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Application Note:

Scintillator Selection

Table of Contents

Introduction

Scintillators are a key component for X-Ray Imaging. X-Scan Imaging selects scintillators to optimize for the best resolution, sensitivity, and speed for specific applications.

Scintillators are materials that can convert X-ray or gamma ray photons into visible-light photons. The technique of coupling scintillators with photodiodes can be called “scintillation”. Below the scintillator is a CMOS or CCD sensor that is capturing the converted visible photons to create the images output from detectors. In some cases, the scintillator material is thin and sensitive enough to provide high resolution images. As the thickness of the scintillator increases, effects of light scattering and cross talk are factors that can impact the final resolution of a detector.

Some Characteristics of scintillators.
- Light yield/output: Number of emitted photons per absorbed energy.
- Decay time (s): Time required for scintillation emission to decrease to e-1 of its maximum.
- Afterglow: Residual light output occurring after the primary decay time of the

main luminescent centers.
- Stopping power: Attenuation coefficient of the absorbed radiation, for a given thickness of a material.

Based on the characteristics of the scintillators above, the ideal scintillators should have high light output, short decay time, minimal afterglow and high stopping power. However, no such perfect scintillator exists. Therefore, we strive to find the ideal scintillator after considering tradeoffs of these combined characteristics for each energy level the users are interested in.

X-Scan Imaging utilizes a wide range of scintillator selections based on user's application needs. Powder formed gadolinium oxysulfide (GOS: Tb) is usually paired with low energy detectors operating 25-130kV. Thallium doped cesium iodide (CsI:Tl) is commonly used where thicker scintillator with high light output is needed. Cadmium tungstate ($CdWO_4$, CWO) crystal has high effective Z number, high density, higher light output, and very low afterglow. Therefore, CWO is often used in high energy x-ray CT applications.

Available Scintillators

Type	Code	Thickness
GOS	**G1**	GOS:Tb, 145mg/cm^2, DRZ-HI
	G6	GOS:Tb, 68mg/cm^2, DRZ-STD
	G7	GOS:Tb, 100mg/cm^2, DRZ-PLUS
	G5	GOS:Tb, 200mg/cm^2, PI-200
	GS60	60mg/cm^2
CsI	**C0400**	CsI:Tl, 400µm
	C0600	CsI:Tl, 600µm
	C3	CsI:Tl, 3mm thickness
	C4	CsI:Tl, 4mm thickness
$CdWO_4$	**W3500**	CWO, 3.5mm thickness
	W5	CWO, 5mm thickness
	W10	CWO, 10mm thickness
	W15	CWO, 15mm thickness
	W20	CWO, 20mm thickness

Table 1. Available scintillators provided at X-Scan Imaging and their thicknesses

Basic Guide for Scintillator Selection

The rule of thumb for choosing a proper scintillator specific to an application is thicker scintillators yield more light output, while thinner scintillators have better MTF performance. Other scintillator material characteristics that need to be taken into considerations are physical structure and decay time. GOS has powder like structure, it could be coupled with sensors of any pixel size. CsI has needle or crystal-like structure that sometimes can only be coupled with sensors of the same or similar pixel sizes. CdWO4(CWO) has a crystal-like structure that is specific to just one pixel size. Decay time of a scintillator determines how fast the imaging process can go without compromising image quality.

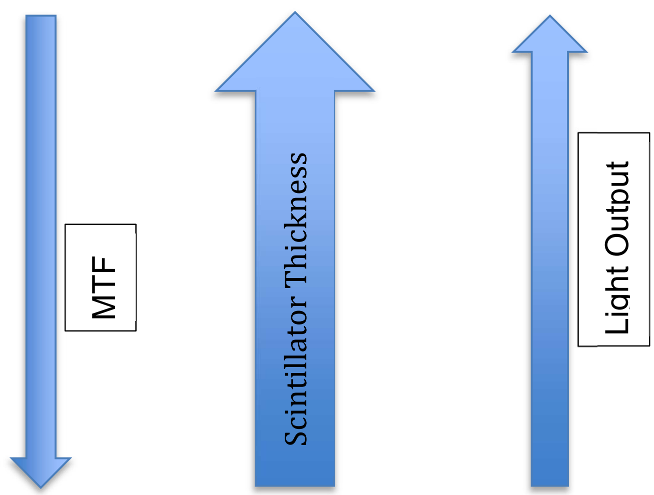

Figure 1. Relationship between scintillator thickness, light output and MTF. The arrow indicates increase in value.

The sensor's light output and MTF performance are points of trade off depending on the scintillator thickness that's coupled with the sensor. Usually, GOS scintillators thicknesses are under 1mm. CsI scintillator can have thickness ranging from under 1mm to 10mm. Therefore, CsI is used for applications where relatively higher KeV and higher light output are needed. CWO has even better light output comparing to CsI at the same thickness, additionally, CWO has more thickness options depending on the x-ray energy level.

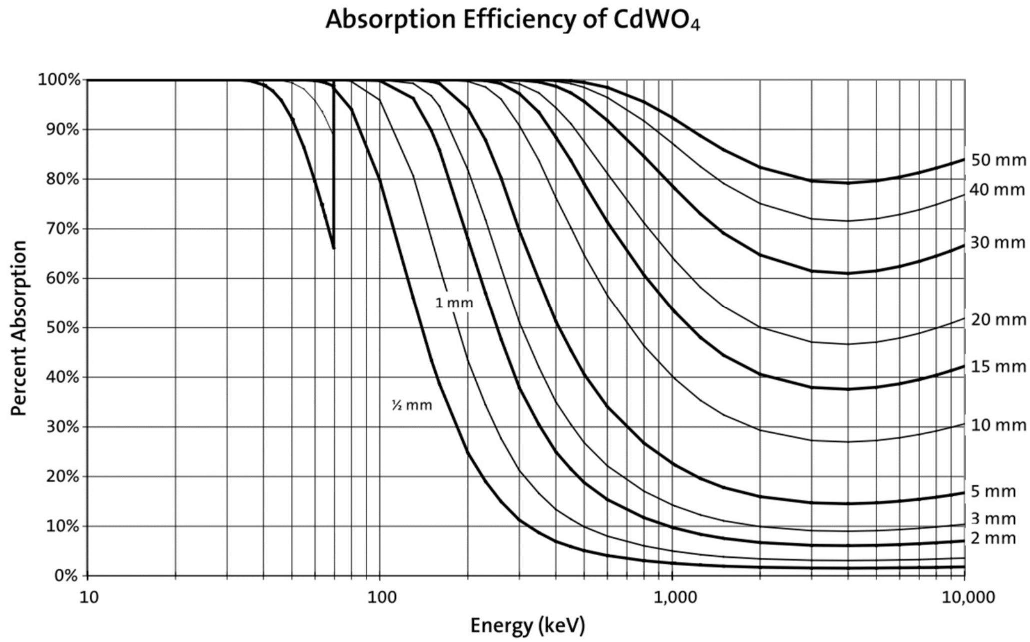

Figure 3. CWO absorption efficiency graph with thicknesses on the right y-asix

Figure 3 shows that in the MeV and above region of the energy spectrum, CWO has better absorption efficiency when the thickness increases. As a result, we always suggest customers to use CWO with our sensors for MeV applications. One might also conclude from figure 3 that under 2mm thick CWO seem to have great absorption efficiency for x-ray energy of 100-200KeV. Why don't we use CWO for those lower KeV applications? CWO is much more expensive than GOS, also thinner scintillator like GOS yields better MTF performance.

Scintillator	Cost	X-ray Energy	Decay Time	Light Output
GOS	Low	Lower KeV	Long	Low
CsI	Medium	Medium-High KeV	Short	Medium
CWO	High	High KeV, MeV	Medium	High

Table 2. Key characteristics of 3 types scintillator in general conditions compared with the same sensor

Summary

Ultimately it is the application that defines if the scintillator selection and detector configuration are meeting the requirements for resolution, sensitivity, and speed. Usually, we can follow the rule of thumb to choose the appropriate scintillators for the best performance. There are cases of exceptions besides the rule of thumb, for example, a GOS of a particular doping material is preferred than CsI for high speed applications. Customers are encouraged to contact X-Scan Imaging's engineering team should these special cases arise.