MATERION

TECH BRIEF

BERYLLIUM TUNING FORKS: THE SCIENCE BEHIND THE SOUND

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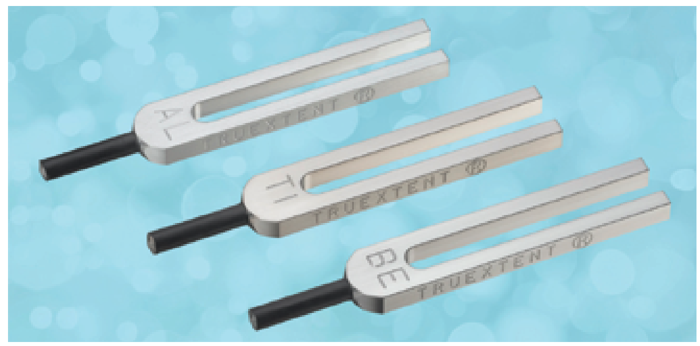
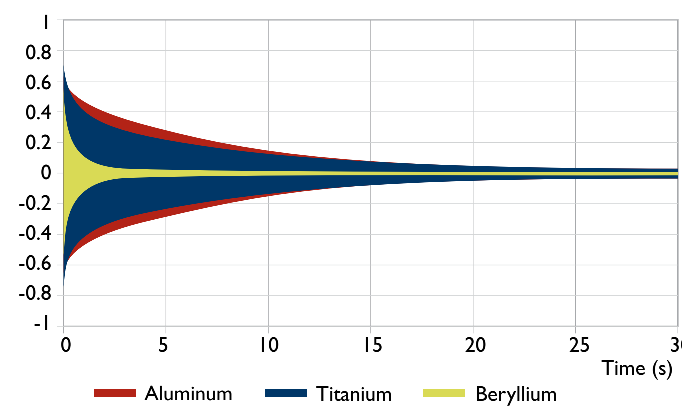
Audiophiles and engineers already know that Truextent® Genuine Beryllium gives the most natural sound quality of any speaker material. Combining extreme stiffness, low mass, and high damping makes it the best material available for high-resolution transducers.

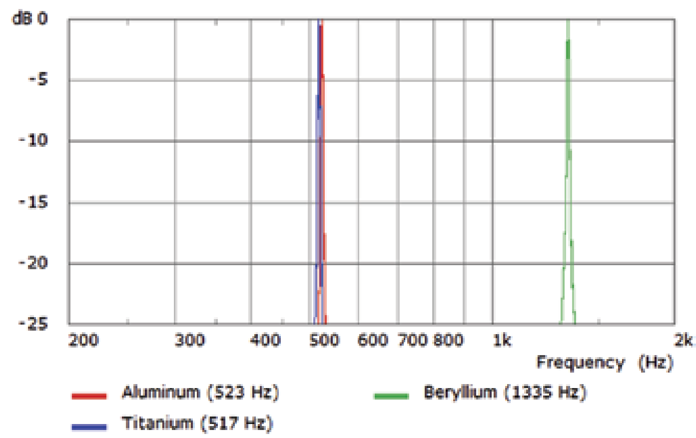
Of course, a lighter speaker diaphragm is 'easier' to move and to stop, so the same coil and magnet will react more quickly (faster transients and extended frequency response). But did you know that all materials continue to move after the coil has already stopped moving? Like a bell, this ringing is a function of the diaphragm's material properties, and can smear the timing of natural sonic details and cloud the sound we hear. When these resonances are absent or greatly attenuated, our ears can clearly hear the crispness of cymbals, the ambience of a room, or the reverb and space around vocals and instruments.

We made a few tuning forks out of different materials so you can hear the superior performance of Beryllium for yourself, even without knowing all the physics behind it. If you strike the three tuning forks of Aluminum, Titanium, and Beryllium, you will hear decaying tones like those recorded below. You will notice the different frequencies, or pitches, at which they ring and the different durations of each tone. As we will show, these differences are due to the material properties of each fork.

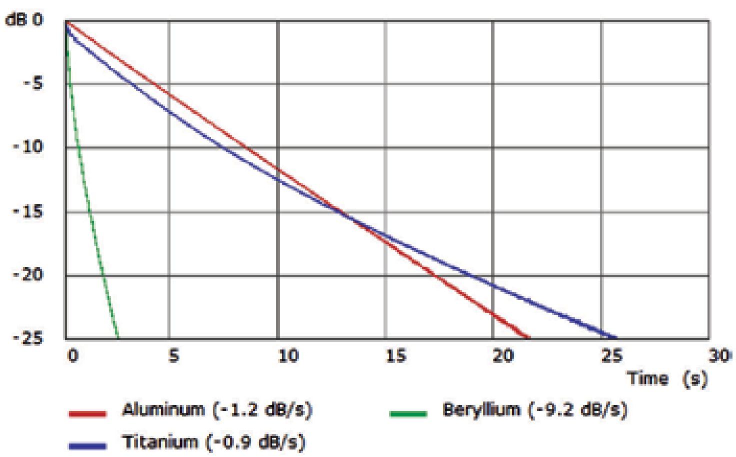
If we look at the Fourier Transform of those tones (bottom right), we see the frequencies at which each tuning fork rings. Though much lower, these frequencies are analogous to those at which a speaker diaphragm of each material will begin to resonate or break-up. Beryllium rings at a frequency about 2.5x higher than aluminum and titanium (musically, this is more than an octave higher!). By analogy, if your 1" aluminum tweeter dome resonates at 22 kHz, then you can expect a similar beryllium tweeter to ring at over 50 kHz! Truextent Genuine Beryllium allows you to take full advantage of the extended bandwidth of today's high-resolution audio.







Also, we can use an Energy-Time Curve to see the loudness of each tone over time (below). This makes an easy calculation of the decay rate (dB/s) which tells us how well-damped each material is, or how quickly it will stop ringing. Note that Beryllium stops much faster than either Aluminum or Titanium, which ring for a very long time and are still audible after even 30 seconds! If you want a good tuning fork (or dinner bell), use Titanium or Aluminum, but if you want a good speaker diaphragm, use Beryllium.



$$c = \sqrt{(E/\rho)}$$

So, why does this happen? As detailed in our white paper on beryllium compression drivers[1], the speed of sound in a solid material is a good indicator of acoustic performance, especially of resonant break-up modes due to diaphragm bending. The speed of sound likewise governs the bending frequency of a beam, or even a tuning fork (which is just two beams the same size).

Since the speed of sound (c) in a solid is equal to the square root of the stiffness or Young's Modulus (E), divided by the density (ρ), tuning forks of the exact same size, made of different materials, will let us hear the speed of sound in those materials. The table below compares these properties and the resulting speed of sound in each material. Notice that Aluminum and Titanium basically trade off weight for stiffness, so they have nearly the same speed of sound and thus ring at the same frequency above. Beryllium is both lighter and stiffer than the others, so it has a speed of sound 2.5x higher, and rings at a frequency 2.5x higher!

MATERIAL/ PROPERTY	ALUMINUM	TITANIUM	BERYLLIUM
Young's Modulus, E	71 GPa	116 GPa	310 Gpa
Density, ρ	2.7 g/cm^3	4.5 g/cm^3	1.85 g/cm^3
Speed of Sound, c	5,128 m/s	5,077 m/s	12,945 m/s
Speed relative to Aluminum	1.0	0.99	2.52

Truextent Advanced Acoustic Materials are specifically engineered to extend and improve the response of your transducer designs. Even without knowing the physics, you can easily compare material properties using our tuning fork demo. Just ping 'em, and let your ears do the math!

Lighter **+ Stiffer =** ***Faster!***

Truextent®

[1]Buck, Andrews, Simmons, and Saye, "Extended Range Beryllium Dome Diaphragm Assembly for Large Format Compression Drivers." Presented at the ALMA Europe Symposium, 9 April, 2011. Available for download at www.truextent.com

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