Beryllium Science & Technology Association

# Beryllium – An Essential Element in Medical Equipment

Beryllium and beryllium-containing materials are essential to some of the most advanced lifesaving and life-enhancing technologies throughout the medical field. Beryllium metal is uniquely transparent to x-rays, which makes it indispensable for use in modern x-ray and other high resolution imaging and analysis tools. Beryllium metal's combined properties exceed that of any other material by providing superior imaging at the lowest x-ray dose, while its high heat-dissipation characteristics reduce overall power consumption. Scientific studies and expert assessments clearly support the need for the continued use of beryllium metal in x-ray equipment and developing superior disease detection and treatment technologies.

## 1. Physical Properties:

From a physical property standpoint, no other material compares to the properties of beryllium especially with regard to transmissivity and thermal conductivity, which are two very important design considerations for x-ray equipment.

Comparison of the transmissivity of beryllium against several other materials at the same thickness over the range of 20keV – 25keV:

Beryllium has 97.24% - 97.54% transmissivity
Aluminum has 51% - 70% transmissivity
Titanium has 0.5% - 5.7% transmissivity
Tungsten negligible

Comparison of thermal conductivity (as per www.matweb.com)

Beryllium 216 W/m-K
Aluminum 210 W/m-K
Titanium 17 W/m-K
Tungsten 163 W/m-K

According to the National Science Center at the Kharkov Institute of Physics and Technology (NSC KIPT), "Authorized technology for thin beryllium foils rolling includes pre-rolling grain size refinement and subsequent multistage flatting of beryllium billets enveloped in stainless covers accompanied by intermediate vacuuming and heat treatment. This is the only foils (sic) made of beryllium of 99.95-99.999% purity available on the market. The impurity-less and vacuum tight foils provide superior x-ray transmission. This improves image definition and/or allows the use of lower intensity x-ray sources. The foils also possess excellent mechanical properties and high corrosion resistance, along with low surface roughness."[1]

[1] National Science Center Kharkov Institute of Physics and Technology, (NSC KIPT), "Thin Vacuum Tight Beryllium Foils for X-ray Windows" http://www.stcu.int/documents/reports/distribution/tpf/Industrial/INNOVATIVE/hannover%204.pdf

## 2. Mammography:

As stated in Chapter 5 - Medical Imaging Informatics Bushberg et al, *The Essential Physics of Medical Imaging, Third Edition,* Lippincott Williams & Wilkins, 2011. "The tube port and added tube filters play an important role in shaping the mammography x-ray energy spectrum. The tube port window is made of beryllium. The low atomic number (Z=4) of beryllium and the small thickness of the window (0.5 to 1 mm) allow the transmission of all but the lowest energy (less than 5 keV) bremsstrahlung x-rays. The tube port and added tube filters play an important role in shaping the mammography x-ray energy spectrum."

When x-ray tubes are energised, there are two mechanisms at work generating the x-rays: Bremsstrahlung ("Braking radiation") and Characteristic radiation. The Bremsstrahlung is a wide band spectrum, but Characteristic radiation spikes at specific energy levels and unique to whatever the target material is used in the anode.

- Mammography imaging is unique in that it is imaging soft tissue exclusively (no bones) and needs to identify very small calcifications/inclusions
- In order to image breast tissue, the radiologist needs to strike a balance between using "soft" x-rays (lower keV energy-level x-rays) and "hard" x-rays. The soft x-rays provide better image contrast and so make it easier to identify the inclusions, but because these soft x-rays don't completely penetrate the tissue, all the energy remains in the patient, which increases the effective radiation dose. Hard x-rays will penetrate and exit the tissue, which reduces the effective radiation dose, but tends to obliterate the image quality. The challenge gets compounded by the fact that there is a wide range of breast tissue density, as well as different tissue sample thicknesses

The x-ray tube components that affect the shape of the energy spectrum include the anode target material (which determines the amount of bremsstrahlung x rays and position of characteristic peaks) and the tube envelope and housing (which determines inherent and added filtration). The amount of filtration is chosen such that very low-energy photons are filtered to reduce patient dose and excessive filtration of the x-ray beam (which would result in reduced image contrast) is avoided. For a given x-ray tube design, the shape of the energy spectrum is substantially affected by the voltage waveform provided by the generator.[2] According to the report of the ACR-CDC Focus Group on mammography equipment:

<u>Recommended specifications for new mammography equipment: report of the ACR-CDC Focus Group on mammography equipment</u>

"**The x-ray source assembly used for screen-film mammography should have the following characteristics: a molybdenum x-ray tube target, a beryllium window of 1.5 mm thickness or less and a molybdenum filter …**"[3]

---

[3] Yaffe, M J; Hendrick, R E; Feig, S A; Rothenberg, L N; Och, J; Gagne, R .. Recommended specifications for new mammography equipment: report of the ACR-CDC Focus Group on mammography equipment. Follow Radiology , Volume 197 (1): 19 Radiological Society of North America, Inc. Oct 1, 1995

Beryllium Science & Technology Association

## 3. Expert Research, Development & Medical Equipment Design Assessments:

Discussions with research and development experts from the medical manufacturing industry provided the following guidance regarding the use of beryllium windows in the design of x-ray systems to save energy.

"Beryllium's combined properties of high transmissivity to x-rays and high thermal conductivity (216 W/m-K) make it ideal for use as an x-ray window for mammography and other medical imaging (such as Computed Tomography). Aluminum, titanium and tungsten are not good candidates for medical imaging since they all have poorer transmissivity, **which would require higher energy levels with reduced imaging quality and more patient radiation exposure, and poorer thermal conductivity which would require more sophisticated cooling systems.** As an example, if a window material with lower transmissivity were used, then the tube would need to generate a **higher intensity of x-rays (increase the filament amperage) to deliver an equivalent dose for imaging.** Because the "other" window material was less transmissive, it would block a larger percentage of the higher intensity beam, which would put significantly more demand on the cooling system. **The net effect would be using more energy to generate a more intense beam and using more energy to keep the system cool**. In the case of a CT tube (which is spun around the patient to capture images of "slices"), the increased mass necessitated **by a more elaborate cooling system would also require more energy**."[4]

According to medical experts from the Mayo Clinic, "Significant design changes are seen in x-ray tubes developed for mammography. In mammographic x-ray tubes, a different target material is chosen for its lower K edge. The molybdenum target commonly used in mammographic tubes produces characteristic energy peaks at approximately *17.5* and *19.5* keV, and those characteristic peaks contribute as much as 40% to the total x-ray intensity (bremsstrahlung process contributes the remainder). **Beryllium (which has a low atomic number) is used for the exit window in mammographic tubes to minimize attenuation that otherwise would occur with a glass exit window at the lower mammographic energies**."[5]

## 4. Expert Health and Environmental Assessments

In 2010, the Öko Institute e.V., the leading European research and consultancy institution which was contracted by the European Commission to review the Restriction of Hazardous Substances (RoHS) Directive determined that beryllium and beryllium oxide ceramic **did not "constitute significant health and environmental risks** when used in electrical and electronic equipment", and concluded that beryllium and beryllium oxide "are not proposed as candidate or phase out substances". Since the review, studies conducted at recycling facilities clearly demonstrate worker beryllium exposures to be nearly non-detectable and well below levels determined to be safe. (*http://beryllium.eu/health-environment-legislation/recycling/*). Additionally, REACH studies and the most recent studies by cancer epidemiologists suggest that beryllium metal is not properly classified. Efforts to seek reclassification within the EU have been initiated by the Beryllium Science & Technology Association. (Current Review of Beryllium Metal and Cancer Endpoints)

[4] Personal communications obtained by Materion Inc. from researchers and medical equipment manufacturers.
[5] Zink, F. "The AAPM/RSNA Physics Tutorial for Residents X-Ray Tubes" The Department of Diagnostic Radiology. Mayo Clinic and Mayo Foundation. 200 First St. SW, Rochester. MN 55905. From the AAPM/RSNA Physics Tutorial at the 1996 RSNA scientific assembly

**5. Summary:**

The above technical review on the use of beryllium in medical equipment is reflected in the criteria for spell out Green Public Procurement (GPP) of the European Commission[6], 2008-07-06 GPP Commission:

- Takes into consideration the net environmental balance between the environmental benefits and burdens, including health and safety aspects.
- Is based on sound data and information, representative as far as possible of the entire EU market.
- Takes into consideration the views of all interested parties involved in the consultation process.
- Is based on life cycle data and quantitative environmental impacts, where applicable in compliance with the European Reference Life Cycle Data Systems (ELCD).

Of highest environmental benefit is beryllium's positive impact on patient care and the ability to help save lives. As only one of many examples of the life saving properties of beryllium, according to publically available statistics[7], *"One-third of breast cancer deaths could be decreased if detected and treated early. In a worldwide context this means nearly 400,000 lives could be saved each year. Breast cancer is the most common cancer in women worldwide. It is also the principle cause of death from cancer among women globally. Despite the high incidence rates, in Western countries, 89% of women diagnosed with breast cancer are still alive 5 years after their diagnosis, which is due to detection and treatment."*

**If the worldwide goal is to detect cancer at its earliest most treatable stage, there is no substitute for beryllium in x-ray technologies.**

[6] Reference Procedure for the development and revision of GPP criteria - Environment - European Commission….
[7] (http://www.worldwidebreastcancer.com/learn/breast-cancer-statistics-worldwide