CHEMICAL RESISTANCE ANALYSIS OF COEXTRUDED ABS/PMMA SHEETS SUBJECTED TO ULTRAVIOLET (UV) LIGHT AND IONIZING ELECTRON BEAM (EB) RADIATION

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Abstract
This study aims to evaluate the chemical resistance of coextruded ABS/PMMA sheets subjected to ultraviolet (UV) radiation and electron beam (EB) irradiation. The samples were exposed to different UV doses (125, 200, and 300 WPI) and EB doses (50 and 100 kGy), and subsequently tested according to the criteria established by the ABNT NBR 15761 standard. Chemical agents were systematically applied to the surface of the samples, and the resulting damage was classified from Grade 4 (no visible change) to Grade 1 (severe degradation). EB-irradiated samples exhibited yellowing, a phenomenon not observed in UV-treated or non-irradiated specimens. Overall, both irradiated and non-irradiated samples showed similar performance in terms of chemical resistance, displaying vulnerability when exposed to acetone, ballpoint pen ink, and permanent markers. The results suggest that radiation-induced crosslinking via UV and EB did not significantly enhance the chemical resistance of PMMA.

Keywords: *ABS, PMMA, electron beam, ultraviolet radiation*

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Introduction

Acrylic, also known as polymethyl methacrylate (PMMA), is a widely used material due to its transparency, mechanical strength, and ease of processing. However, its resistance to ultraviolet (UV) radiation and electron beam (EB) irradiation varies depending on the material's formulation and the presence of protective additives [1].

Both ultraviolet (UV) and electron beam (EB) radiation can significantly affect extruded acrylic sheets, particularly under prolonged exposure [1]. Figure 1 illustrates the electromagnetic spectrum, highlighting the ultraviolet region.

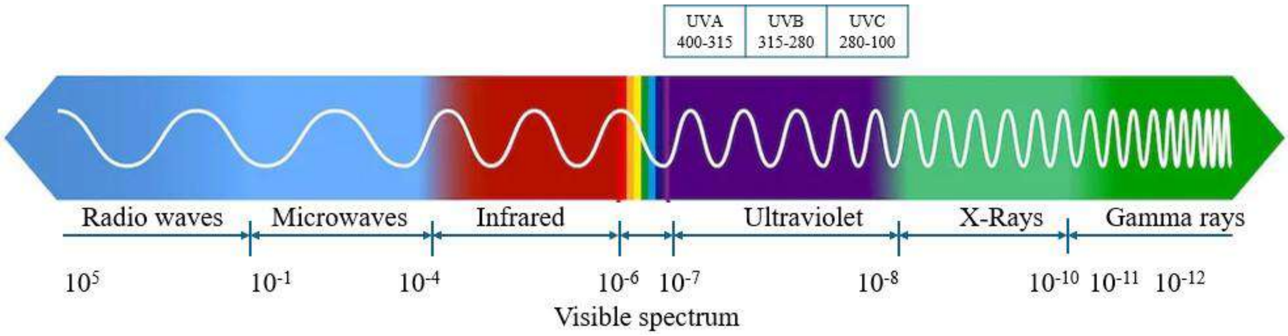

Figure 1- Electromagnetic spectrum

Ultraviolet (UV) radiation is a form of electromagnetic radiation located in the spectrum between visible light and X-rays. It is typically divided into three characteristic bands: UVC (100 - 280 nm, corresponding to 12.40 - 4.43 eV), UVB (280 - 315 nm, 4.43 - 3.94 eV), and UVA (315 - 400 nm, 3.94 - 3.10 eV) [2-4]. This type of radiation is highly effective in degrading organic materials through photochemical oxidation processes, playing a decisive role in reducing the service life of polymers, especially when exposed to environmental conditions. The chemical transformations induced in polymeric materials by UV radiation are permanent and lead to significant alterations in their mechanical properties [5].

In the context of ionizing radiation, the electron beams employed in this study, generated by particle accelerators [6] represent a powerful tool for material modification. The interaction of high-energy radiation, including gamma rays, X-rays, and charged particle beams, with polymeric materials results in energy absorption and the formation of reactive species such as free radicals, which initiate secondary chemical processes [7].

The microstructural transformations observed in polymers can generally be categorized into two distinct mechanisms: physical aging, which occurs without changes in the material's chemical composition [8], and is marked by phenomena such as macromolecular chain scission and crosslink formation; and chemical aging, involving irreversible modifications to the polymer's chemical structure [9,10].

Despite their degradative effects, combined strategies involving UV and EB treatments, together with the application of protective coatings and appropriate maintenance protocols, have shown potential for mitigating structural damage, significantly extending the service life of materials while preserving their mechanical properties and chemical resistance [1].

Experimental

This study documents the testing procedures used to assess the chemical resistance of decorative laminates that were either non-irradiated or subjected to ultraviolet (UV) light and electron beam (EB) irradiation.

The specimens analyzed consisted of coextruded sheets composed of Acrylonitrile Butadiene Styrene (ABS) and PMMA.

Sample Irradiation

The samples were exposed to UV radiation at doses of 150, 200, and 300 WPI (watts per inch) using the Labcura device, model GC 150-1A, equipped with an Ultracura lamp (Fig 2a). EB irradiation was conducted at doses of 50 and 100 kGy (kilogray) using a Dynamitron® linear accelerator, model DC 1500/25 JOB 188, with a maximum energy of 1.5 MeV (megavolts) and a beam current of up to 25 mA (Fig 2b). Both devices are housed at the Centro de Tecnologia das Radiações (CETER) - IPEN.

a) b)

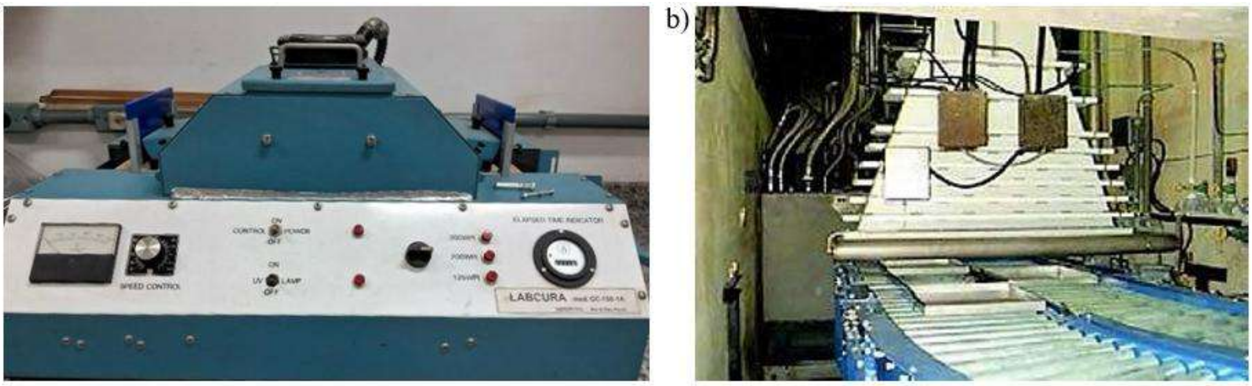

Figure 2 a) Labcura equipment, model GC 150-1A; b) Dynamitron® linear electron accelerator, model DC 1500/25 JOB 188

Preparation for Chemical Resistance Testing

The chemical resistance tests were conducted in accordance with the ABNT NBR 15761 standard - Wood furniture - Requirements and test methods for decorative laminates [11].

Specimens were prepared by precisely cutting the sheets into standardized dimensions of 10 × 10 cm. Each sample was then subdivided into an experimental grid consisting of 6 columns by 6 rows, resulting in 36 test cells. This configuration enabled the systematic and individualized application of various chemical agents, ensuring consistent experimental conditions for each treatment.

The selection and application of the staining agents followed the specifications of the standard, taking into account both the chemical nature of the substances and the specified exposure times.

The experimental layout included a control column, in which no agent was applied (blank), allowing for direct comparison with the other columns treated with chemical agents. This methodological design was essential for establishing reference parameters and identifying changes resulting from chemical exposure.

Results and Discussion

EB-irradiated sheets exhibited noticeable color change (yellowing) following irradiation, in contrast to UV-irradiated samples, which remained visually unaltered (Fig 3).

The adopted classification system for evaluating surface effects is based on four progressive levels of alteration:

- Grade 4 represents the ideal condition, with no visible surface changes. This level indicates full resistance to the tested agents.
- Grade 3 corresponds to minimal effects, such as slight color or texture changes that are only noticeable upon close inspection. These changes do not compromise material integrity.
- Grade 2 indicates moderate alterations, with visible changes in surface color or texture, but without significant detriment to the specimen's original appearance.
- Grade 1 reflects severe damage, including pronounced changes such as cracking, fissures, blistering, intense discoloration, whitening, or delamination. This level represents substantial compromise of the material's original properties.

This progressive scale allows for an objective and comparative assessment of surface damage, which is essential for the accurate interpretation of chemical resistance test results. The classification ranges from no detectable changes (Grade 4) to significant structural damage (Grade 1), offering clear benchmarks for evaluating the performance of tested materials. Table 1 presents the observed results after exposure to the chemical agents.

Table 1- Results obtained after experimental chemical resistance tests

Agent	Grade				Comments
	4	3	2	1	
Ag 1				x	Visible opacity, spill area easily identified
Ag 2	x				No visible alteration
Ag 3	x				No visible alteration
Ag 4	x				No visible alteration
Ag 5	x				No visible alteration
Ag 6	x				No visible alteration
Ag 7	x				No visible alteration
Ag 8		x			Minor color change observed at application site in irradiated and non-irradiated samples
Ag 9			x		Pronounced color change detected at application site in irradiated and non-irradiated samples
Ag 10	x				No visible alteration
Ag 11	x				No visible alteration
Ag 12	x				No visible alteration
Ag 13	x				No visible alteration
Ag 14	x				No visible alteration
Ag 15	x				No visible alteration
Ag 16	x				No visible alteration
Ag 17	x				No visible alteration

The sample marking scheme was: Ag 1 - acetone, Ag 2 - mustard, Ag 3 - detergent, Ag 4 - disinfectant, Ag 5 - coffee, Ag 6 - acetic acid, Ag 7 - hydrogen peroxide (3%), Ag 8 - ballpoint pen ink, Ag 9 - permanent marker ink, Ag 10 - ammonia (10%), Ag 11 - red lipstick, Ag 12 - sodium hydroxide (3%), Ag 13 - hydrogen peroxide (30%), Ag 14 - sodium hypochlorite (2.5%), Ag 15 - iodine (2%), Ag 16 - shoe polish, Ag 17 - citric acid (10%), Ag 18 - acetic acid (5%).

Figure 3 illustrates the final condition of each laminate sample after chemical exposure. The effects of agents Ag 1 (acetone), Ag 8 (pen ink), and Ag 9 (permanent marker ink) were clearly visible across all samples whether non-irradiated, UV-irradiated, or EB-irradiated.

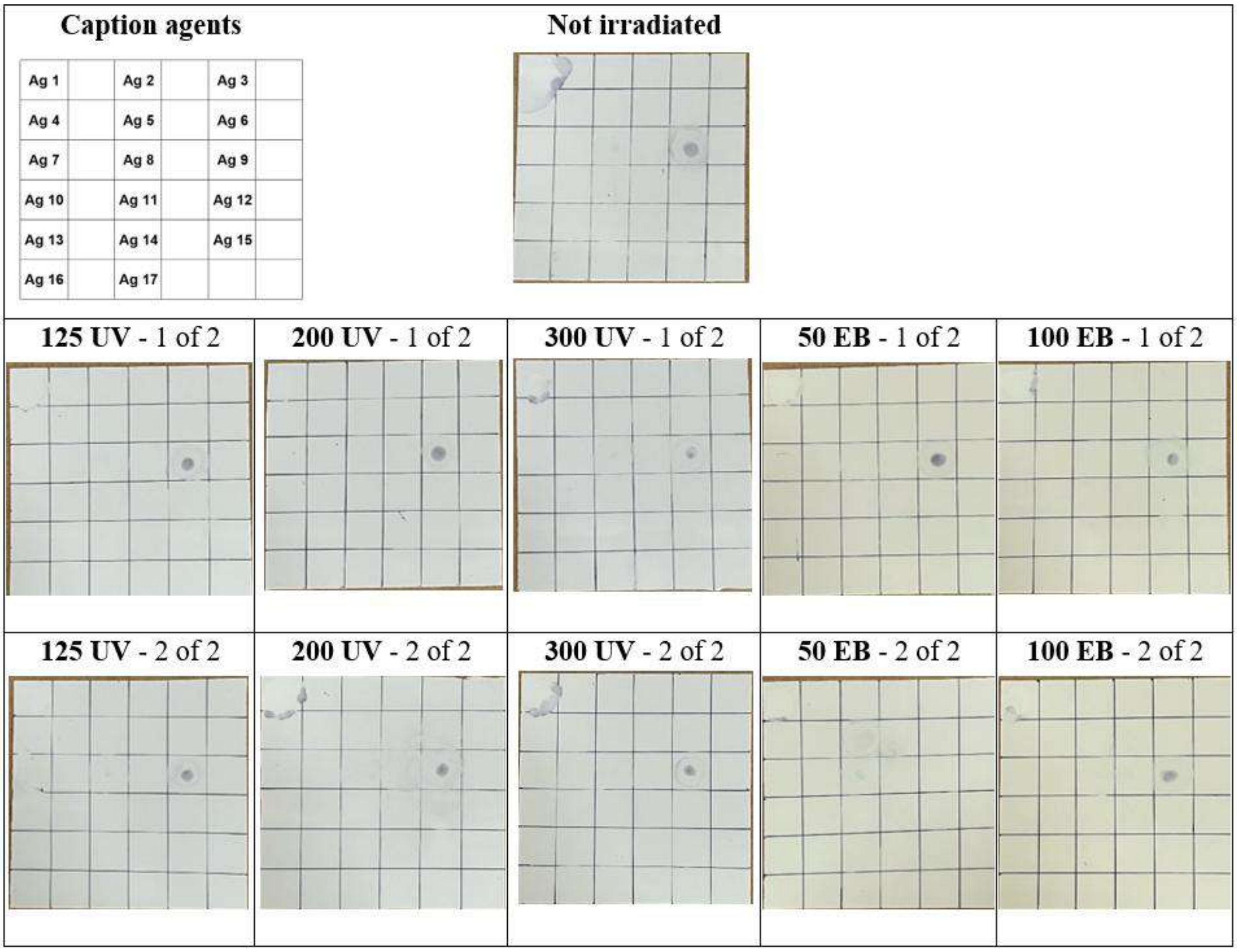

Figure 3 - Final appearance of samples after chemical testing

Conclusion

Yellowing was observed exclusively in samples irradiated with EB, indicating a specific effect induced by this type of radiation. However, PMMA did not exhibit improved chemical resistance following either UV or EB irradiation, maintaining a behavior similar to that of the non-irradiated samples when exposed to acetone, ballpoint pen ink, and permanent marker ink. This suggests that crosslinking of PMMA induced by UV or EB radiation does not lead to enhanced chemical resistance. The remaining samples, regardless of irradiation, showed no signs of chemical attack.

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