. Diola Bagayoko, we thank him for his unique and visionary approach to the processes of teaching and learning.

To the faculty and staff at Southern University, we thank them for all of their assistance and for allowing the use of their facilities through the summer.

The current work is funded by the NSF EPSCoR LA-SiGMA project under award #EPS-1003897.

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