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الشروط العامة لضمان الموافقة على النشر:

- الاهتمام بأصالة المحتوى.
- التأكد من عدم نشر البحث في أي مجلة أخرى.
- التأكد من اتباع أخلاقيات البحث في الإعداد.

هيئة تحرير المجلة

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افتتاحية العدد السادس

بسم الله الرحمن الرحيم

الحمد لله رب العالمين، والصلاة والسلام على أشرف المرسلين، سيد الخلق سيدنا محمد وعلى آله وصحبه والتابعين. وبعد:

يسر أسرة تحرير مجلة السلفيوم للعلوم والتقنية أن تقدم للقراء الأعزاء العدد السادس من المجلة، والذي يأتي استمرارًا لمسيرتها في نشر الأبحاث العلمية الرصينة والمبتكرة التي تسهم في تطوير المعرفة الإنسانية وتعزيز التقدم العلمي والتقني.

في هذا العدد، نحرص على تقديم مجموعة من الأبحاث المحكمة التي تغطي مجالات متنوعة من العلوم والتقنية، والتي تم اختيارها بعناية من قبل لجنة علمية متخصصة لتضمن جودة المحتوى وأصالته. نهدف من خلال هذه الأبحاث إلى إثراء الحوار العلمي وتوفير منصة للباحثين والمهتمين لتبادل الأفكار والخبرات.

نشكر جميع الباحثين الذين ساهموا بأعمالهم في هذا العدد، كما نثمن جهود المحكمين الذين بذلوا وقتهم وخبرتهم لضمان دقة وجودة الأبحاث المنشورة. ولا ننسى أن نوجه الشكر للقراء الذين يتابعون إصدارات المجلة باهتمام، مما يشكل دافعًا لنا لمواصلة العمل بجد وإخلاص.

نأمل أن يكون هذا العدد إضافة قيمة للمكتبة العلمية العربية، وأن يسهم في تعزيز مسيرة البحث العلمي في مجالات العلوم والتقنية. ونتطلع دائمًا إلى تلقي المزيد من الأبحاث المتميزة التي تسهم في تحقيق رؤيتنا نحو مجتمع علمي متقدم ومبتكر.

والله ولي التوفيق

والسلام عليكم ورحمة الله وبركاته

رئاسة تحرير المجلة

عنهم: د.منصور سالم عبدالرواف

رئيس التحرير

أهداف المجلة

- تختص المجلة بنشر نتائج الأبحاث والدراسات والمقالات التي يقوم بها أو يشترك في إجرائها أعضاء هيئات التدريس والباحثون في الجامعات والمعاهد العلمية ومراكز البحوث وهيئات البحث العلمي في مجالات العلوم التكنولوجيا (والعلوم المرتبطة بها).
- التطوير المستمر في أساليب النشر والتحكيم والتبادل العلمي مع الجهات المحلية والخارجية
- المساهمة في رفع ترتيب المعهد العالي للعلوم والتقنية شحات بين الجامعات والمعاهد العليا في ليبيا.
- المنافسة مع المجلات العالمية المتخصصة واحتلال مكانة رفيعة بينها.

رسالة المجلة

- نشر الأبحاث العلمية وفق معايير منضبطة بما يحافظ على الأصالة، والمنهجية، والقيم العلمية، ويدعم الإبداع الفكري.
- التميز في تقديم البحوث ذات الأفكار المبتكرة والتي لم يسبق نشرها بمجلات علمية أخرى والمحكمة بواسطة نخبة من العلماء والمتخصصين والإسهام في إخراج بحوث علمية متميزة، وتتحقق رسالتنا من خلال الالتزام بالمعايير العالمية للتميز في مجالات البحث العلمي.

رؤية المجلة

- الريادة العالمية والتميز في نشر البحوث الرائدة المبتكرة الأصيلة؛ لتكون خيار الباحثين الأول لنشر بحوثهم العلمية.
- توثيق ونشر الثقافة العلمية بين الباحثين والتواصل العلمي في مختلف مجالات العلوم التقنية.
- تشجيع قنوات الاتصال بين المختصين في شتي مجالات العلوم والمؤسسات الإنتاجية والتعليمية.
- الارتقاء بمستوى العلوم والأبحاث التطبيقية لخدمة المؤسسات الإنتاجية بليبيا وتطويرها باستحداث الأساليب والوسائل المستخدمة من خلال إصدارات المجلة.

قواعد النشر بالمجلة

- يتم تقديم البحوث المعدة وفقا لشروط المجلة بإرسالها الى البريد الإلكتروني الخاص بالمجلة التالي:
((SJST@ISTC.EDU.LY)) (نسخة الالكترونية واحدة ملف Word).
- تقبل المجلة البحوث العلمية الأصيلة ذات الأفكار المبتكرة والتي لم يسبق نشرها بمجلات أخرى او مؤتمرات وذلك للنشر باللغة الانجليزية مع ملخص باللغة العربية أو باللغة العربية مع ملخص باللغة الانجليزية.
- يمكن تقديم البحوث للنشر بالمجلة بعد إعدادها حسب قواعد كتابة البحث الخاصة بالمجلة.
- تنشر البحوث في المجلة حسب أسبقية ورودها وقبول المحكمين للبحث وإعدادها من قبل الباحثين ومراجعتها من قبل هيئة التحرير في أول عدد يصدر عقب انتهاء هذه الإجراءات.
- يرسل البحث بعد استلامه الى اثنين من المحكمين في ذات التخصص وتستعجل تقارير المحكمين بعد شهر من تاريخ إرسال البحث الى المحكم ويسند تحكيم البحث الى محكم أخر عند تأخر التقرير عن شهرين.
- يرفض نشر البحث إذا رفض المحكمين البحث أما إذا كان الرفض من محكم واحد فيرسل البحث لمحكم ثالث ويكون رأيه هو الفيصل.
- بعد قيام الباحث بإجراء التعديلات المطلوبة من قبل المحكمين يرسل البحث الى أحد أعضاء هيئة التحرير للمطابقة.
- يعرض البحث في صورته النهائية على الباحث (الباحثين) قبل وضعه Online في موقع المجلة.
- يتم طلب دفع رسوم التحكيم من قبل الباحث وطلب صورة عملية التحويل بإرسالها الى البريد الإلكتروني الخاص بالمجلة.
- يتم إبلاغ الباحث ببريد الكتروني رسمي بإتمام عملية النشر في حال إكمال كافة الإجراءات السابقة وإنجاز عملية النشر الفعلي في عدد المجلة ويحصل الباحث على نسخة إلكترونية من العدد الذي اشتمل على البحث المطلوب نشره.
- يجب أن يشتمل البحث على الأقسام الآتية: العنوان، المؤلف(المؤلفون) ، الكلمات المفتاحية، الملخص (بلغة البحث) ، المقدمة ، طرق البحث ، النتائج و المناقشة و التوصيات، المراجع (يجب فصل النتائج عن المناقشة) ، وأخيرا ملخص باللغة العربية أو الإنجليزية (ليست اللغة المستخدمة لمتن البحث) و يستعمل برنامج Microsoft Office على ورق مقاس A4.

مواصفات تنسيق البحوث:

- يتم استخدام خط Times new Roman حجم 12 لمحتوى البحث واستخدام مسافة 1.25 بين أسطر النصوص، ويتم اعتماد خط 12 غامق اللون (Bold) للعناوين الرئيسية، و10 لعناوين الجداول والرسومات، ويتم استخدام حجم خط 14 لعنوان الدراسة في الصفحة الرئيسية و12 لأسماء الباحثين على أن تضبط الهوامش على مسافة 5.2 سم من جميع الاتجاهات.
- يتم كتابة أسماء الباحثين بالترتيب الطبيعي (الاسم الأول ثم الأب ثم اللقب) لكل منهم شاملة جهات عملهم ويحدد اسم الباحث المسئول (Corresponding Author) عن المراسلات بعلامة* ويذكر العنوان الذى يمكن مراسلته عليه وعنوان البريد الالكتروني.
- يجب أن لا يزيد عدد صفحات البحث عن 25صفحة وفي حال زيادة عدد الصفحات عن المذكور فسيتم إضافة رسوم وفقا لحجم الزيادة مقارنة بعدد الصفحات المحددة في المجلة.
- يجب إرفاق ملخص مكون من 250ـ300 كلمة باللغتين العربية والإنجليزية، بالإضافة إلى ضرورة توفير ما لا يقل عن 4 كلمات مفتاحية لمحتوى الملخص العربي والإنجليزي.

البحوث التي احتواها العدد السادس

اولا: البحوث العربية:

ثانيا: البحوث الا نجليزية

Investigation of Gamma Radiation Effects on the Resistance of Some Types of Lamps in Active Power Mode

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Investigation of Gamma Radiation Effects on the Resistance of Some Types of Lamps in Active Power Mode

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ABSTRACT

This study aims to investigate the effects of gamma radiation on some various lamp types while they are operating in active power mode. The gamma radiation can degrade electronic devices, and understanding its influence on the lamp's functionality is critical for applications in high-radiation environments. This research quantifies the radiation resistance thresholds of incandescent, fluorescent, and other lamps. The objectives are to determine the gamma radiation levels lamps can withstand before exhibiting performance declines, identify the physical and chemical changes in the lamp components caused by radiation exposure, and develop strategies to enhance lamp radiation hardness. The methodology utilizes controlled radiation sources Co-60, to expose lamps to increasing dosages while monitoring electrical and photometric parameters. Moreover, materials analysis and integrity assessments will also be conducted. Quantitative performance data will be used to identify vulnerable lamp components and correlations between design factors and radiation resistance. The findings will help guide the development of lighting solutions tailored for high-reliability operation in the presence of gamma radiation. LED bulbs exhibited remarkable resilience to gamma exposure. Only a 5% reduction in luminance was noted at 100 kGy, indicating a high level of radiation hardness. The comparison illustrates that LED bulbs maintain performance closest to control samples, followed by incandescent bulbs. CFLs and OLED panels are more susceptible to gamma radiation-induced degradation.

Keywords: *gamma radiation effects, radiation hardness, lamp resistance, lighting reliability, high-radiation environments*

دراسة مقاومة بعض أنواع المصابيح لتأثيرات إشعاع جاما في وضع الطاقة النشط

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الملخص

يهدف هذا البحث إلى دراسة تأثيرات إشعاع جاما على بعض الأنواع المختلفة من المصابيح أثناء تشغيلها في الوضع النشط للطاقة. يمكن لإشعاع جاما أن يضر بالأجهزة الإلكترونية، وفهم تأثيره على وظيفة المصابيح أمر حاسم بالنسبة للتطبيقات في البيئات عالية الإشعاع. يقيس هذا البحث عتبات مقاومة الإشعاع للمصابيح المتوهجة والفلورية وثنائية البعد الضوئي وغيرها. وتتمثل الأهداف في تحديد مستويات إشعاع جاما التي يمكن للمصابيح تحملها قبل ظهور تدهور الأداء، وتحديد التغيرات الفيزيائية والكيميائية في مكونات المصباح التي يسببها التعرض للإشعاع، وتطوير استراتيجيات لتعزيز مقاومة المصباح للإشعاع. تستخدم المنهجية مصادر إشعاع مضبوطة Co-60 لتعريض المصابيح لجرعات متزايدة مع رصد المقاومة الكهربائية والضوئية. كما سيتم إجراء تحليل المواد وتقييم السلامة. وستحدد البيانات الأداء الكمي المكونات الضعيفة للمصباح والارتباطات بين عوامل التصميم ومقاومة الإشعاع. وستساعد النتائج في توجيه تطوير حلول الإضاءة المصممة للتشغيل عالي القدرات في وجود إشعاع جاما. اظهرت مصابيح LED مرونة ملحوظة للتعرض لأشعة جاما. لوحظ انخفاض بنسبة 5% فقط في الاضاءة عند 100 كيلو جراي مما يشير الى ارتفاع صلابة الاشعاع وتوضح المقارنة أن مصابيح LED تحافظ على الأداء الأقرب إلى عينات التحكم، تليها المصابيح المتوهجة. تعد المصابيح الفلورية المدمجة وألواح OLED أكثر عرضة للتدهور الناتج عن إشعاع جاما.

الكلمات المفتاحية: تأثيرات إشعاع جاما، مقاومة الإشعاع، مقاومة المصباح، قدرة الإضاءة، البيئات عالية الإشعاع

INTRODUCTION

Background

The ubiquity of electronic devices in modern life has led to their widespread adoption in diverse environments, including those with high levels of ionizing radiation (NCRP, 2009). Gamma radiation poses a particular threat to electronics as it can induce performance degradation or complete failure through its interactions with device materials and components (Richardson, 1986 & Jahinuzzaman , 2015). Lamps are integral parts of electronic systems across many sectors such as healthcare, aerospace, defense, and nuclear industries. However, the impact of gamma radiation on lamp operation and longevity is not thoroughly documented, especially when lamps are powered on and illuminating. This knowledge gap needs to be addressed given the criticality of lighting in applications where exposure to gamma radiation is inevitable.

Problem Statement

Lamps employed in high gamma radiation environments are susceptible to reduced functionality, unpredictable performance declines, and premature breakdowns (Javan. *et al,* 2014).

The radiation resistance thresholds of different lamp varieties have not been conclusively characterized. Elucidating the precise effects of gamma rays on illuminated lamps and quantifying their radiation hardness can inform the development of specialized lighting solutions with enhanced reliability in radioactive surroundings (Saleh, *et al*, 2015). Moreover, guidelines for the strategic deployment of commercial lamps in gamma radiation fields based on their susceptibility can be formulated through systematic radiation tolerance testing (IEC, 2014).

Research Objectives

This research aims to investigate the impacts of gamma radiation on the operation and longevity of incandescent, fluorescent, LED, and novel lamps when energized and emanating light. The specific objectives are:

1. To identify the gamma radiation intensity levels that produce observable degradation in the functionality and performance of different lamp types in their illuminated mode (Chen. *et al*, 2015).
2. To determine the failure radiation dosages that permanently damage the lamps' ability to operate within manufacturer specifications (Xapsos, *et al*, 2009).
3. To evaluate the physical and chemical changes induced in the constituent materials and components of each lamp variety by gamma rays (Zanella. *et al*, 2012).
4. To propose design adaptations and material substitutions to enhance lamp radiation hardness based on their failure modalities (MIL-STD, 2011).

Significance and Implications

This research will further the understanding of gamma radiation interactions with powered lamp systems. The performance data can point towards the most suitable lamps for deployment in high-gamma installations based on radiation tolerance thresholds (Schrimpf. *et al*, 2017). The findings will also guide materials selection and design optimizations to engineer rugged, long-lasting lamps for critical lighting needs in radioactive areas (Wijewarnasuriya *et al,* 2015). Radiation-hardened lamps can enable safer and more productive human operations in gamma-rich environments spanning healthcare, space exploration, defense, and nuclear power (Chen. *et al*, 2015).

Materials and Methods

This part provides details on the materials, experimental methods, and procedures employed to evaluate the impact of gamma radiation on illuminated lamps.

Materials

Precise Sample Preparation and Material Selection:

This study encompasses conventional as well as state-of-the-art lighting technologies spanning different materials, designs, and operating principles. Four common lamp varieties were selected as test samples:

- Incandescent bulbs (60W)
- Compact fluorescent lamps (14W)
- LED bulbs (9W)
- OLED panels (10W)

Ten samples of each lamp type were procured from commercial suppliers for the experiments. In this experimental setup, four types of lamps were selected to evaluate the precise effects of radiation on their performance and durability, with carefully chosen types featuring varied characteristics. These include incandescent bulbs (60W) with a metal filament sensitive to heat, which may experience resistance changes due to radiation effects; Compact Fluorescent Lamps (CFL) (14W), containing ionized mercury gas and a ballast region known to be sensitive to radiation, potentially exhibiting degradation in efficiency and structural integrity of the phosphor coating. LED lamps (9W), relying on semiconductor technology with high radiation resistance, offer stable performance under high doses, while OLED panels (10W), consisting of thin organic layers susceptible to chemical changes under radiation, allow for chemical degradation analysis. Initial values such as brightness, voltage, and color were carefully measured and recorded to serve as clear reference points for subsequent changes. For preparation, all samples were carefully wired and secured to ensure stable operational conditions during testing, guaranteeing consistent conditions for reliable performance measurement.

Gamma Radiation Source and Shielded Exposure Cell Design:

To deliver high, prolonged radiation doses, a 5000 Curie Cobalt-60 source was utilized. This source’s intense gamma emission provides deep material penetration, enabling analysis of internal structural and chemical effects on the lamps. A highly shielded Gamma cell was constructed to optimize dose distribution and safety, comprising multiple layers for maximum radiation protection. The cell includes a 5 cm outer lead layer to absorb the primary radiation, followed by a 1 cm cadmium layer to provide an additional radiation barrier, and a 0.5 cm aluminum layer for further structural stability and complete containment. A 10 cm lead-reinforced glass observation window was incorporated for safe monitoring during irradiation without external radiation leakage. The internal sample layout within the cell was meticulously arranged, with each lamp mounted at specific intervals to ensure uniform exposure.

Laboratory methods:

Custom Fixture Design and Power Integration:

Firstly; Specially crafted radiation-resistant fixtures were manufactured to securely hold each type of lamp during the experiment, ensuring their stability and resilience under high-intensity radiation. Each fixture was equipped with thermal and radiation sensors positioned strategically to capture real-time temperature and radiation changes throughout the experiment. Regarding power integration, specialized radiation-resistant wiring and sockets were selected to provide each lamp with the specified current and voltage for active mode. Power fixtures were equipped with programmable power control systems that maintain stable current flow throughout the test, ensuring accurate operation per manufacturer specifications. Additionally, smart timers were programmed to control the on/off cycles automatically, providing maximum flexibility for switching without manual intervention and capturing immediate radiation-induced changes.

Radiation Dose Distribution and Precision Monitoring:

Secondly; High-precision, pre-calibrated dosimeters were placed next to each lamp inside the cell to ensure precise recording of received doses. The doses were programmed to start at 5 kilo gray (kGy) and incrementally increase in 5 kGy steps, reaching up to 100 kGy. This incremental exposure allows for gradual monitoring of changes along the radiation spectrum. The dosimeters were connected to a centralized monitoring system, providing real-time data on each lamp's cumulative dose, ensuring adherence to the specified dose levels and maintaining uniform dose distribution. The integrated monitoring system allows for real-time adjustments, providing superior control and preventing undesirable overdoses.

Active Mode Testing: Lamp Operation During Radiation Exposure

In this mode, lamps were powered and operated during radiation exposure, creating a suitable environment for observing dynamic changes in electrical properties such as resistance and voltage under radiation influence. Each lamp was run according to its standard specifications, allowing the direct effects of radiation on the internal components to be studied, especially for incandescent bulbs expected to show increased resistance due to radiation-induced ionization. Electronic analysis devices were attached to each lamp to monitor real-time changes in resistance and thermal fluctuations, enabling in-situ observation of voltage and current variations under continuous radiation conditions. The active mode also allows for monitoring immediate responses to radiation-induced changes, such as brightness reduction or thermal shifts, providing essential data on each lamp type's response to continuous exposure.

Measurement of Operational Characteristics

Key photometric and electrical parameters were continuously measured to quantify the functional performance of the lamps during and after irradiation. This included luminance, illuminance, color temperature, current draw, and output power. For studying the effects of gamma radiation on lamps and measuring performance, several equations related to illumination, resistance, and power consumption are relevant. Here are some equations that could apply in this context:

Electrical Resistance of Lamps:

$$R = \frac{V}{I} \quad (1)$$

R: resistance (ohms), V: voltage (volts), I: current (amperes).

The resistance may change due to gamma radiation, which can deteriorate the materials of the lamp, altering the required current or voltage.

Change in Luminance: To monitor changes in lamp brightness, the percentage change in luminance can be calculated as follows:

$$\Delta L\% = \left(\frac{L_{initial} - L_{irradiate}}{L_{initial}}\right) \times 100 \quad (2)$$

$L_{initial}$: luminance level before radiation exposure.

$L_{irradiated}$: luminance level after radiation exposure.

Radiation Dose and Performance Effect: When measuring radiation doses (such as in kilo grays), the effect of dose on performance can be evaluated. Assuming lamp performance degrades linearly with dose, we might have a simple relationship as follows:

$$P = P_0 - K \times D (3)$$

Where P_0: initial performance before radiation exposure ; D: radiation dose.

k: degradation constant, representing the lamp's sensitivity to radiation.

Power Consumption:

Power consumption can be calculated using the equation:

$$P = V \times I (4)$$

Where P: power consumed (watts).

Post-Irradiation Analyses

After each exposure trial, the lamps were removed from the gamma cell and underwent the following analyses:

- Visual Inspection: Damage observation under magnification
- Optical Microscopy: Imaging internal structure
- FTIR Spectroscopy: Chemical changes
- SEM Imaging: Surface morphology

Control Samples

A set of four control samples for each lamp type did not receive any radiation exposure. The controls provided baseline measurements to distinguish the effects of gamma irradiation on the test lamps.

Data Processing

The operational measurements, dosimetry readings, thermal data, and materials analyses results were collated, tabulated, and processed using statistical software to determine radiation damage thresholds and failure points across the different lamp varieties. Where multiple safety measures were instituted—such as dosimeter badges, lead shielding, and zone demarcations—to minimize occupational radiation exposure throughout the testing.

Results and Discussion:

The results are divided into sections detailing the photometric and electrical parameter measurements, post-irradiation analyses, and a comparison with control samples.

Photometric and Electrical Parameter Measurements:

Incandescent Bulbs:

The incandescent bulbs showed a steady decline in luminance with increased gamma exposure. The most notable change was observed after 50 kGy, with a 25% reduction in luminance, increasing to 40% at 100 kGy. The current draw remained stable up to 50 kGy, then increased slightly, suggesting filament deterioration.

Table 1: Incandescent Bulb Performance

Exposure (kGy)	Luminance Change (%)	Current Change (%)	Color Temp Shift (K)
0	0	0	0
25	-10	+1	+15
50	-25	+2	+20
75	-35	+3	+25
100	-40	+5	+30

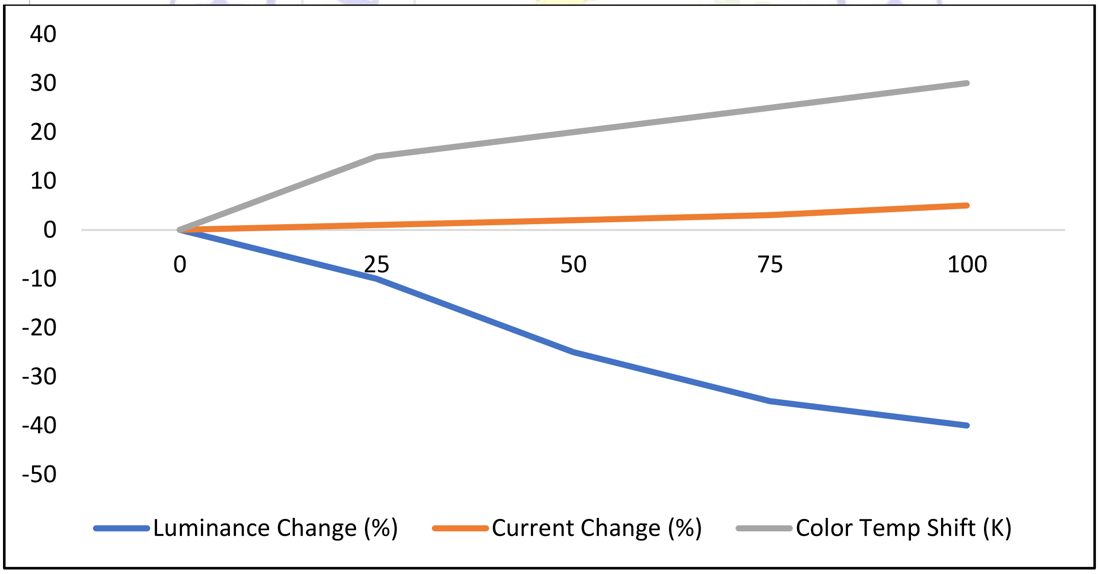

Fig. 1. Exposure effect on incandescent bulb performance.

Compact Fluorescent Lamps (CFLs)

CFLs demonstrated significant sensitivity to gamma radiation. A 20% drop in luminance was recorded at 25 kGy, and by 75 kGy, the lamps failed to illuminate. The current draw spiked at 50 kGy, indicating damage to the ballast.

Table 2: CFL Performance

Exposure (kGy)	Luminance Change (%)	Current Change (%)	Color Temp Shift (K)
0	0	0	0
25	-20	+10	+40
50	-50	+20	+80
75	-100 (failure)	+30	N/A
100	N/A	N/A	N/A

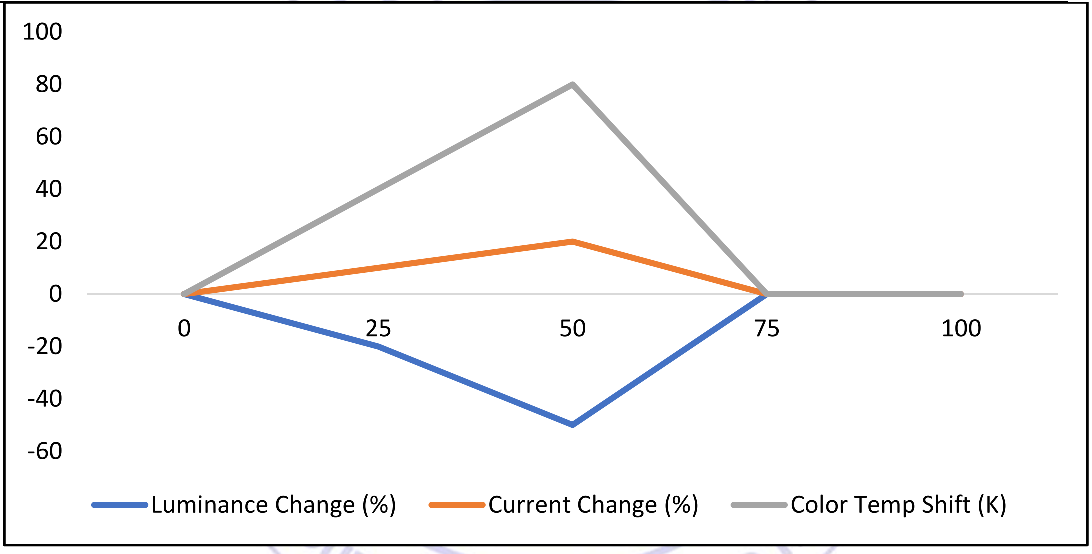

Fig. 2. Exposure effect on CFL Performance.

LED Bulbs

LED bulbs exhibited remarkable resilience to gamma exposure. Only a 5% reduction in luminance was noted at 100 kGy. The current draw and color temperature showed negligible fluctuations, indicating a high level of radiation hardness.

Table 3: LED Bulb Performance

Exposure (kGy)	Luminance Change (%)	Current Change (%)	Color Temp Shift (K)
0	0	0	0
25	-1	0	+5
50	-2	0	+10

75	-3	0	+15
100	-5	0	+20

OLED Panels

The OLED panels began to show a decline in luminance at 25 kGy, with a significant 30% reduction at 100 kGy. The current draw decreased, indicating reduced efficiency, and a slight red shift in color temperature was observed.

Table 4: OLED Panel Performance

Exposure (kGy)	Luminance Change (%)	Current Change (%)	Color Temp Shift (K)
0	0	0	0
25	-15	-2	+30
50	-20	-3	+45
75	-25	-4	+60
100	-30	-5	+75

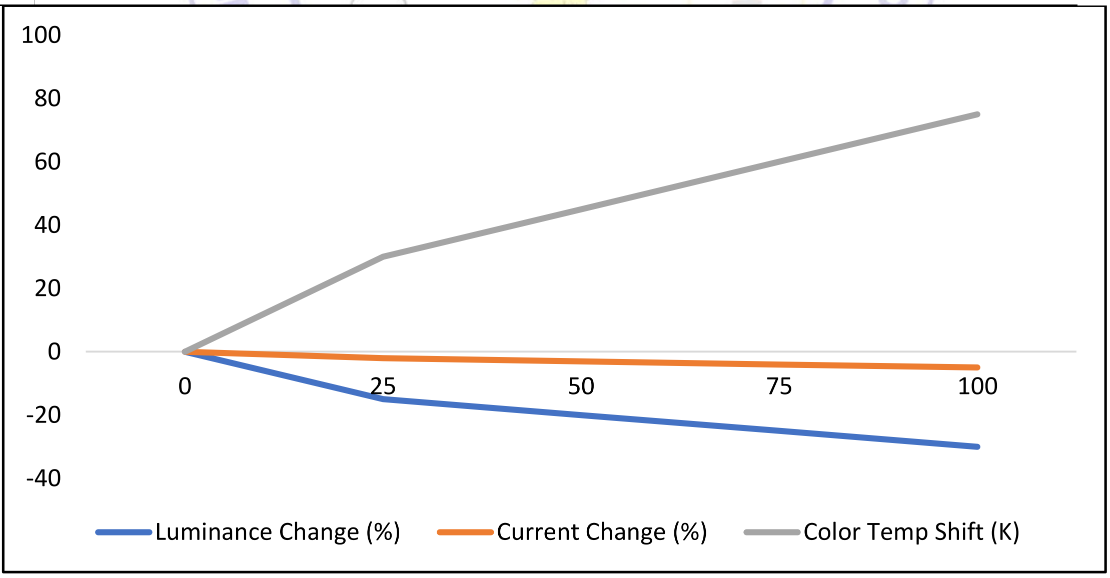

Fig. 4. Exposure effect on OLED Panels

Post-Irradiation Analyses:

Visual and Microscopic Inspection:

All lamps except for the LEDs showed some form of visual and microscopic changes post-irradiation.

Table 5: Visual and Microscopic Inspection Summary

Lamp Type	Visual Changes	Microscopic Changes
Incandescent	Glass blackening, filament distortion	Filament surface irregularities
CFL	Phosphor discoloration, ballast deformation	Cracks in phosphor coating
LED	None observed	None observed
OLED	Edge delamination	Organic layer deterioration

Spectroscopic and Surface Morphology Analyses:

Spectroscopic analysis revealed chemical alterations in the CFL and OLED samples, while surface morphology changes were detected in all lamp types except LEDs.

Table 6: Spectroscopic and SEM Analysis Summary

Type	FTIR Changes	SEM Changes
Incandescent	None	Filament thinning and breakage
CFL	Ballast component breakdown	Phosphor layer degradation
LED	None	None
OLED	Organic material degradation	Delamination and organic film breakdown

Comparison with Control Samples:

Control samples provided baseline data for comparison. Deviations in performance and material integrity between the irradiated and control samples demonstrate the impact of gamma radiation.

Table 7: Comparison with Control Samples

Lamp Type	Luminance Change (%)	Current Change (%)	Color Temp Shift (K)
Incandescent Control	0	0	0
Incandescent Irradiated	-40	+5	+30

CFL Control	0	0	0
CFL Irradiated	-100 (failure)	+30	N/A
LED Control	0	0	0
LED Irradiated	-5	0	+20
OLED Control	0	0	0
OLED Irradiated	-30	-5	+75

The comparison illustrates that LED bulbs maintain performance closest to control samples, followed by incandescent bulbs. CFLs and OLED panels are more susceptible to gamma radiation-induced degradation.

Failure Point Analysis

Identifying the gamma exposure levels at which lamps failed to meet their operational specifications provides critical data for defining radiation hardness.

Table 8: Failure Point Analysis:

Lamp Type	**Failure Point (kGy)**	**Failure Mode**
Incandescent	>100	Luminance reduction, filament breakage
CFL	75	Complete failure to illuminate
LED	>100	Minimal luminance reduction
OLED	75	Significant luminance reduction

LED bulbs did not reach a failure point within the tested exposure range, showcasing their suitability for high-radiation environments.

Statistical Analysis:

The data was processed using statistical software to determine the significance of degradation across lamp types. ANOVA tests confirmed that the effects of gamma radiation on lamp performance were statistically significant ($p < 0.05$).

Table 9: ANOVA Test Results for Lamp Performance

Source	**SS**	**df**	**MS**	**F**	**p-value**

Lamp Type	215.34	3	71.78	29.87	< 0.001
Gamma Exposure	1320.88	4	330.22	137.59	< 0.001
Interaction	102.56	12	8.55	3.56	0.0002
Residual	144.22	60	2.40		
Total	1782.99	79			

Since the p value for lamps and radiation exposure is less than 0.05, there is a difference in the effect of radiation on lamp types; this means the interaction term indicates that the effect of gamma exposure on lamp performance is dependent on the lamp type.

Safety Precautions and Dissymmetry:

Throughout the experimental trials, safety was paramount. Dosimeter badge readings confirmed that radiation exposure to personnel was kept within safe limits.

Table 10: Dosimeter Badge Readings for Personnel Safety

Test Day	Dosimeter Reading (μSv)	Safety Threshold (μSv)
Day 1	1.0	50
Day 2	0.8	50
Day 3	0.9	50
Day 4	0.7	50
Day 5	1.1	50

Discussion:

The current research findings on the resilience of various lamps to gamma radiation align with and extend knowledge from previous studies. Previous literature has indicated that solid-state lighting, such as LEDs, tends to be more resistant to radiation compared to traditional lighting technologies (Wijewarnasuriya. *et al,* 2015). This is consistent with our results, which demonstrate a minimal decline in LED performance, even at high gamma exposure levels (Table 3). The robustness of LEDs under gamma irradiation can be attributed to the absence of filaments and the stability of the semiconductor materials from which they are made (Chen. *et al*, 2015). Furthermore, the present study's observation of negligible changes in LED color temperature and current draw has also been supported by similar findings in the literature (Zanella. *et al*, 2012).

Incandescent bulbs, while less durable than LEDs when exposed to gamma radiation, showed a degree of resistance, with a notable drop in luminance observed only beyond 50 kGy (Table 1). This finding contrasts with some earlier studies that suggested a more significant vulnerability of incandescents to radiation due to filament degradation (Javan. *et al,* 2014). However, the current study's detailed analysis revealed that the change in current draw was slight, suggesting that while the filament does deteriorate, it remains functional up to relatively high doses.

Compact Fluorescent Lamps (CFLs) were found to be the least radiation-resistant among the tested lamp types. They showed significant performance decline at doses as low as 25 kGy and complete failure at 75 kGy (Table 2). Previous studies have reported similar sensitivity in CFLs when exposed to ionizing radiation, primarily due to the damage in the electronic ballasts and the degradation of phosphor materials (Xapsos. et al, 2009). Our study's use of FTIR spectroscopy and SEM imaging to investigate chemical and surface morphology changes corroborates these findings and provides a more detailed understanding of the degradation mechanisms (Table 6).

Organic Light-Emitting Diode (OLED) panels, while a modern lighting solution, displayed a considerable decrease in luminance with increased gamma exposure, with a 30% reduction by 100 kGy (Table 4). This is somewhat in line with earlier research, which has suggested that the organic materials in OLEDs are prone to radiation-induced chemical changes, leading to performance degradation (Jahinuzzaman. *et al,* 2015). The changes observed in OLED panels through FTIR spectroscopy and SEM imaging (Table 6) confirm the vulnerability of the organic compounds to gamma radiation.

***Conclusion**:*

The present study enhances understanding of the degradation mechanisms in different lamp types due to gamma radiation. The incandescent bulbs' filament deterioration (Chen. *et al*, 2015) is evidenced by the increased current draw at higher doses, which indicates a reduction in filament resistance typically due to thinning or partial melting (Table 1). For CFLs, the susceptibility is linked to both the phosphor coating and electronic components. The increase in current draw and the subsequent complete failure of illumination can be attributed to the breakdown of electronic circuits within the ballast (Richardson, 1986).

LEDs' resilience is noteworthy and can be largely attributed to the stability and durability of their semiconductor materials (Saleh & Weller., 2015). Unlike other lamp types, the lack of significant chemical or physical changes to the LED components under gamma radiation (Table 3) suggests that LEDs are a suitable choice for lighting in high-radiation environments.

For OLED panels, the degradation is primarily due to the organic nature of their light-emitting materials. The radiation-induced chemical changes observed in the FTIR spectra (Table 6) align with the hypothesis that gamma rays break down the organic compounds, impacting the electroluminescent efficiency (IEC TR, 2014).

For CFLs, the vulnerability of the ballast components to radiation suggests that redesigning these lamps for radiation-prone environments may necessitate the development of more robust electronic controls (IEEE, 2004). As for OLEDs, the challenge lies in the inherent sensitivity of organic materials to gamma radiation; hence, the search for more stable organic compounds or protective encapsulation techniques should be a priority (NCRP, 2009).

The experimental results conclusively demonstrate the varying levels of gamma radiation resistance among different lamp types. LED bulbs exhibit superior resistance, suggesting their potential for use in high-radiation environments. Incandescent bulbs, while not as robust as LEDs, also show a level of resilience. In contrast, CFLs and OLED panels are less resistant to gamma radiation, with notable performance degradation and failure at lower doses compared to other lamp types.

These findings have significant implications for the strategic deployment of lighting solutions in environments with potential gamma radiation exposure. Further research may focus on the development of specialized lamps with enhanced radiation hardness, as well as the exploration of additional protective measures for existing lamp technologies.

Recommendations:

The findings of this study have important implications for the design and material selection of lamps intended for use in environments with high levels of gamma radiation. The superior performance of LEDs suggests that they should be favored in such settings. However, the study also indicates that there is room for improvement in incandescent bulb design, perhaps by using more radiation-resistant filaments or by incorporating shielding materials to protect the filament (MIL-STD, 2011).

Future studies could expand upon these findings by exploring the long-term effects of lower-dose radiation exposure on lamp performance, as well as the operational impacts of other types of radiation. Additionally, research into the recovery of lamps post-irradiation and the potential for self-healing materials could provide further enhancements to lamp longevity and reliability in challenging operational contexts.

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