

7 Common Problems with X-ray CT & How to Avoid Them



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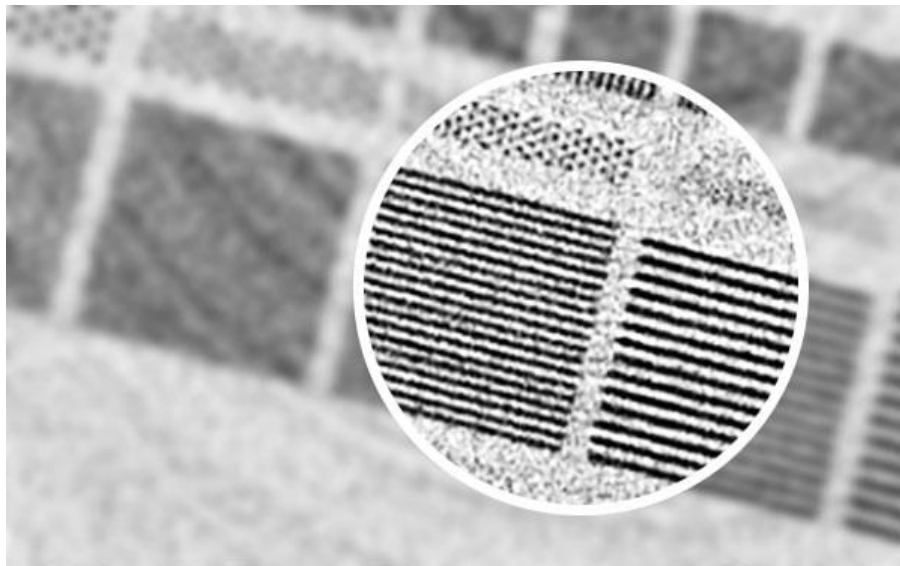
Although I love X-ray CT ([computed tomography](#)) and want everyone to use it, it is not for everyone. Depending on your research needs, it might not be the right tool. There are pros and cons of X-ray CT. Its ability to obtain cross-sectional images of an object non-destructively and minimum sample preparation are some of the pros. The cons include measurement and analysis time, large file size, limited resolution, etc.

One of the most common concerns I see our customers having when purchasing a micro-CT scanner for the first time is that they are not sure if it is the right tool to invest in or if it is going to do the job. One of the most common consultation requests we receive is, "I just started using CT but not getting the results I hoped for. What should I do?" The last thing you want is to spend a lot of money on a brand-new instrument and realize it is not going to do the job or solve the problem as

you hoped. So, in this article, I am going to review seven common problems people experience with X-ray CT and discuss how you can avoid them.

1. Resolution is too low
2. Can't scan the whole sample
3. CT image is all too dark or too bright
4. There is no density contrast
5. Scans take too long
6. Files are too big
7. Analysis is too involved

1. Resolution is too low



The resolution of standard laboratory-based micro-CT and nano-CT systems is from submicron to submillimeter. If the resolution you need is under 500 nm, you might need a [specialized ultra-high resolution CT scanner or go to a synchrotron beamline](#). You also might want to consider switching to optical microscopy that can achieve about 200 nm resolution. If you need even higher resolution, scanning electron microscopy (SEM) or transmission electron microscopy (TEM) would be a better choice than X-ray CT. Optical and electron microscopy is in general used for 2D imaging. [FIB-SEM \(dual focused ion beam-scanning electron microscopy\)](#) can provide the third depth dimension with typically a few hundred slices in the depth direction.

If the resolution you need is greater than 500 nm but you are not seeing what you want to see, check the specification of your CT scanner. If the CT scanner is capable of achieving that resolution, there is a very good chance you can get it by adjusting measurement conditions.

Read: [How to improve the resolution of X-ray CT images](#)

2. Can't scan the whole sample



There are three possible reasons why you can't scan the whole sample.

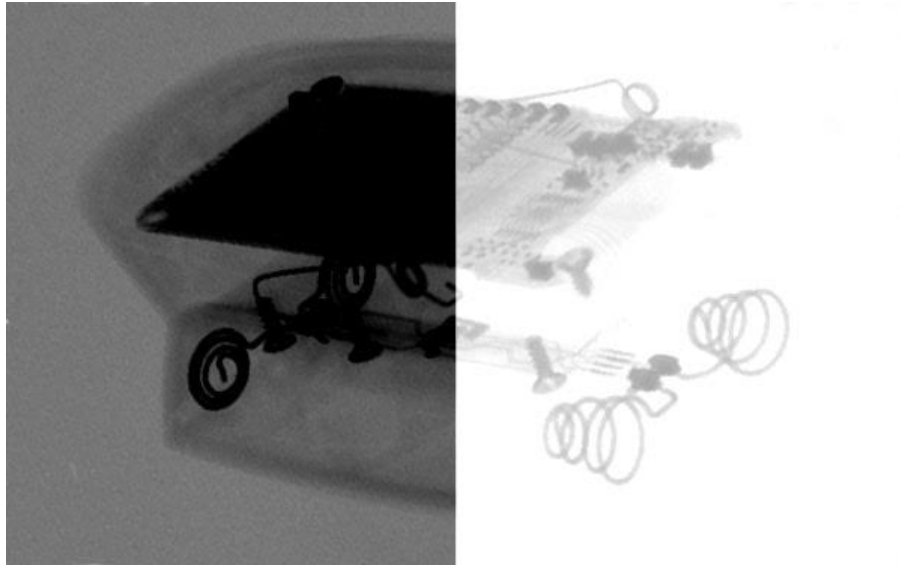
1. The sample doesn't fit into the CT scanner.
2. The sample is larger than the largest [FOV](#) (field of view) available.
3. The sample is too X-ray absorbing (dense).

If your sample doesn't fit into the CT scanner, unfortunately, there is not much you can do. You probably need a bigger CT scanner or reduce the sample size.

If the sample fits into the CT scanner but not into the FOV, there are a few things we can consider. Is it really necessary to scan the entire sample? Can you scan just the area of interest and use an FOV smaller than the sample? If you do need to make the whole sample fit in the FOV, the next thing to check is if you are using the largest FOV setting available on your CT scanner. Some scanners have stitching, helical, or offset scan modes that can make the FOV larger than what the detector can cover in a standard scan.

If the sample is too X-ray absorbing either because of its size or density, you need to increase the X-ray energy. You can do this by increasing the X-ray voltage and using heavier and thicker filters. If the highest voltage setting still is not enough, you might need to consider reducing the sample size or using a CT scanner with a higher-energy X-ray source.

3. CT image is all too dark or too bright



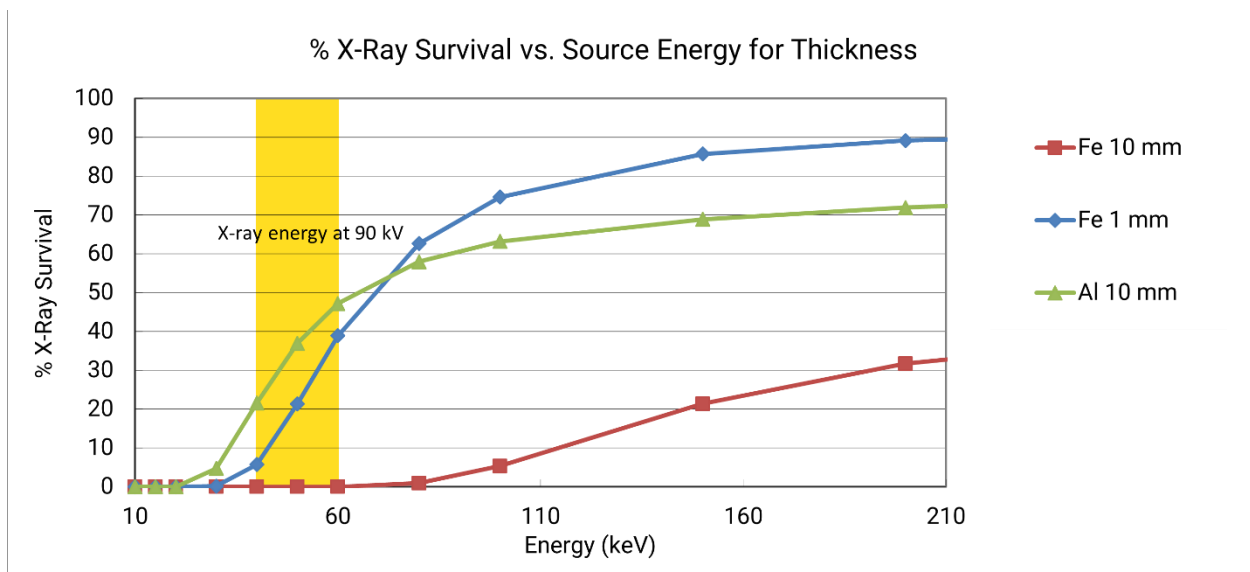
X-ray CT is an [absorption contrast imaging](#) technique. Therefore, we need to see the variation in X-ray intensity coming through the sample to construct its 3D image. The principle of X-ray absorption is as follows: The denser and the thicker the sample is, the more X-rays are absorbed. The lower the X-ray energy is, the more X-rays are absorbed. The absorption rate depends on the elemental composition, but that dependency is negligible. You can use the mass density as the guide to assess the absorption rate of your sample.

If the sample is too heavily absorbing for the X-ray energy used to scan it, the projection images will be all dark, and the CT image will be bright with little-to-no contrast. It often shows [beam hardening artifacts](#). If the sample is too lightly absorbing for the X-ray energy used to scan it, the projection images will be all bright, and the CT image will be dark with little-to-no contrast. Therefore, this problem is caused by a mismatch of the sample absorption rate and the X-ray energy.

With most X-ray sources using a tungsten anode, you can adjust the X-ray energy by changing the applied voltage. For example, if you apply 90 kV to the X-ray source, there will be some 90 keV photons, but not many. The X-ray energy is spread over a wide range, with the peak energy about 40-

60 keV, depending on the filter. Thicker and more heavily absorbing filters shift the peak energy toward the higher side.

Because the X-ray CT absorption rate depends on the X-ray energy, sample density, and sample size, things can go wrong if the X-ray energy is too low or too high for the sample. Let's say that you use low-energy X-rays to image a large or high-density sample; for example, X-rays excited at 90 kV to scan a 10 mm thick stainless steel part. In this case, all X-rays are absorbed by the sample and nothing comes out the other side, as you can see in the graph below. To have more X-rays go through the sample and get good contrast, you need to increase the X-ray energy or reduce the sample size.

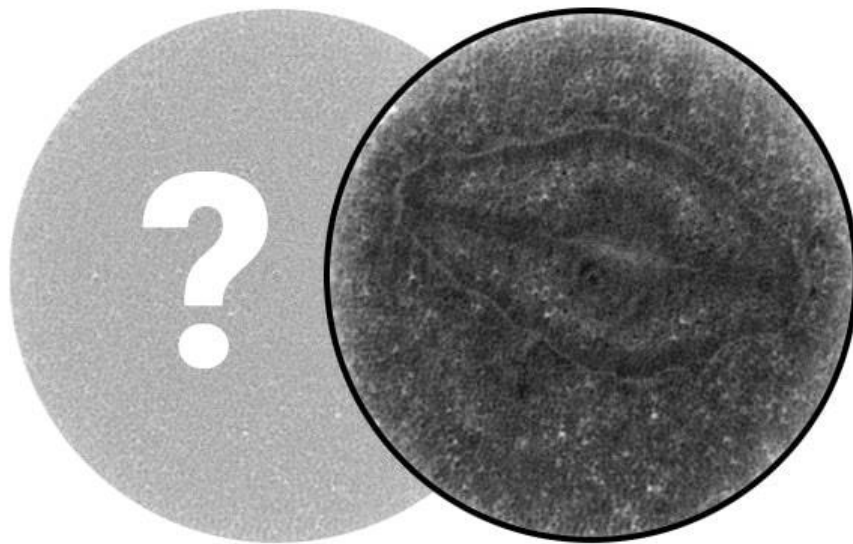


(Calculated using [MuCalc](#))

Now let's think about an opposite case. You use high-energy X-rays to image a small or low-density sample; for example, X-rays excited at 90 kV to scan a sesame seed. In this case, not many X-rays are absorbed by the sample, and you see a bright white image with no contrast on the detector. To get good contrast, you need to lower the X-ray energy.

There is one thing to note when lowering the applied voltage to scan low-density samples. Lowering the voltage reduces the X-ray intensity, but you can go only so low. To scan small and low-density samples such as organic materials, you need bright and low-energy X-rays. Using an X-ray source with transition metals that emit bright yet low-energy characteristic radiation can help improve the contrast. Chromium, copper, and molybdenum are typical anode materials that emit 5.4, 8, and 17 keV characteristic radiations, respectively.

4. There is no density contrast



If there is no density contrast, there is no X-ray absorption contrast, which means you can't get any meaningful CT images. If the density is low and there is a small density contrast, you can try using low-energy X-rays, [phase retrieval reconstruction](#), or [phase contrast imaging](#). If there is not enough density contrast, you can also try "staining" the sample. Organic samples are often stained with an X-ray absorbing agent.

Read: [How to improve X-ray contrast for organic samples](#)

5. Scans take too long



Scan time is one common drawback of micro-CT, especially when relatively high-resolution is required. There are a couple of things we can do to speed up CT measurements, but let's do a reality check first.

A CT scan using a laboratory-based instrument takes anywhere from a few seconds to tens of hours. The reconstruction calculation takes about ten seconds to half an hour or so, depending on the reconstruction algorithm and software you use. If your desired speed is within the range of 30 seconds to hours, you might be able to get what you want by adjusting the scan conditions. The scan time is in a trade-off relationship with the resolution and SNR (signal-to-noise ratio). These factors need to be balanced.

Read: [How to Improve the Signal-to-noise Ratio of X-ray CT Images](#)

If you need to scan hundreds of samples a day at a few seconds per scan for process control, for example, X-ray CT might not be the best choice. Consider switching to 2D radiography. Radiography requires only one projection measurement, whereas CT requires hundreds to thousands. So the measurement is a lot faster with radiography, and it is often used for process control and product inspection.

6. Files are too big



A CT scan file can be anywhere from a few hundred MB to tens of GB. Large files can be a problem for two reasons:

1. The analysis takes too long
2. The storage space runs out too fast

The first one is tough, and we might just need to wait for computers to become faster. But for now, you can consider reducing the file size by cropping down the image to the important or representative area or down-sampling it. Or, you can get a faster computer. When investing in a faster computer, make sure to consult with the manufacturer of the analysis software. Different analysis software use RAM, GPU, and CPU differently. Adding RAM and GPU when the bottleneck calculation runs on the CPU doesn't help. Alternatively, you can use cloud computing. Companies like [Object Research Systems](#) and [digiM](#) Solution offer cloud computing functions for CT image analysis.

The second one, the storage space, is another common problem. If you run a few 20 GB scans Monday through Friday, you fill up a 10 TB disk within a year. There are three levels of a solution to this problem.

The first one is relatively easy. Buy a bunch of terabytes external drives and use them to move the data from the internal storage drive. [The annualized failure rate of those external USB drives is about 1%, and their lifetime is about 4 – 6 years.](#) I don't consider this a safe backup media for my scientific research. So, always make two copies.

The second level solution is to use NAS (network-attached storage). A NAS device is a data storage device that can be accessed through a network. The maximum storage size of a NAS device can be up to 108 or 200 TB. The same rule applies here, and you should set up all the drives to RAID1 just in case they fail.

The third level solution is to use a cloud storage service. Most commonly used services, such as Google Drive, are designed for general documents, and the available storage space is relatively limited. I would recommend a service specializing in X-ray CT or microscopy image storage. It is easier to browse the data if you can see the thumbnail of the CT cross-section, scan conditions, etc., in the data management interface. With a specialized data management system, you can also tag images with users and instruments and link the derived analysis results and reports to the original data.

Read: [How should I manage X-ray tomography data? – The danger of relying on hard drives and how to avoid costly problems](#)

7. Analysis is too involved



Everybody gets excited when they get the first X-ray CT image. It's pretty, cool, and interesting. Then before long, it dawns on you that you are not quite sure how to quantify what you are seeing and call it scientific research. X-ray CT image processing and quantitative analysis can get pretty involved, but chances are it is nothing you can't handle with the right software tool and proper training.

What you don't want to do is to purchase a CT scanner and realize that the analysis is more than what you would like to take on. I recommend you get a demonstration of the analysis process as well as data collection from the CT manufacturer before making purchasing decisions. You can also get a free trial version of analysis software to give it a test drive.

Read: [How to Get Started with X-ray CT Image Analysis in 3 Steps](#)

But what if you need to do just one very specific but complicated analysis over and over on the same type of samples? It might not make sense for you to invest a lot of time in mastering the analysis software that can also do fifty other things. Also, you might want to automate the analysis process. Most analysis software manufacturers such as [Object Research Systems](#), [Volume Graphics](#), [digiM Solution](#), and [Thermo Fischer Scientific](#) offer a service designing custom analysis macros (automated routines) on a pay-per-project bases. In this case, you purchase their software license and they will provide a customized macro that does the specific analysis you need with minimum operator interactions.

Takeaways

As much as I want more people to see the potential of X-ray CT and introduce this technology to their research, I don't want you to make the wrong decision and regret it later. I hope this article will help you avoid these common problems. Our team of application scientists can help you if you have any questions or need help deciding if CT is the right solution for you. Talk to one of our CT experts by clicking the "Talk to an expert" button at the right top of the page or contact us imaging@rigaku.com.



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Director of X-ray Imaging at Rigaku Americas Corporation. Aya holds a MA in physics from Tokyo University of Science and has been with Rigaku for 22 years. She started in the X-ray Diffraction Application Lab and transitioned to X-ray Imaging in 2017. Her goal: Help non-expert X-ray users achieve expert results with less time and effort. She has worked on many projects designing automated and user-friendly X-ray instruments and analysis software. She is very passionate about helping people learn more about X-rays and working with X-ray users to solve their specific problems.