Review *The Radiographer* 2007: 54 (1) 3–5

Myth busting – in the world of x-rays

Lino Piotto, Roger Gent, Giovanni Bibbo

Department of Medical Imaging
Women's and Children's Hospital
72 King William Road, North Adelaide, South Australia 5006, Australia
Correspondence: ltpiotto@adam.com.au

Abstract Have you seen the television show 'MythBusters'? It was decided to carry out a radiographic version of 'MythBusters'. The study involved the investigation of the urban myth about a female radiographer who accidentally x-rayed her hand, only to discover that her diamond engagement ring was a fake. To prove or disprove the legend, a number of natural diamonds and cubic zirconia crystals were radiographed. Sure enough, there was a definite and consistent difference between the resultant images. The study confirmed part of the myth that radiography can differentiate between a diamond and a cubic zirconia fake diamond.

Keywords: cubic zirconia, diamond

Introduction

It is sometimes difficult to separate truth from urban legend, but when it comes to radiography, x-rays do not lie, although they do need to be interpreted properly. In this myth-buster study we investigated the radiographic urban legend that x-rays can tell whether a diamond is real or fake. The study explores what is real and what is fiction. Will the first myth be busted, plausible or confirmed? These are the questions the authors endeavoured to answer, so read on and follow the study on the path of solving the mystery of the urban legend to see if all that sparkle are the 'real thing'.

The urban myth

A popular radiographic urban legend originated many years ago, involving a recently engaged female radiographer working in an x-ray department of a public hospital. As the story goes, she accidentally left her hand in the primary beam whilst immobilising an uncooperative patient. On the resultant radiograph, some of her fingers were seen, including her left ring finger on which her brand new 'diamond' engagement ring was placed. Tears flowed when a colleague who saw the film pointed out that the stone could not be a diamond because of its radiographic density. By all accounts, there is no indication in the story as to what subsequently transpired. Was the fiancé a cheapskate or was the ring bought from a crooked jeweller?

Historical aspect

Radiography, inadvertent or not, of jewellery is nothing new. In December 1895 Wilhelm Conrad Röntgen produced the first Röntgen photograph of his wife's hand.[1] On her hand was a radio-opaque ring, seen in Figure 1.[2] On 23rd January 1896 during Röntgen's initial lecture before the Wurzburg Physical Medical Society, he performed the first public x-ray photograph on his colleague Albert von Kölliker.[3] Apart from the bones of his hand, von Kölliker's ring as seen in Figure 2[2] can also be seen in the radiograph.

In June 1896, Edward Trevert published one of the first books on radiology.[4] In his book *Something about x-rays for everybody,* there is a picture which is possibly the first published radiograph of a diamond ring.

For most part of the early 20th century it was common to leave jewellery and clothing on whilst having an x-ray.

In 1912, von Laue[5] was the first to suggest the use of a crystal to act as a grating for the diffraction of x-rays, showing that if a beam of x-rays passed through a crystal, diffraction would take place and a pattern would be formed on a photographic plate placed at a right angle to the direction of the x-rays.[5] The pattern would mark out the symmetrical arrangements of the atoms in the crystal. The primary method is still used today for identifying and analysing crystalline materials. The diffraction pattern is compared with a database of mineral diffraction patterns and the crystal is identified. This technique can also be used to identify different gemstones.

Nearly all diamonds fluoresce with blue light[6] when exposed to x-rays and this property is used extensively in mining to separate the fluorescing diamonds from the non-fluorescing rocks.

The best and most commonly used imitation of diamond so far is zirconia crystal because of its low cost, durability, and close visual likeness to the real thing.[7]

Method

The study involved taking some certified natural diamond rings and radiograping them on a detailed rare earth film screen combination cassette. The exposure factors used were 40 kV and 1.8 mAs at 110cm FFD. Next, radiographs of several cubic zirconia 'genuine' crystals were obtained using the same exposure factors as those used for the diamonds.

Results

The resultant radiographs of two diamonds are shown in Figures 3 and 4, while those of the cubic zirconia crystals are shown in Figures 5 and 6. The diamonds consistently appeared more radiolucent than the cubic zirconia crystals.

These radiographs demonstrate that radiography can easily

Figure 1 Röntgen's first radiograph showing his wife's hand and the ring on her finger.

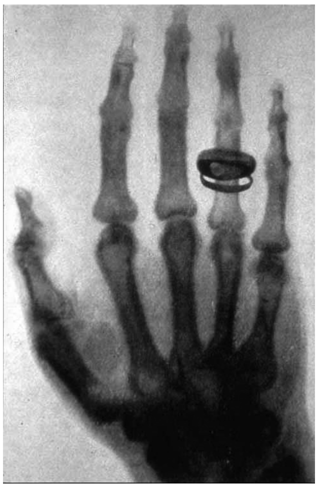

Figure 2 First public radiograph showing von Kölliker's ring.

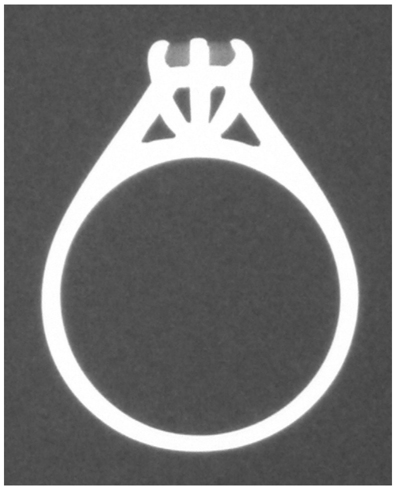

Figure 3 Radiograph of a diamond.

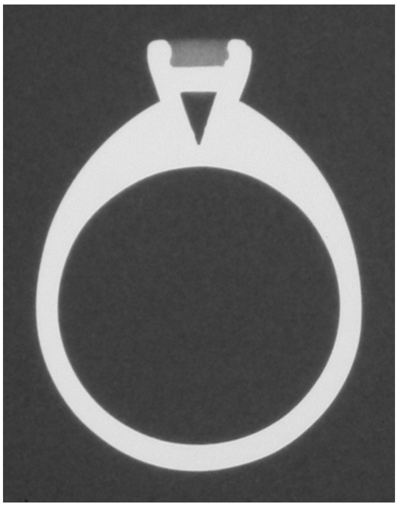

Figure 4 Radiograph of a diamond.

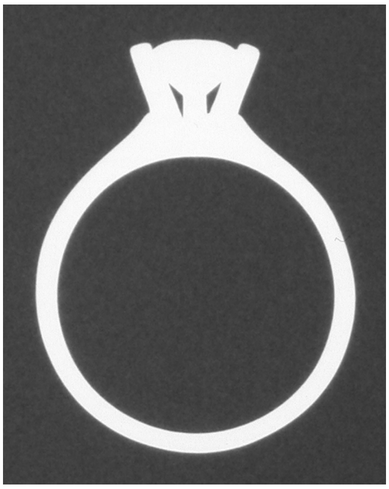

Figure 5 Radiograph of cubic zirconia crystal.

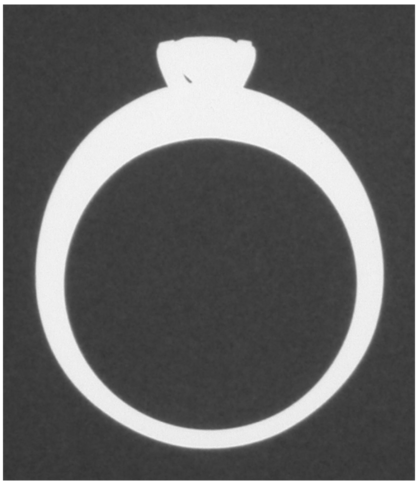

Figure 6 Radiograph of cubic zirconia crystal.

discriminate between a natural diamond and its most common imitation, a cubic zirconia crystal.

Discussion

Why can radiography discriminate between a natural diamond and a cubic zirconia? Consistently, a diamond appears on radiographs to be more radiolucent than a cubic zirconia. To explain the difference between these two stones, it is necessary first to recall the factors that influence the attenuation of x-ray photons in a medium. The attenuation of x-ray photons depends upon the physical nature of the attenuating medium, particularly its atomic number, its thickness, and the wavelengths of the incident x-ray radiation.[8] An x-ray beam produced in a diagnostic x-ray tube is polychromatic, that is it is of different energies and, therefore, wavelengths.[8]

Diamonds appear radiolucent because they are usually small and are composed of carbon. Carbon has a low atomic number of 6 and attenuates x-rays to a much lesser degree than high atomic number elements such as lead which has an atomic number of 82. More specifically, if for simplicity we assume that the x-ray beam is monochromatic with an energy level of 40 keV, then the linear attenuation coefficient of carbon[9] at 40 keV is 0.078 cm^{-1}. Zirconium has an atomic number of 40 and, therefore, a higher linear attenuation coefficient than carbon. Its linear attenuation coefficient is 3.78 cm^{-1} at a monochromatic x-ray beam of 40 keV. When the linear attenuation coefficients are compared, it can be seen that zirconium attenuates the x-ray beam by a factor of approximately 40 times that of carbon.

The argument is complicated slightly by the fact that cubic zirconia is zirconium oxide (ZrO_2), a mineral that is extremely rare in nature but is widely synthesised in laboratories. The natural zirconium oxide mineral was discovered[7] in 1892 but because of its extreme rarity in nature, it was not commonly used in jewellery. In the 1930s, artificial zirconia crystals were produced, but they were small in size. It was not until the early 1970s that a technique for the mass production of large crystals was developed.[7] By 1980, the annual global production[7] of zirconia crystals reached 50 million carats which is 10,000 kg as 1 carat = 0.2 gram.[10] The term carat here represents a measure of weight and should not be confused with the measure of purity[11] as used in gold and platinum alloys.

The artificial zirconia crystal contains a certain percentage, typically10 per cent to 15 per cent, of a metal oxide stabiliser.[7] The stabiliser is required for cubic crystal formation and although different manufacturers use varying amounts and different types of stabilisers, a common one is yttrium oxide. Yttrium has an atomic number of 39 and a total linear attenuation[9] coefficient of 2.37cm^{-1} at a monochromatic x-ray energy level of 40 keV. If 10 per cent of the yttrium is added to zirconium, then a cubic zirconia crystal will have a linear attenuation coefficient of 3.64 cm^{-1} at a monochromatic energy of 40 keV. If cubic zirconia crystal is compared with the natural diamond, it can be seen that the imitation diamond will attenuate the x-ray beam by a factor of approximately 35 times more than a diamond of the same size. This is why there is such a difference in the resultant radiographic appearance.

For simplicity, the calculations in this study did not take into account the x-ray attenuation effect of the oxide component in the zirconia crystals because of the low atomic number of oxygen, which has an atomic number of 8, compared to those of zirconium and yttrium.

Conclusion

From the evidence presented in the study, the authors conclude that this myth is definitely confirmed.

The reader may question if this is of any relevance. Well, the internet has changed the way in which many people shop. Recently in the media there have been several reports of persons purchasing 'diamonds' online only to find that, when they are evaluated by a jeweller, they are fake. So the question arises: Do YOU have a fake engagement ring?

Acknowledgment

The authors would like to express their sincere thanks to Vince Meccariello, a trusted and experienced manufacturer jeweller at Oro Duemila, Adelaide, for lending samples for this study.

References

1 Eisenberg RL. Radiology an illustrated history. St. Louis: Mosby – Year Book; 1992. pp 22–24.

2 Dibner B. The new rays of Professor Röntgen, Norwalk Connecticut: Burndy Library Inc.; 1963.

3 Eisenberg RL. Radiology an illustrated history. St. Louis: Mosby – Year Book; 1992. pp 30–31.

4 Trevert E. Something about x-rays for everybody. Lynn, Mass: Bubier; 1896.

5 Hellemans A, Bunch B. The timetables of science. New York: Simon and Schuster; 1988. pp 421.

6 Diamond simulants. http://geogem.com/diamondsimulants.html, GeomGem International Jewellers, accessed 10/4/2006.

7 Zirconia. http://www.emporia.edu/earthsci/, Emporia State University, accessed 16/8/2006.

8 Chistensen EE, Curry TS, Dowdey JE. An Introduction to the physics of diagnostic radiology. 2nd Ed.. Philadelphia, USA: Lea and Febiger; 1978.

9 Stotm E, Israel HI. Photon Cross Sections from 0.001 to 1001 MeV for elements 1 through 100. University of California, Los Alamos, New Mexico, USA. Distributed by National Technical Information Service U. S. Department of Commerce; 1967.

10 Carat. http://en.wikipedia.org/wiki/Carat, Wikipedia, accessed 16/8/2006.

11 Carat (purity). http://en.wikipedia.org/wiki/Carat_(purity), Wikipedia, accessed 16/8/2006.