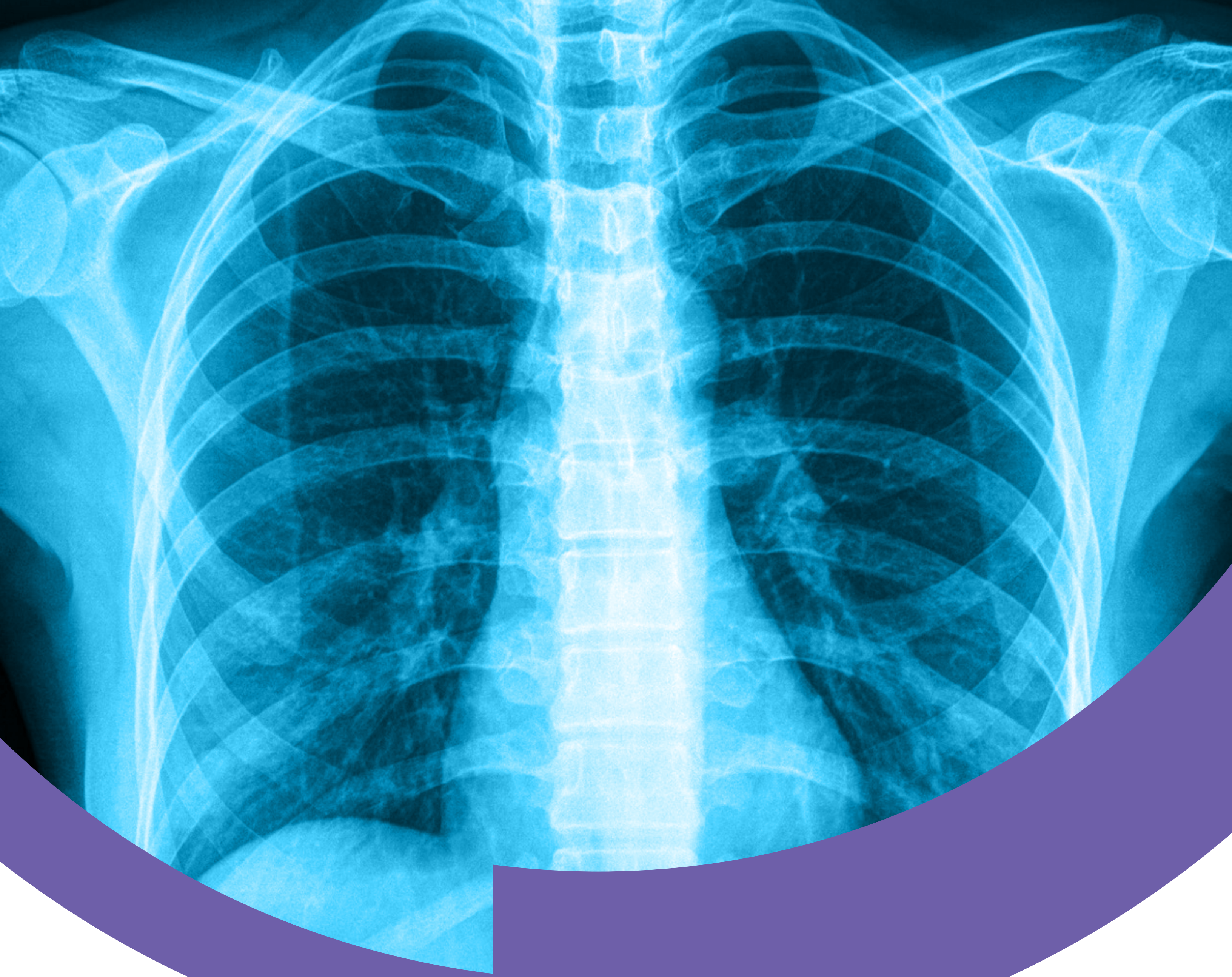

Radiopacity of Polycarbonate for Healthcare Applications

WHITEPAPER

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1 Abstract

In this article, we examine the visibility of polycarbonate materials in X-ray images. Part thickness, color recipe and reinforcement all influence the opacity of a material and its visibility in X-ray images. In a simulated chest X-ray, the polycarbonate materials were discernable as shadows; signal to noise for samples measured against the simulated chest background prevented quantitative determinations.

2 Introduction

Visualization of medical devices or surgical tool placement with X-rays often rely on the radiopacity of materials. Radiopacity (radiodensity) refers to how effectively materials absorb X-rays and, therefore, how visible they are in X-ray images. Higher density materials like metals are generally more visible in X-ray images, while most plastics appear only faintly on account of their lower density. To make plastics more visible, they are often blended with higher density additives. This approach to increase visibility is common in materials used for catheters, where the very thin walls (0.1 mm is not uncommon) would otherwise make them virtually invisible during critical procedures like stent placement. Makrolon® polycarbonate from Covestro is extremely robust, lightweight with glass-like transparency and is impact resistant – even at low temperatures. It also has a high dimensional stability and is easily molded, yet displays excellent heat resistance. In this article, we delve deeper into the question of how colorants and reinforcing agents influence the visibility of polycarbonate in X-rays.

3 Methodology

The radiopacity of a series of injection-molded Makrolon® polycarbonate compositions was measured according to ASTM F640-20. Test articles of 1 mm and 4 mm thickness were imaged using a high-resolution digital X-ray unit (Kubtec XPERT 80-L). Figure 1a illustrates the simple configuration for quantitative comparisons. A step-wedge made from aluminum was chosen as a reference material because it is well-documented as a reference material in radiology.

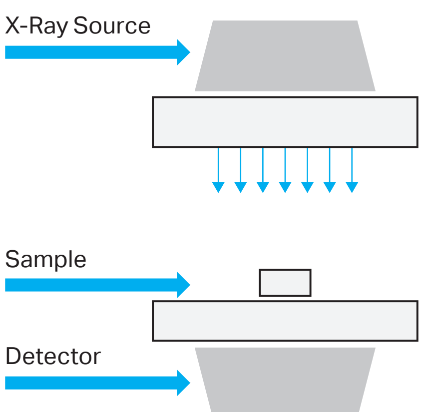

Figure 1a. Set up of X-ray unit for evaluating radiopacity.

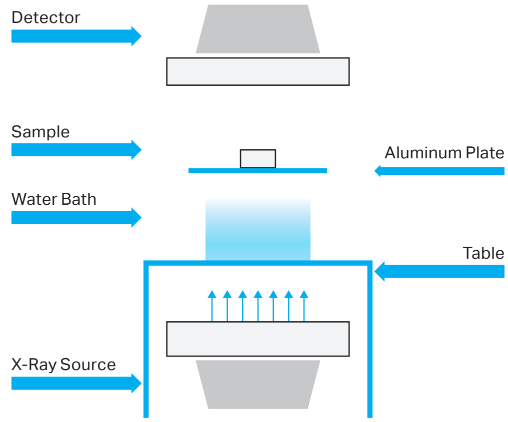

Figure 1b. Representative set-up of chest mimic, fluoroscopy unit, table, and test articles for measuring radiopacity.

The visibility of the polycarbonate materials against a background like a patient's chest was also studied with a configuration that could mimic clinical setting by fluoroscopy. A C-arm fluoroscopy unit (GE Healthcare, OEC 9900 Elite) unit was used for these measurements. Figure 1b shows the setup where a water bath designed to simulate the density of a patient's chest in the path of the X-ray was included in the line of sight. Digital image files were captured and analyzed on the basis of black/white intensity, and correlated to an equivalent aluminum thickness with the same X-ray visibility.

4 Results and Discussion

Figure 2a and 2b illustrate the images obtained from the samples with both X-ray configurations.

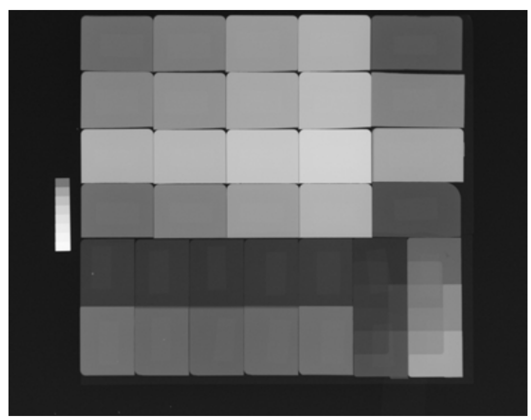

Figure 2a. Image of samples studied with Kubtec X-ray unit for evaluating radiopacity. Lighter = more opaque. Aluminum step-wedge shown at left.

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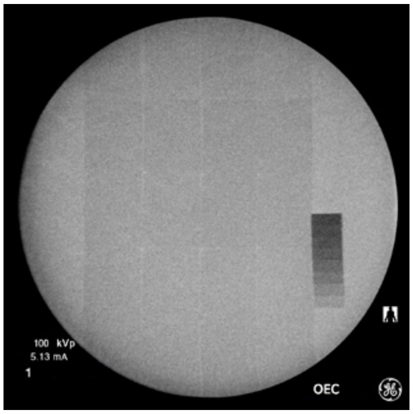

Figure 2b. Representative image of samples against chest mimic, measured with a fluoroscopy unit. Darker = more opaque. Aluminum step-wedge shown at right.

The image in Figure 2a allows us to make a comparison of the relative X-ray opacities of polycarbonate-based materials. Overall, our observations were consistent with organic matter having much lower X-ray attenuation than aluminum or heavier metals.[1] With the exception of carbon fiber reinforcement, highly filled polycarbonate (either glass fibers (GF) or inorganic colorants) were more visible. Carbon-fiber reinforced polycarbonate appeared dark and radiotransparent.

Figure 3 compares the relative visibility of: a) natural polycarbonate, b) a highly colored polycarbonate and c) a highly colored 30% GF polycarbonate.

Figure 3. Relative X-ray opacity of three medical-grade polycarbonates studied with Kubtec X-ray (each at 4mm thickness).

Inclusion of glass fibers in polycarbonate increases visibility more significantly than colorants. Figure 4 summarizes the opacities expressed in equivalent aluminum thicknesses for three common polycarbonate materials with thicknesses of 4mm. Natural polycarbonate gave the lowest visibility, where a 4mm thick part is as opaque to X-rays as a 0.25mm thick part made from aluminum. An opaque polycarbonate (white-colored) was only slightly more radiopaque and a 30% GF polycarbonate was significantly more visible.

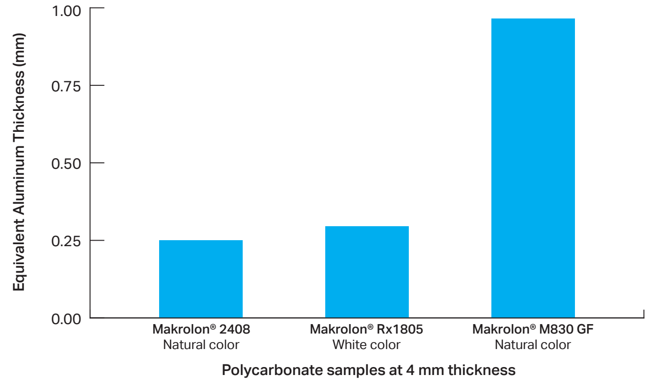

Figure 4. Equivalent aluminum thicknesses derived from X-ray visibility of various polycarbonate samples (4.0mm thickness) measured.

Figure 2a also shows some materials were examined at multiple thicknesses, and the Equivalent Aluminum Thickness showed a linear response to thickness of the plastic parts. Similarly, the Equivalent Aluminum Thickness was also found to respond linearly to the concentration of glass fibers in the samples.

The image that simulates the polycarbonate samples within a simulated chest X-ray, Figure 2b, shows that although plastic parts can be discerned from a simulated chest background (slight shadow) the different samples cannot be easily distinguished. Moreover, digital analysis of various image areas showed the signal-to-noise was too low to draw correlations to either the formulation or the part thickness.

Summary

The discussed data shows that existing Makrolon® polycarbonate materials span the range of just visible to distinctly visible on X-rays. We can show that there are several ways to increase the radiopacity of Makrolon® polycarbonate materials. Wall thickness has a significant impact on the radiopacity also. A readily available medical grade product like Makrolon® M430 GF polycarbonate containing 30% glass fiber with a certain color formulation is five times as radiopaque as clear Makrolon® polycarbonate materials, and one third as radiopaque as aluminum. The different radiopacities available in commercially available medical grade Makrolon® polycarbonate materials give medical device engineers considerable flexibility to achieve their product design goals. As a polycarbonate market leader with more than 50 years' experience in healthcare, Covestro is committed to the future success of our customers through our market leading products and on-going support. Connect with a Covestro expert today.

References

1. W. Huda, R.B. Abrahams, *Am. J. Roentgen.* **204** (2015) W126-W131.

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