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X-ray radiation shielding and microscopic studies of flexible and moldable bandage by *in situ* synthesized cerium oxide nanoparticles/MWCNTS nanocomposite for healthcare applications†

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This research reports a robust method for developing advanced flexible and moldable X-ray shielding bandages by harnessing an *in situ* synthesized polygonal cerium oxide nanoparticles/MWCNTs nanocomposite. The developed advanced hybrid nanocomposite was thoroughly blended with silicone rubber, namely polydimethylsiloxane (PDMS) to form an advanced hybrid gel which was then coated on a conventional cotton bandage to develop an advanced flexible, moldable X-ray shielding bandage. The combined effects were analyzed to determine their unique X-ray reduction properties and were very effective. The linear attenuation value of the developed bandage (untreated cotton bandage coated with CeO_2/MWCNT/PDMS), varied from 1.274 m^{-1} to 0.549 m^{-1} and the mass attenuation values from 0.823 $m^2\ kg^{-1}$ to 0.354 $m^2\ kg^{-1}$ for kVp 40 to 100 respectively. The improved features of high density and efficiency of protection are because of the binary protective effect of CeO_2 nanoparticles and MWCNT. The morphological features of the developed material were characterized using various techniques such as TEM, SEM, XRD, and EDXA. The developed bandage is an entirely lead-free product, thin and light, has high shielding performance, flexibility, durability, good mechanical strength, doesn't crack easily (no crack), and can be washed in water. It may therefore be useful in various fields, including diagnostic radiology, cardiology, urology, and neurology treatments, attenuating emergency radiation leakages in CT scanner rooms or *via* medical equipment, and safeguarding complex shielding machinery in public areas.

1 Introduction

When X-rays pass through the sample material, they are reflected, scattered, and transmitted. Such materials have unique importance in medical fields, especially diagnostic and therapeutic medicine.[1] These diagnostic applications include CT scan imaging, diagnostic radiology, fluoroscopy, microscopy, *etc.* However, owing to their ionizing properties and incorrect application, these X-rays may have seriously deleterious consequences on the end-users.[1] They can even induce tumor growing cells, alter DNA, and thus have severe gene mutation effects.[1] One can minimize these adverse radiation effects by using an appropriate radiation shielding material to attenuate the X-ray radiation energy during their use.

Although non-flexible radiation shielding materials such as tiles, paver blocks, concrete blocks, sheets, and so on are widely accessible, flexible shielding materials such as bandages, scarves, and aprons are few. The non-flexible radiation shielding materials have disadvantages as they are not flexible due to their rigidness and thus have minimal usage. The flexible and mouldable radiation shielding materials are convenient to prepare and handle, therefore play a significant role as effective radiation shielding materials in various sectors like X-rays, CT scanner rooms, defense, electrical and electronic equipment, nuclear research, aerospace, astronomy, industries, hospitals, chemical industries, electricity power plants, *etc.* Further, conventionally, the lead (Pb) based radiation shielding aprons have been utilized as protection equipment by patients, doctors, and operators. The conventional X-ray shielding aprons are

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