ADAMANTIS

Creation of a Nano Infused Zero Resonance Loudspeaker

a paper by:

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Æquo Audio

Graceful. Smart. Uncompromised.

Contents

“Discovery consists of looking at the same thing as everyone else

and thinking something different.”

― Albert Szent-Gyorgyi, Nobel Laureate

Introduction

Aequo Audio was established in 2012 by a team of music and hi-fi enthusiasts and is situated in 'Brainport' Eindhoven in the Netherlands, one of the world's leading high-tech regions. The focus of this enterprise is to design and create graceful, smart and uncompromised loudspeakers for the audiophile market. Determined to get across an enhanced 'musical message' to an audience listening in their dedicated listening room and ultimately into the living rooms of all music lovers, Aequo Audio places emphasis on in-house R&D and production facilities. Its unique 'Octagon Philosophy' represents a full-spectrum vision and design approach, for which the Octagon is incorporated into the company's logo. By this philosophy, focus and mission, Aequo Audio developed new innovative solutions that enabled the achievement of uncompromised performance in the actual and real-word experience of listeners around the globe. This success is illustrated by the many awards won in a very short period of time and the unanimous appraisal of expert reviewers of very different tastes and styles, representing some of the most respected international platforms covering high-end audio.

The products responsible for these appraisals are innovative hybrid passive/active loudspeakers that have set new standards in big sound versus compact elegance. They come equipped with unique and very audiophile analogue room size and placement adjustments. Regardless of price and actual size, these speakers have redefined *holographic* in terms of large three-dimensional 'walk-about' sound-staging. Their naturally clean, very open, and truthful gesture in musical reproduction excels both in high resolution and low-fatigue listening pleasure. The company's first loudspeaker 'Ensis', and the later launched and especially successful 'Stilla', are both highly sensitive and active-supported designs that provide for an easy drive by any amplifier, including class-A transistors and SET tube amplifiers.

Plans for a fully passive speaker have been in the making for several years, and while earlier designs/prototypes based on commonly used materials would have probably pleased many audio enthusiasts, we still felt we were falling short when it came to pushing forward by our 'graceful, smart, uncompromised' criteria. At the same time we were developing a cost-no-object loudspeaker named 'D I L U V I U M' for which very little engineering limits where set towards using the best possible materials, including novelty Nanotech-ingredients. Meanwhile, the outcome gave birth to a sister-company specialized in anti-vibrational materials: 'D I L U V I T E Nanotech Composites' Some findings proved to be of great impact on the passive loudspeaker that is the subject of this paper.

By implementing cutting-edge material science we were able to create a totally new loudspeaker that represents every aspect stated in our slogan, with much greater extent than we could hope for when starting the project. Much of this has been made possible by our relentless R&D efforts into next-level acoustic materials for sound reproduction equipment, most importantly: loudspeaker cabinets. Both the material design as well as production design have turned out to be a time consuming enterprise, but by committing to this vast amount of engineering work we also reduced the speaker's production time and much improved its scalability. The sharp price-proposition of the new ADAMANTIS loudspeaker is deliberately chosen to increase the loudspeaker's reach towards more listeners in pursuit of next-level sound satisfaction, and a deeper connection to their musicians of choice.

Ultimately, we have made a loudspeaker unparalleled in value, suitable to join side-to-side with audiophiles that want to go ahead in big leaps, especially when pairing it with mighty electronics. In this paper I will explain why, and show you how deep the anti-vibrational rabbit hole actually goes.

The status quo in high-end loudspeaker cabinets

The Holy Grail in loudspeaker materials is a compound that in synergy exhibits high levels of two properties that normally appear to be each other's opposites: *stiffness* and *damping*. Why exactly?

This combination is desired to firstly: not allow unwanted vibrations inflicted by the force of the moving/vibrating driver-units. Stiffer materials are harder to bend (to vibrate), and they also shift the material's resonance -plus most resulting harmonics- up in frequency (ideally far outside the audio band). And secondly: high damping materials when put in vibration, will immediately convert that energy into something inaudible, typically heat. This is the real cure against unwanted resonance. All cabinet vibration, regardless of being excited by sound waves (amplitude phase) or fast-travelling pressure waves (from both inside and outside the enclosure) or being directly or indirectly inflicted by the driver's movements, should be contained in such a way that the cabinet seizes to exist and gives way to pure music. Resonance highly depends on reoccurring dimensional lengths, so triangles and ellipses are better than rectangles, and rectangles are not as bad as circles and squares. Still, the material itself as used for building the structure is the real show-stopper or performance-ceiling.

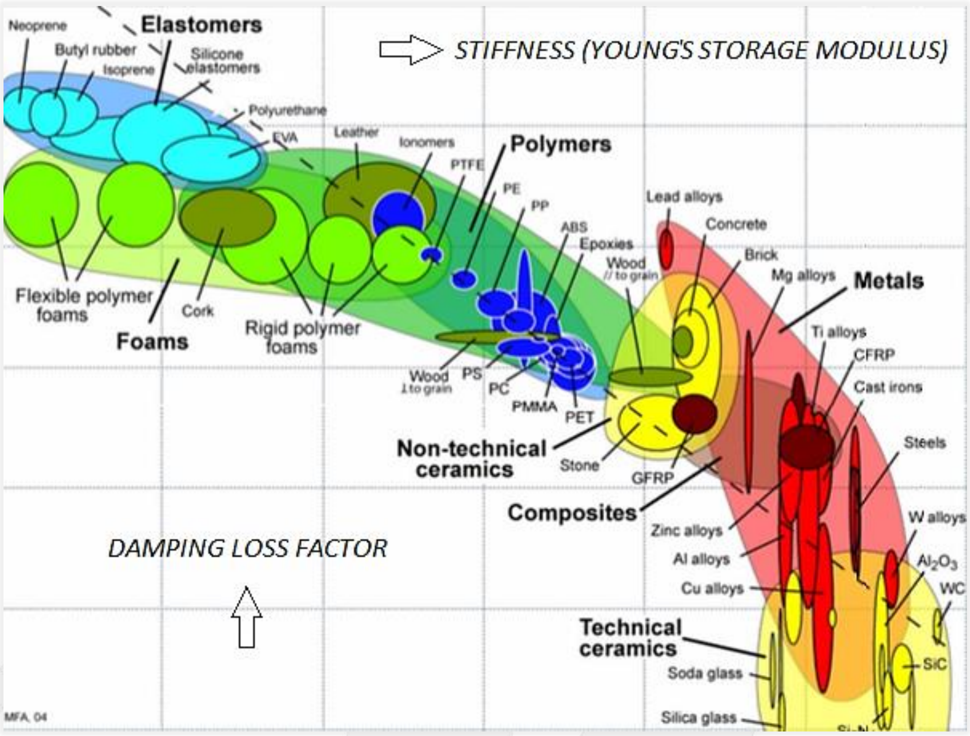
If a material is heavier, there will be more energy needed to create unwanted resonance. This especially helps for higher frequencies that put in much less energy. Stiffness must save us from harm especially in the lower octaves, since that larger energy is probably still able to move a large mass. Manufacturers usually improve the structural stiffness by increasing the enclosure's wall-thickness, effectively multiplying the torsional force needed in order to bend it. Adding material also adds helpful weight. The real challenge is born from the following fact we have to deal with: just one small spike, resonating in only a small frequency area but at audible amplitude, has the power to destroy overall acoustic performance. Even a thicker wall of the same material can have its specific problems and could fail to resist torsional vibrations by lack of stiffness and/or fail to stop moving longer after initial excitement, by lack of damping loss at the specific frequencies where it suffers from resonance.

Bending and pre-tensioning walls/panels will increase their anti-torsional stiffness. The pre-stressed structure also provides vastly better damping-properties. Still, some material-specific resonance might occur. Anti-vibrational properties are effectively multiplied when using two different materials: one material dampens the other by not allowing it its specific bad behaviours at their specific individual problematic frequencies. It's even better to choose one material that provides high stiffness whilst another one added excels in damping. Those nicely curved walls made with sandwich and multi-material solutions might perform better, but are also harder to predict. And they make for higher production costs. The Ensis uses a combination of various materials: a ceramic/polymer composite on front and top, billet aluminium (opposite from woofer) and Finnish birch-ply bracings all placed in a forged multi-wood sandwich hull. Then, located by measurements and evaluation, made totally resonant free with the help of a very expensive tungsten-filled resin composite. Stilla uses similar features, but is more cost-effective using a full shell of ceramic composite and no use of tungsten. Applying all of all of these measures, the compact and extensively braced Ensis and Stilla need their shell's walls to be only 1cm, with some extra material added at specific problematic areas.

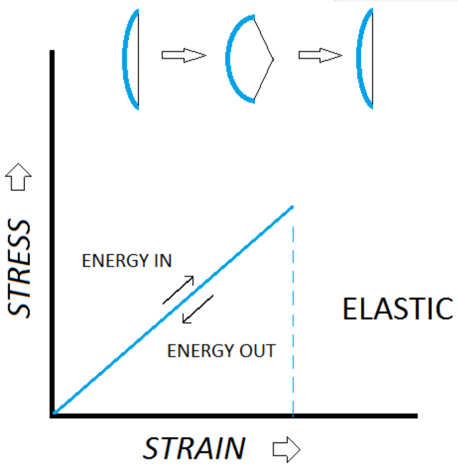
Most larger and/or less curvy high-end speakers need much thicker walls. Even those made from the variety of more advanced materials that we see being used. Let me list some examples including material implementation: high damping but not so stiff 'pantzerholz' (Kaiser); fair damping and fair stiffness (ceramic) composite (Kronos, Wilson Audio); a combination of pantzerholz and ceramic composite (Kronos); or quite stiff but low damping Aluminium (YG, Magico). Some brands use aluminium or wood with damping layers in between (Gauder) or are built by carbon, epoxy and MDF (Rockport); or by glass fibre with balsawood (Vivid). We also see pre-tensioning by bolts (Magico); or by mechanical features (Sonus Faber). Looking at performance versus price, increasing value for the listener's money seems not so easy to accomplish by any of the high-end speakers offered today.

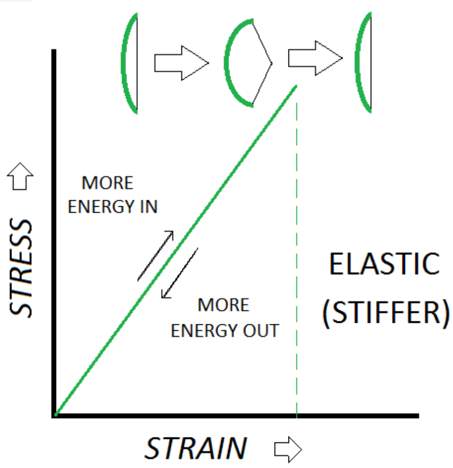
The future of high-end loudspeaker cabinets

There is an obvious contradiction between stiffness and damping in materials. An overview:

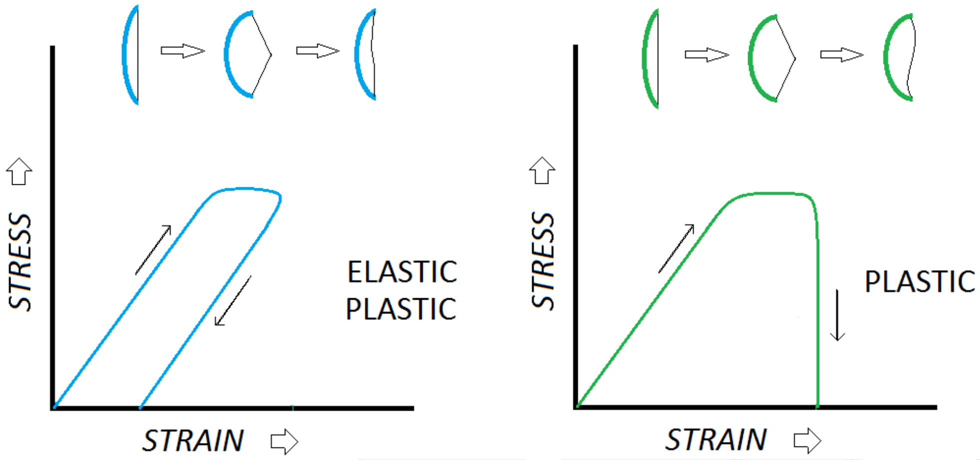


In order to engineer new composite materials that are stiff yet also high in their potency to damp resonance, we had to get a better understanding of the physics responsible for how materials react on dynamic energy input and output. Let's take a fast trip through the basic principles of this theme. First, there is elasticity defined by Hook's law. Solid materials if *elastic,* can bend and store energy and then reverse that movement (turn straight again) and release that same energy. Stiffer materials have a higher 'storage modulus': they can store more energy with less movement. Imagine two identical shaped bows to shoot arrows: one made of steel and one of wood. To pull the bow, you would need more force to span the steel bow to reach the maximum length of the arrow. When you let go, the bow returns to its original shape and (some of) the energy that is set free is used to accelerate the arrow. In case of the steel bow, the arrow should develop more speed since there was more energy stored that after release can be used for its acceleration. This movement of bending and unbending (strain) and storing and releasing energy (stress) works by Hook's law of elasticity.

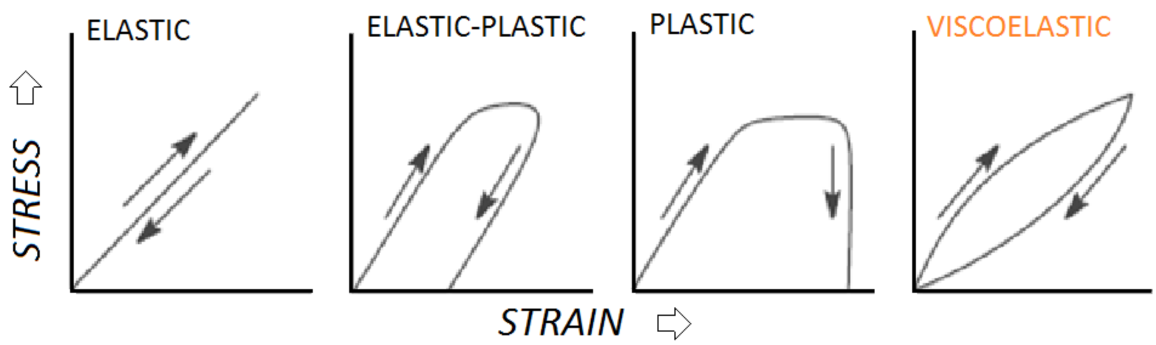




Some materials will permanently deform at a certain amount of force, and this is called *plasticity*. Probably your steel bow will be overstretched and not return to its original shape. In that case you reached the *plastic* phase of the material. Most polymers are *elastic-plastic* and will deform if pushed over their limits while also move a bit back into the original shape of before stress and strain were applied. This is in contrast to fully *plastic* materials that stay in the exact shape left at the moment of maximum force (the behaviour expected when shaping clay into a desired object). A true *plastic* will store energy until its maximum stress-platform is reached and then spends all its stored energy on changing its internal structure: it stays permanently deformed and will remain at the maximum level of strain. So in case of the bows: the *elastic-plastic* bow will go only partly back to its original shape, while the pure plastic bow will keep in the exact same shape reached at maximum pull. The *elastic-plastic* bow is pictured in blue below, in which it turned half of its energy to heat at bending, passing only half the normal force to the arrow. The purely *plastic* bow, now in green, has turned all energy into heat and the arrow will not move at all, leaving the cord to be longer than the new span width.



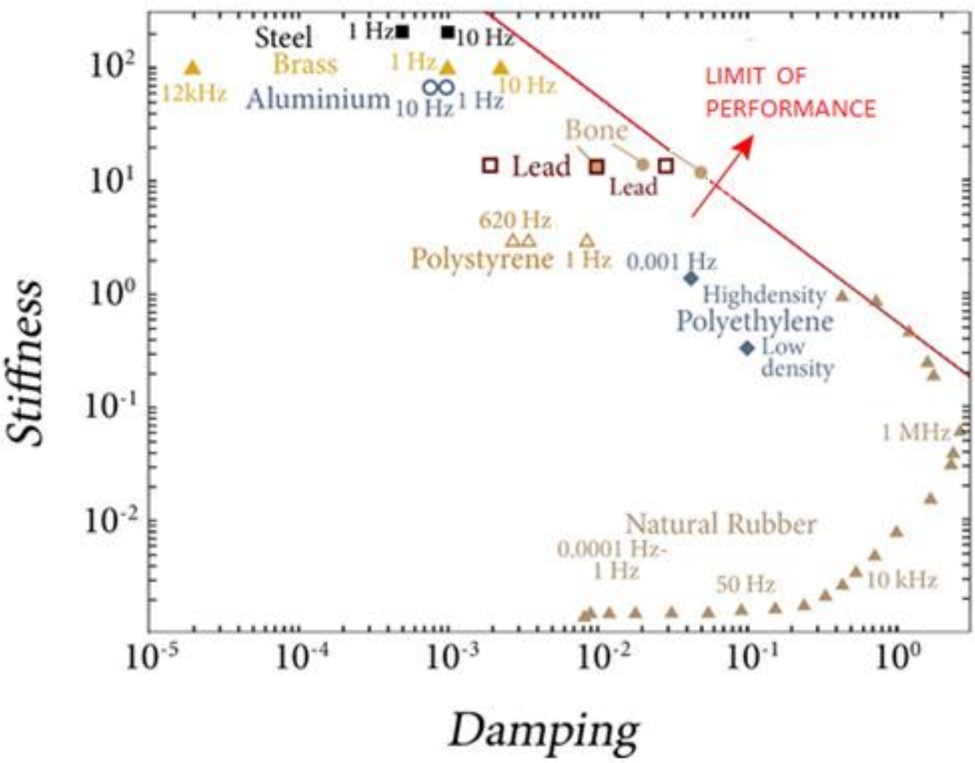
In reality all materials, and especially rubbers/elastomers (but also polymers commonly referred to as 'plastics') behave somewhat as a *viscoelastic*: they derivate from Hook's law by losing some of the stressed energy, yet still move fully back into the original shape (back to zero strain). This means some energy had to be lost by internal friction instead of by permanent deformation. This is why low pressured tires turn hotter and consume more fuel yet still maintain to stay round after countless cycles of temporary deformation. The ideal bow has maximum capability to store energy without permanent deformation in order to provide maximum speed to the arrow, but has also some internal damping by being a bit viscoelastic. In contrast, a pure elastic bow would do 'POINGGOINGGING' at release and will resonate still after it reached its original shape. At this time, the arrow is still making its way across the bow (since when unused, the bow is already bend), so there is still some time left during which the arrow's end travels between the cord and the bow. If some energy would be turned to heat after release, without deformation of the bow, there will be less resonant vibrations, and this will immensely improve the accuracy of the aim by anyone who's using that bow to shoot arrows.



Like bows, there are many other examples where maximum stiffness (or energy storage capabilities) as well as high damping (by high viscoelastic properties), would ideally be optimised at the same time. So, what exactly happens when a material can damp energy without deformation? And why is it so hard to accomplish high levels of that internal energy-loss magic in stiff materials especially?

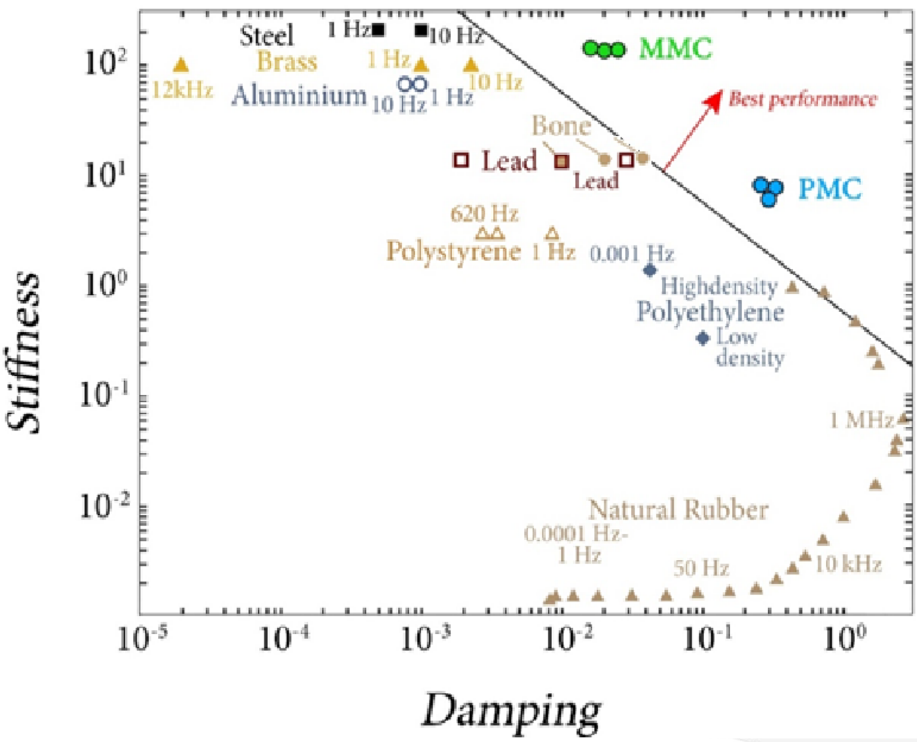
The extent of the viscous part in the material's properties provide for internal movement, or sliding, within the solid item. Internal means in this case that it can lose energy without losing its external shape. The kind of material-friction that is more commonly known happens in bulk accumulations of materials like liquids and gasses rather than solids. For example: a spaceship returning in our (very cold) atmosphere causes air molecules to slide over each other as well as over the spaceship's hull at extreme speed. This happens in such extend that it heats up to extreme temperatures. In fluids we use viscosity to describe how much energy will be inflicted by friction, depending on how 'thick' the liquid is. You will need more energy to swim through olive oil than through plain water. A car filled with higher-viscosity motor oil uses more fuel, although this oil could also provide better protection against harmful forces inside your engine, as it can turn shock/impact forces into harmless heat.

Now back to solids: in order to go back to the original shape (zero strain) we need a viscoelastic solid such as rubbers. Being able to provide for that internal viscous 'liquidity' is something quite opposite to being stiff, so it's no surprise that rubbers are usually not stiff at all. We can learn from nature in how it deals with this problem by evolving natural 'composites' from simple wood to more advanced bones and exoskeletons. In those natural composites the friction between cells allows much better energy dissipation. In contrast, some of the mined metals and other organic and inorganic materials found on this earth -as well as the alloyed or factory synthesised solids we create from them- can be plenty stiff, but then lack in damping. Meanwhile, material science has explored many man-made composites and put them into good use. These can be based on a combination of stiff and high-damping materials or include natural materials like wood fibres or paper pulp. Over the last decades the addition of organic carbon fibres and flax fibres in composites has showed further potential. Specific properties have even reached very impressive values but mankind has found it hard to do better than bones on combined stiffness and damping, as is the key to anti-vibrational performance.



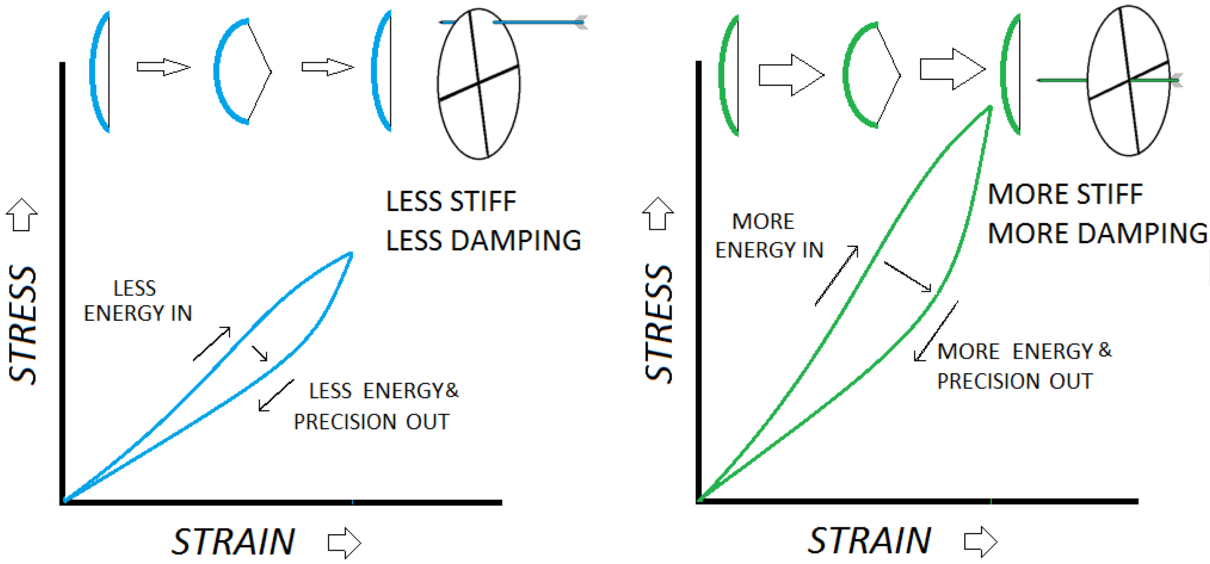
The map shows some common engineering materials as well as human bone, described for their stiffness (Young's Modulus E in GPa) and damping (factor tan δ) at room temperature and plotted for several frequencies. When looking at a wider frequency-band, bones still do better than metals, even if it's super heavy (and toxic) lead. There is also a diagonal line that represents the highest combined performance of stiffness x damping loss, as often described by scholars for all mined, alloyed, synthesized and natural materials performing left/under this threshold. The future's best materials for loudspeaker cabinets would leave this paradigm and perform in the up-right triangle beyond that line. Making parts from one solid material is usually easier and more cost-effective, so this single homogenous material has to truly excel in both stiffness *and* damping. If using two materials to optimize the structure's total performance towards even higher levels, both should do well on combined properties with one material placed further up (stiffer) and one further to the right (higher damping loss) to cancel out each other's specific vibrational weaknesses. And important: stiffness and damping performance must be consistently high at any frequency of the vibrations applied.

Looking at the various plotted measurements per material, it becomes clear that some typical viscoelastic materials like rubbers/elastomers can vary in both stiffness and damping per frequency. Perhaps more troubling is the fact that many consistently stiff materials, such as metals/alloys, suffer from severe resonance or ringing at specific frequencies where level of damping loss is greatly compromised. For example: brass will move far left at higher frequencies and ring like a bell at that frequency (see the 12 kHz measurement). This is nice for specific-sounding instruments to take their specific harmonic position in the soundscape of the total band or orchestra, but it's terrible for components that should not bring any coloured signature into musical reproduction. This brings us to the two novelty composites making up the ADAMANTIS-cabinet, plotted below on the same map:



The material plotted in green is our super stiff and very high damping Metal Matrix Composite (MMC) used for the very strong main structure. In blue, the stiff and ultra-damping Polymer Matrix Composite (PMC) applied as inserts/add-ons at the most critical hotspots. As can be seen, they far surpass the level of combined stiffness and damping as considered the usual maximum figure of merit for materials represented by the diagonal line (stiffness x damping factor of 0.6 GPa). In case of the MMC material, almost the same high damping was achieved measured from 1Hz - 100.000Hz (!).

When explaining the role of viscoelastic properties combined with stiffness, I mentioned that the ideal bow is both stiffer and more viscoelastic. Stiffer for more arrow speed and more damping for enhanced accuracy. Below a comparison, where the green bow is stiffer and has more damping loss.



Unlike bows, for stationary components such as loudspeaker cabinets, audio furniture (or the chassis of electronics exposed to musical energy), all kinds of machining equipment and various components in vehicles, there is no need to provide elastic energy to an arrow. Instead, the stiffness helps rather to prohibit vibration before it starts. The bow and arrow metaphor however still provides for a nice example of how pre-tensioning can also help anti-vibrational behaviour on two fronts. Firstly, the amount of energy needed to bend the bow increases the further you have already bent it. So the pre-bend bow is in fact a stiffer structure. Secondly, it will also increase the internal friction of the bow's matter. So it's no wonder that when using the same material, it's a specific amount of pre-bending that provides for optimal shooting range and impact force, combined with optimal aiming accuracy.

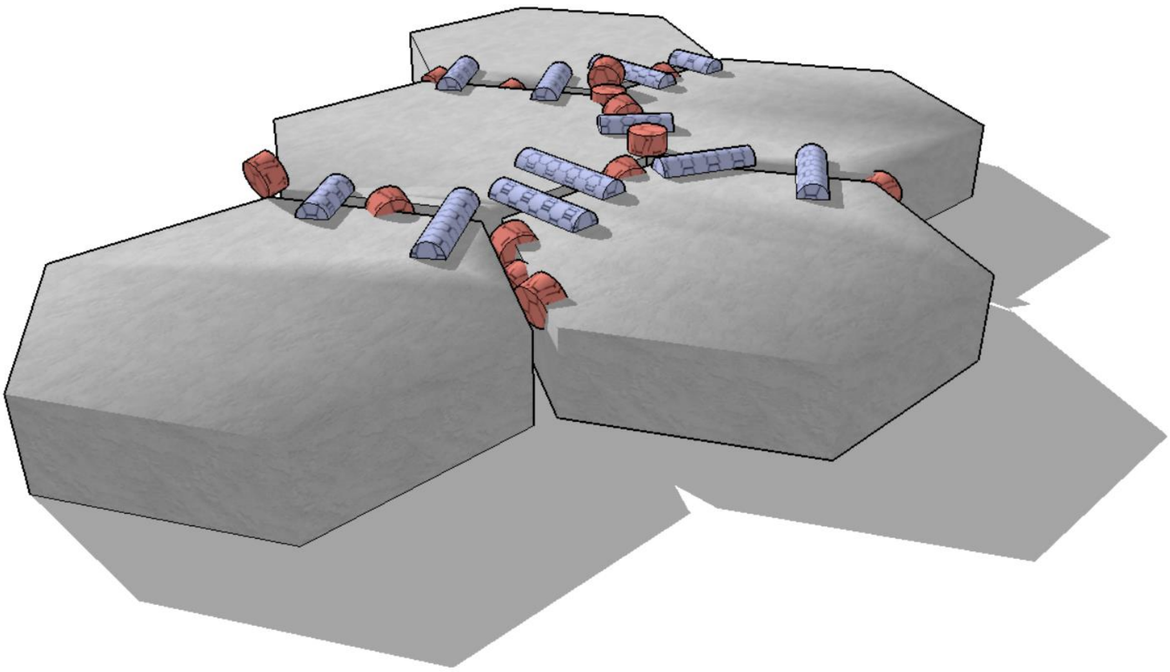
Both of the novelty composite materials we used for the cabinet of the ADAMANTIS were engineered by implementing unique Nanotech engineering we discovered while trying to overcome the rules of physics as normally encountered in macro material science. And they far surpass the performance of other recently appeared applications of typical Nano candidates such as Carbon Nano Tubes and Graphene. These innovations are a result from the extensive material research project that was initiated by the development of the cost-no-object flagship prototype loudspeaker D I L U V I U M. The big breakthrough occurred when it became possible to implement Nano-technology in new ways so that they do increase at the same time the material's stiffness and damping to high levels.

In order to create these new stiff solids with high internal friction (damping): we zoomed all the way in to happenings within the crystalloid matrix of composites and took Nano-engineered control of those events. With our proprietary technology, we could create friction and thus energy dissipation without the need of the molecular 'fluidity' such as is normally found in rubbers and would be compromising stiffness. At the same time we could use Nano-assemblies to actually increase stiffness without losing damping potential. And even more important, by altering the crystalloid structure of the metals applied in some of these composites towards desired specification (and without the loss of damping properties as is the common result of grain refinement by alloying towards usable materials), a high consistent damping loss factor is achieved at *all* frequencies. These new Nano-Composites are free from toxic metals such as lead and beryllium. Both PMC and MMC materials can be casted for better three-dimensional a design, which enables huge savings on labour cost. They will provide next-level performance and value in our future loudspeakers, starting with ADAMANTIS.

Nano-tech composites in the ADAMANTIS loudspeaker

The picture below portrays how the technology of NANOCAST™ does the three following things:

1. Helps forming an ideal crystalloid configuration of the (metal) molecules (silver hexagons below). This ensures the damping properties regardless of frequency, and does so consistency and permanently, without the need of the tension that anneals down over time.
2. Enhances stiffness by providing Nano elements for connection (violet tubes below), holding the grid tighter together. This prohibits bending and allows more energy storage capacity.
3. Optimizes damping by increasing friction between the crystals with Nano boundary modifiers (red in picture) as well as improving thermal conductivity by bridging the molecular grid for increased energy transfer. This greatly improves thermal conductivity of the composite.



The resulting properties go far beyond that what can be accomplished by the most advanced alloys out there. But even more significant is perhaps that it does things not possible by natural and synthetic macro-engineered composites. Overall, the D I L U V I T E technology represents a totally different approach than that of other Nano-tech materials which usually focus on properties like conductivity, stiffness or strength only, or don't consider the consequences for wideband frequencies.

Originally the more traditional all-wood passive speaker (the prototype project named 'Gladium') was set to cost around 10.000 euro per pair. Since then we have upgraded the tweeter and various other components. But most importantly, we made the new cabinet from D I L U V I T E NANOCAST™ composites and we redesigned the entire enclosure in such ways it eliminated resonances to zero. It also prohibits indirect sound reflections and overcomes edge-inflicted diffraction issues. Furthermore, we vastly improved time alignment of each driver's position relative to the listener. After all these changes the new ADAMANTIS loudspeaker is set to be priced at 14.500 euro per pair.

It would be a big understatement to say that all these upgrades affect performance just more than suspected from those financial numbers. In fact, it moved to a different league altogether.

Before turning our full attention to the loudspeaker's development and achieved sound qualities, I'd like to complete this chapter with the product descriptions of the two featured Nano-composites. More information on the breakthroughs in material Nanotechnology and the resulting performance potential for various implementations can be obtained by visiting www.DILUVITE.com .

D I L U V I T E NANOCAST-PMC™

Stiff & ultra-damping Polymer Matrix Composite. Ultra-lightweight Nano-enhanced thermoplastic for casting and forging, also suitable for thin wall designs.

Suitable as ultra-high damping material add-on for stiff structures, but especially developed for thin, lightweight standalone structures such as smaller engineered parts and membranes, this Polymer Matrix Composite (PMC) sets new standards in the combination of super low mass combined with ultra-high damping, whilst providing unparalleled stiffness amongst polymers.

Its attractive price proposition within the D I L U V I T E™ portfolio make it an excellent choice for its use as damping-inserts into designated cavities and as an add-on at larger production volumes of products in need of optimum damping capacity. It's especially suitable to further improve structures made from NANOCAST™ metal matrix composites (NANOCAST-MMC™ and -LMMC™).

The product's thermoplastic polymer matrix is enhanced by state-of-the-art implementation of very innovative Nano material assemblies, specifically designed to overcome unwanted resonance by rising the composite's stiffness above levels typically found in polymers, whilst optimizing it's damping at the same time. This Nano-polymer also overcomes dispersion problems in the matrix, as are often encountered in CNT (Carbon Nano Tubes) infused polymer/resin composites. The composite can be vacuum or pressure casted or semisolid-forged by hot-compacting. It is seven times lighter than NANOCAST-MMC™ and up to two times lighter than carbon fibre applications.

The material's damping properties are far better than any of the CNT polymer/resin solutions that have recently become available. Both stiffness and damping are much higher than that of advanced epoxy resins. Additionally, comparable with NANOCAST-MMC™, this polymer version provides for a standalone solution without the need of laminating (different from e.g. carbon ply). This makes complex forged/moulded designs possible, even at much thinner wall requirements than those applicable at metal casting or regular thin ply laminating.

The embodiment of all these highly desired properties together, position this high-tech Nano composite as the ideal choice for advanced structures, such as high-end loudspeaker (midrange) membranes and lightweight aerospace applications that should remain free of unwanted resonance.

D I L U V I T E NANOCAST-MMC™

Super-stiff & high damping Metal Matrix Composite, superb thermal properties. Resonance-free from 1Hz-100kHz with very good fluidity and castability, suitable for manufacturing of complex designs.

In the last century, many metal alloys were specifically created to help fight resonance issues. Most of the alloys with high damping capacity were based on copper (Cu) and manganese (Mn), marketed under names as 'Sonoston' and 'Incramute', best known for their implementation in ship screws. In the 1980's, both practice and research showed that these (costly) materials lost quite a lot of their damping power over time. Even at low temperatures, these alloys self-anneal (restructure their crystalline arrangement). This means the crystalloid tension/stress between the Cu and Mn components is lost, which was actually responsible for most of the elevated dissipation of vibrational energy.

In the 1990's, improved Cu-Mn alloys appeared -such as the M2025 from Japan- with the addition of iron and nickel. Still, these were low in thermal conductivity. Also, stiffness and damping varies with frequency, temperature and application. In the last decades metal matrix composites became more popular. More recently there was the addition of Carbon Nano Tubes and Graphene. Despite the high scores in some particular properties, these expensive Nano-composites offer mixed results, especially when considering the costs. Although there have been big advances in all kinds of properties in all the mentioned materials, the most important challenge of stiffness vs. damping remained largely unsolved: the stiffest ones would lack damping and vice versa. Also, combined performance would vary heavily with the frequency of the vibrations and resulting resonance.

In search of the best possible material structures most inert to unwanted resonance under the most demanding circumstances, D I L U V I T E™ Nanotech Composites developed a specially structured crystalloid metal matrix, enforced by the latest developments in Nano materials (such as Graphene and Nano Tubes), implemented in new and unique ways at far better cost vs. performance proposition. These composites set new standards of extreme stiffness in combination with high damping at any vibrational frequency. One of the most important and best applicable among the products in the portfolio is this castable Metal Matrix Composite (MMC). It provides better damping loss capacity than any commercially available alloy, even surpassing that of lead whilst also being much stiffer than e.g. aluminium alloys.

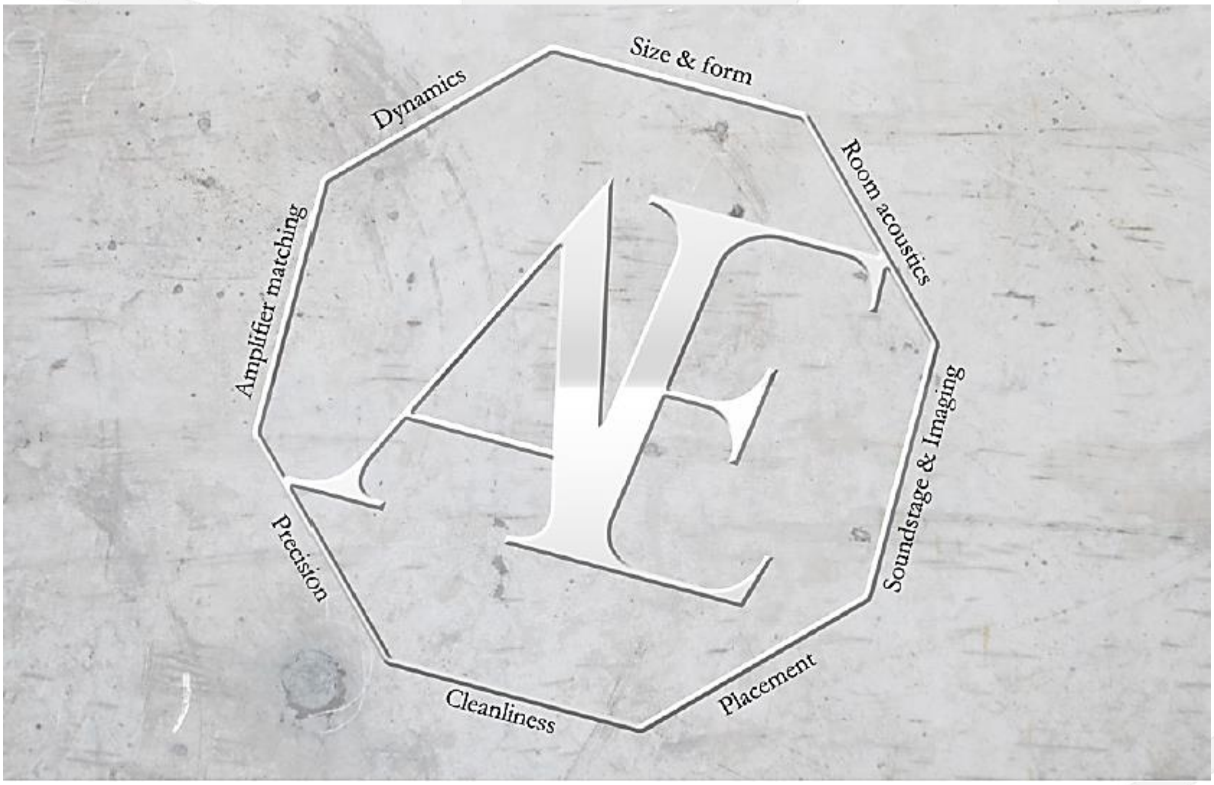
Furthermore, its unique crystal structure makes for excellent damping loss of virtually the same high value for any frequency from <1Hz to >100kHz, something normally never seen in alloys or polymers that suffer from resonance problems at certain frequencies. The composite is stable up to temperatures beyond 300 degrees Celsius and its excellent thermal conductivity is comparable to that of aluminium alloys. This means it can be used as a heat dissipation material (heat sinks) in advanced audio cabinets and chassis, as well as industrial equipment such as precision machine parts, tool holders, measure and lab equipment, and various other high-end applications.

The material's wideband energy dissipation is maximized whilst its density remains significantly lower than that of steel. Additionally, it is free of typical toxic materials such as lead, mercury or beryllium. Opposed to cast iron, the material is naturally corrosion resistant. Other properties such as thermal radiation (infrared heat dissipation) can be further enhanced by coating the casted material with NANOCOAT-VANTAC™ surface treatment.

ADAMANTIS design choices

After explaining how new composites paved the way for the exquisite sound quality of this new loudspeaker, I would like to list the conceptual goals for the design in which they were implemented, and the general aspects of these and other technical solutions we applied to best meet those goals:

Performance goals	**Involved Octagon-Philosophy aspects**	**Design choices /solutions**
Fully passive loudspeaker with deep bass extension whilst being free of some of the most important issues considering bass problems found in large high-end loudspeakers that have that capability.	-Size & Form -Room acoustics -Placement -Cleanliness -Dynamics	~4x the Ensis/Stilla inside volume. Ten inch woofer derived from Ensis optimized to resemble the roll-off set at XL, in combination with front horn loaded 20hz port, derived from Stilla.
Graceful cabinet allows precise time alignment without active controls. The cabinet should be resonance free yet at such costs it can ensure extreme value.	-Size & Form -Soundstage & Imaging -Precision	Two-piece, aerodynamic, casted cabinet made from novelty metal matrix Nanotech composite. Integrated baffle tilted variable from 5 to 12 degrees.
Transducers, wiring, connectors and crossover parts chosen by the same standards as the improved cabinet and much on par with those found in Ensis and Stilla, exceeding the quality of those found in and beyond this price range and optimized for this specific speaker.	-Room Acoustics -Soundstage & Imaging -Amplifier matching -Cleanliness -Precision -Dynamics	Midrange: paper pulp membrane derived from Stilla woofers, FEA optimized motor with identical resolution as Ensis/Stilla. Woofer and tweeter derived from Ensis, with HF speed identical to Ensis. Identical filter topology, wiring and WBT connectors.
Our famous holographic walk-about soundstage qualities fully applied, without compromise.	-Room Acoustics -Soundstage & Imaging	EHDL™ tweeter from Ensis. Compressed wool front derived from Stilla. Smallest possible cabinet width near mid/tweet.
Although passive and ported, very decent amplifier matching and if paired to big power even exceeding the dynamic capabilities of Stilla/Ensis.	-Amplifier matching -Dynamics -Cleanliness -Precision	10 inch woofer is now in ported enclosure almost doubling the dynamic capabilities of Ensis. Above average 88db @ 4 ohm sensitivity.

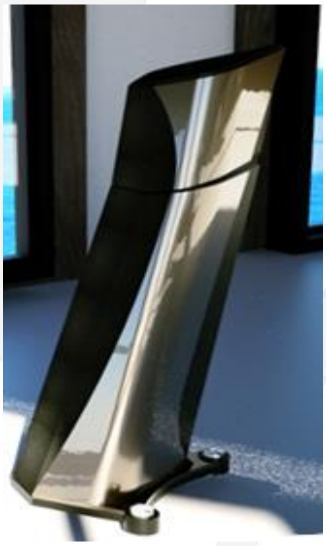


From Gladium to ADAMANTIS

So what exactly was the impact of the novelty Nano-composites that, since our departure from Gladium, led us on-route for arrival at the ADAMANTIS? What became possible, that wasn't before?

It allowed us to use walls at fraction of the thickness required by more traditional wood or aluminium panelling whilst providing vastly improved anti-vibrational qualities. It also allowed great freedom of design, without increased labour cost in production. The ADAMANTIS has similar internal volume as the Gladium prototype, but can be considered a much more graceful speaker. It also scores higher points on our credo of 'form follows function'. For example: Gladium needed a smaller tweeter to reach sufficient vertical dispersion of acoustic energy, as it was mounted on a baffle that had to be tilted enough for satisfactory time alignment between mid/high and bass section. Although it already did a better job on timing than most speakers costing fewer than 20k/pair (or even far above 20k), ideally a loudspeaker's baffle is curved with a different tilt between midrange to woofer versus that of midrange to tweeter. This is achieved in the new design, among many other beneficial mechanical and dimensional features that lower diffraction and eliminate any unwanted sound or distortion.

From left to right: Gladium, ADAMANTIS and Stilla.



D I L U V I U M

The new design allows the tweeter to be used at similar tilt as the Ensis and Stilla, giving room for an equally big membrane without hurting dispersion in the vertical domain. This enables the same ideal energy distribution that makes our speakers do so well in terms of their holographic capabilities, and provides for the increased resolution that results from a lower crossover point (using a smaller, faster driver at the frequencies otherwise reproduced by a larger midrange driver). Other than membrane size, the Gladium tweeter had its parameters based on the one found in the Stilla. But when evaluating the vast overall potential of our newly created ADAMANTIS, we felt it would be best fitted with the super high-res motor of the Ensis. Fully equipped to be used in absolute top-notch systems, this combination is positioned to push forward the performance of those high-end systems that are owned by the most demanding audiophiles, far beyond any passive loudspeakers at this price point.

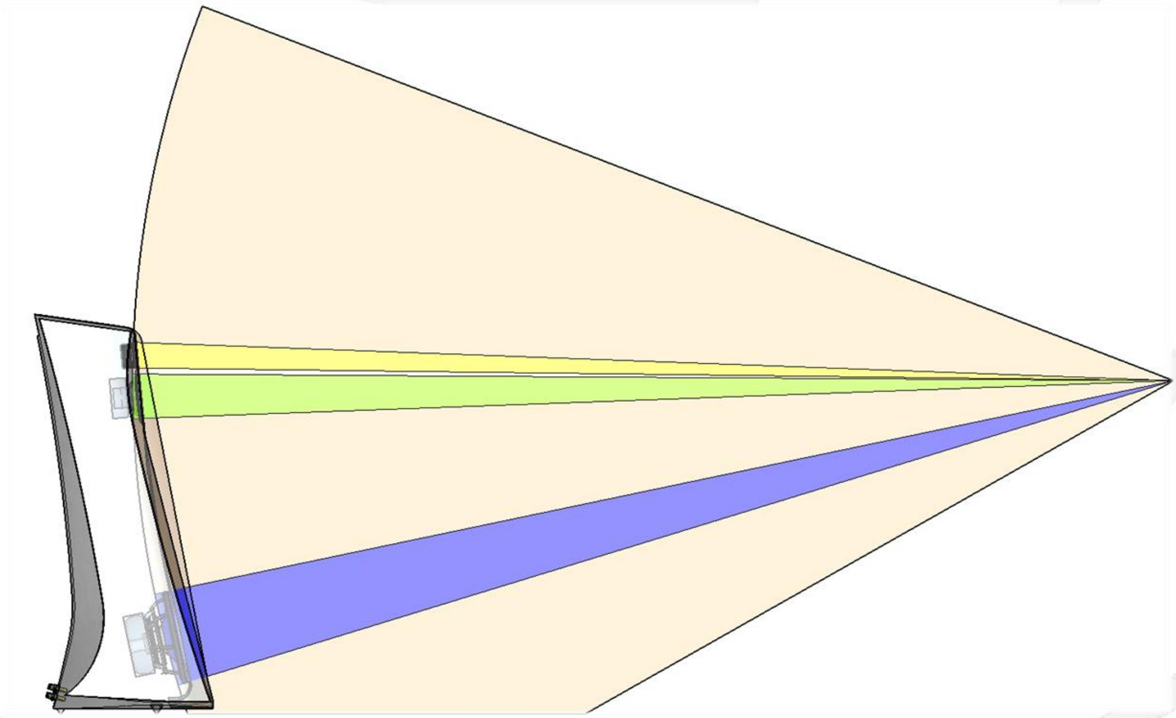
Immediately striking, is the resemblance to our flagship-innovation-project D I L U V I U M. You can expect future speaker models to be also designed accordingly. The signature lines of this design are a direct consequence of optimizing the performance of any given loudspeaker-concept by all relevant parameters without restrictions. The D I L U V I U M has a totally separate mid/high cabinet while the acoustic decoupling in the Stilla is provided by a gap between the upper and lower cabinet shells. This paper will explain how decoupling techniques were also implemented in the ADAMANTIS, but now hidden from sight behind the side panels (the panels finished in white in the picture above).

Time alignment

One of the first and most important things to consider when designing a multi-way passive loudspeaker is the time alignment of all the drivers it encloses. Each driver has a specific acoustic centre and different transient response behaviour. One might try and use smart phase aligning crossover techniques, but that won't overcome nature's speed of sound: we can influence the way a wave moves (phase), but not it's absolute start (time). Filtering a multi-driver system works better without introducing phase-correcting shifts as applied in order to deal with the different alignment of each filtered driver. When using each source of sound in a different frequency band, many aspects have to be considered to fully benefit from multi-way designs, as each driver comes with individual transient speed response that accompanies their specific tasks. When simply looking at the phase diagram of a low frequency wave compared that of a high frequency wave, it obviously takes longer to fully develop maximum amplitude. The problem shows itself at the crossover frequency between two drivers. Each driver adds specific delay by having a different built and differently sized motor and voice-coil (not to mention the additional time smear depending on membrane-dimensions, waveguide AND baffle). For a team of drivers to sound as a point source, time alignment is key.

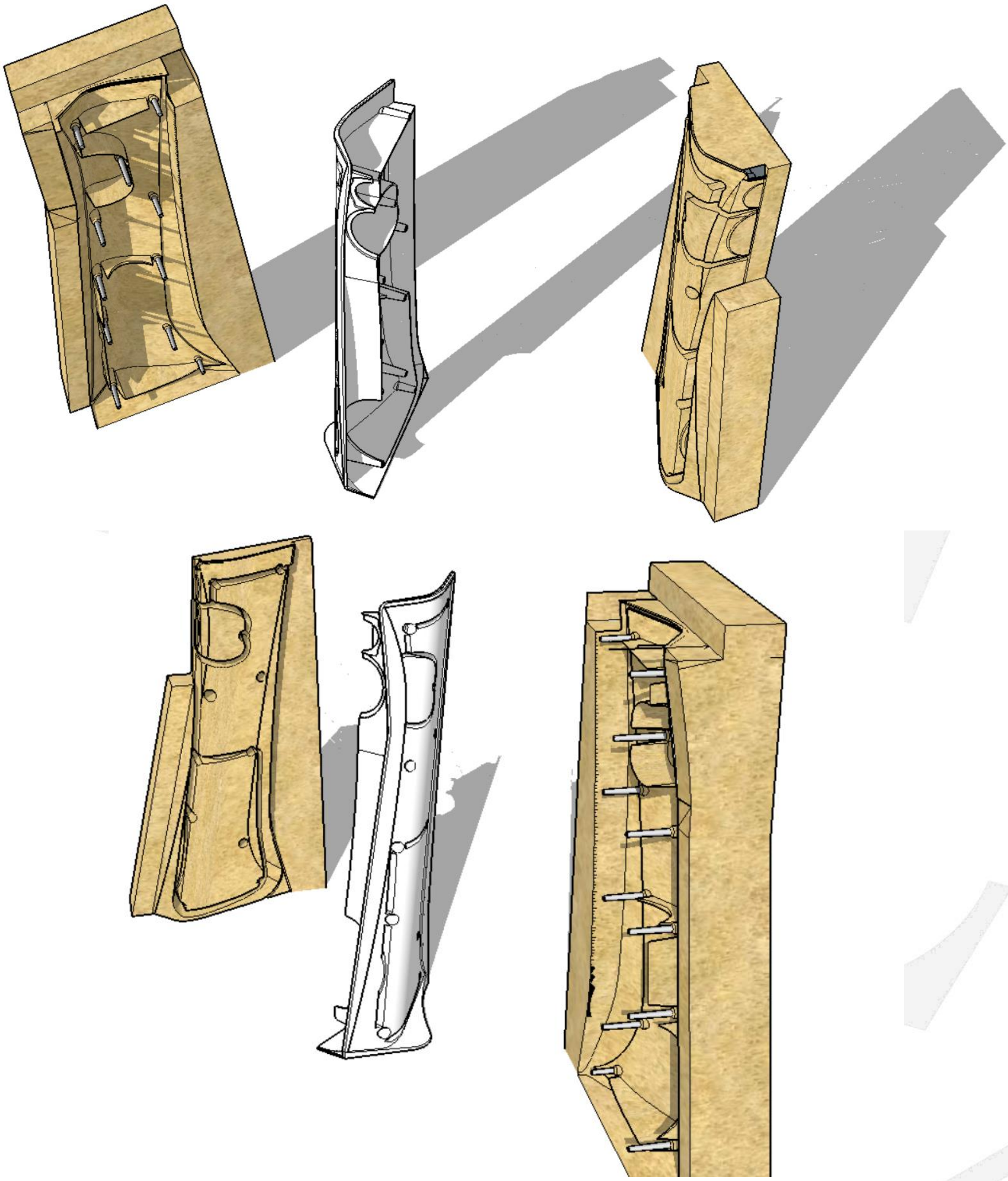
At Aequo Audio we spent effort on measuring the exact time/phase behaviour of different drivers and filters choices. But more importantly, we are obsessive in our curiosity of the translation of all this data to real-world listening in order to achieve the best performance in realistic projection of all instruments, vocals and venue reverbs/decay. Also taken into account, is the variety in how different listening rooms respond to, and work together with, the speakers placed in them in order to finally come up with exactly those optimum design features that carry us to the best musical experience.

It is no secret that there is a big difference between each optimum distance of each driver and its position towards the listener. Still many designers look for a perhaps too easy solution and settle for compromised time alignment, the worst case being a passive three- (or more) way speaker baffle in just one straight plain. And regardless of filter topology (and some overall tilt), this will surely be of bad influence for the palpability and holographic realism of imaging. Such designs spoil the potential of maximum musical connection for the listener in his main listening spot, and are even worse for listening positions elsewhere. Instead, all listeners should take their virtual place at the music venue.
As for the ADAMANTIS: we took in account all the above mentioned aspects, without compromise:

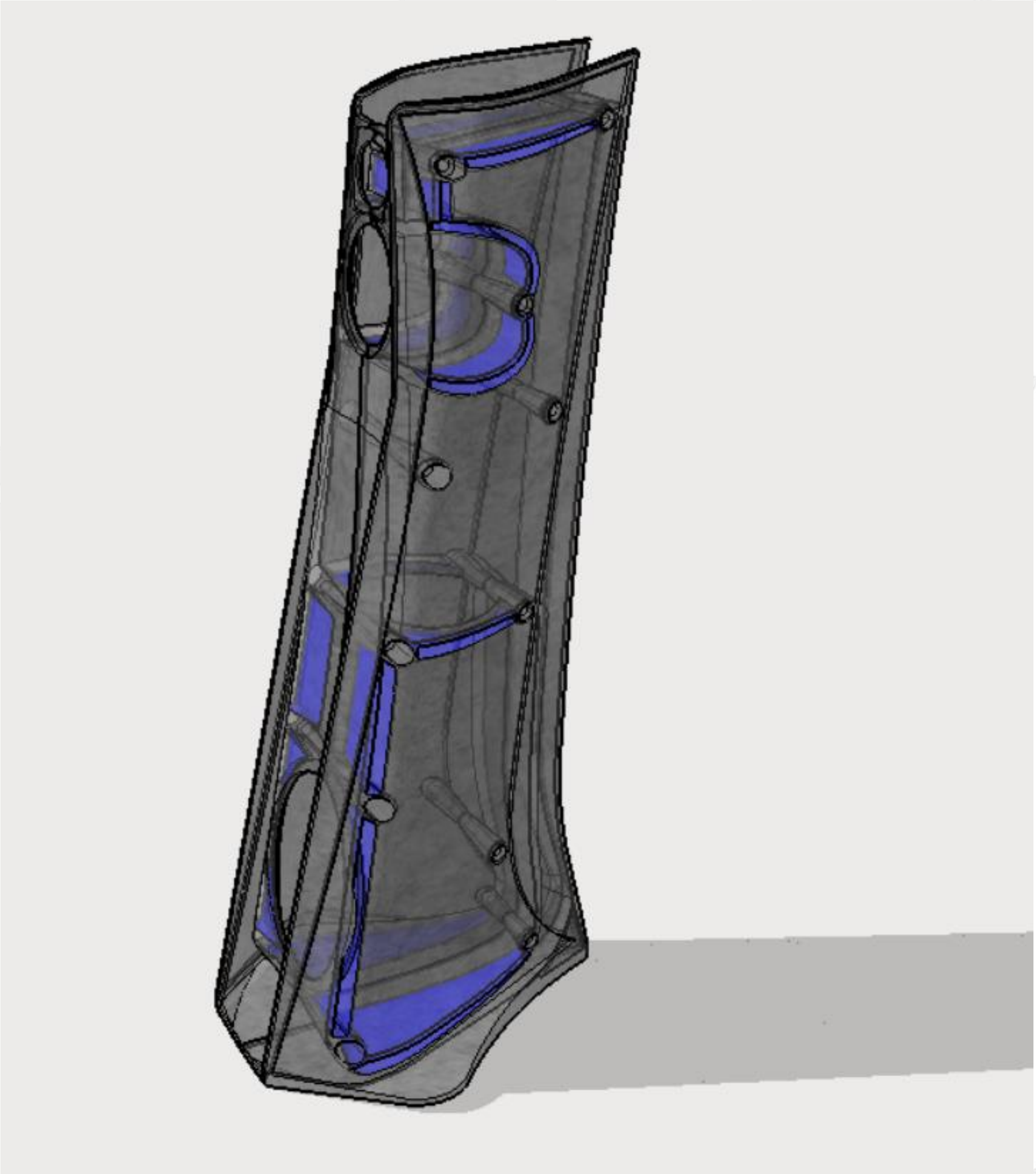


Casted shell and its casted inserts

The cabinet is constructed from two complicated shells, casted from the resonant-free Metal Matrix Composite (NANOCAST-MMC™). The shells are bolted together using eleven big bolts to provide the full and very strong enclosure. These custom made bolts used to mount and seal the enclosure, apply damping-enhancing tension into this structure to further reduce any vibration as could be inflicted by the transducer's moving parts that itself should be the actual only source of sound. Choosing a stronger quality of steel bolts, the amount of tension they can provide is over 3 times that of bolts of standard quality. Size is also of big importance and perhaps more than you would expect: M10 sized bolts can be tensioned with about 3.3 times the force of equal quality M6 bolts. Altogether, the eleven bolts in the ADAMANTIS provide a force more than one hundred standard quality M6 bolts.



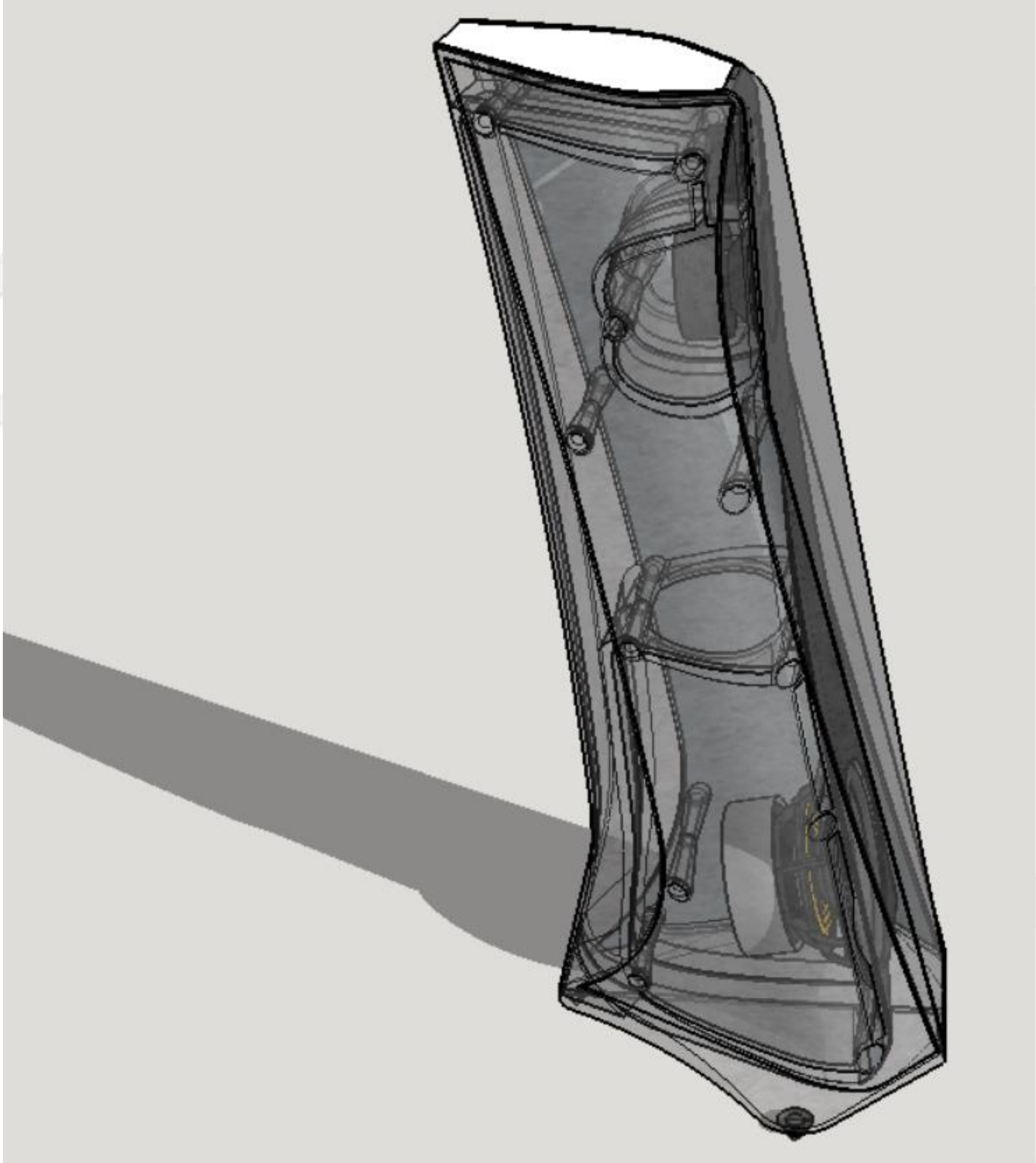
Derived from computer modelling and simulating the dynamic forces at play, the cabinet provides two additional side-enforcements in front of the bass driver with strong connection to the speaker's bottom platform. Additionally, there are several slanted inserts added to the main structure, positioned between the bolts and between areas that fulfil different functions. These inserts are filled up with the newly featured thermoplastic Nanotech damping polymer composite (PMC) to effectively decouple the enclosures of the tweeter and filter from the enclosure of woofer and its port, as well as providing for an acoustic barrier between the higher and lower half of the cabinet. The inserts are highlighted blue in the picture below. Also notice the open top, straight above the space dedicated to the crossover filter. Although this cavity is covered at the finalized product, it sprang from our desire for easy access when voicing/optimizing the sound qualities of the prototype as efficient as possible: the final and fine-tuned sound during real-world listening is what counts.



Transducer driver-units

Both in the Ensis Whitepaper and Stilla Development Story, many things have been said about the drivers developed for these speakers that now also fully apply to those found in the ADAMANTIS:

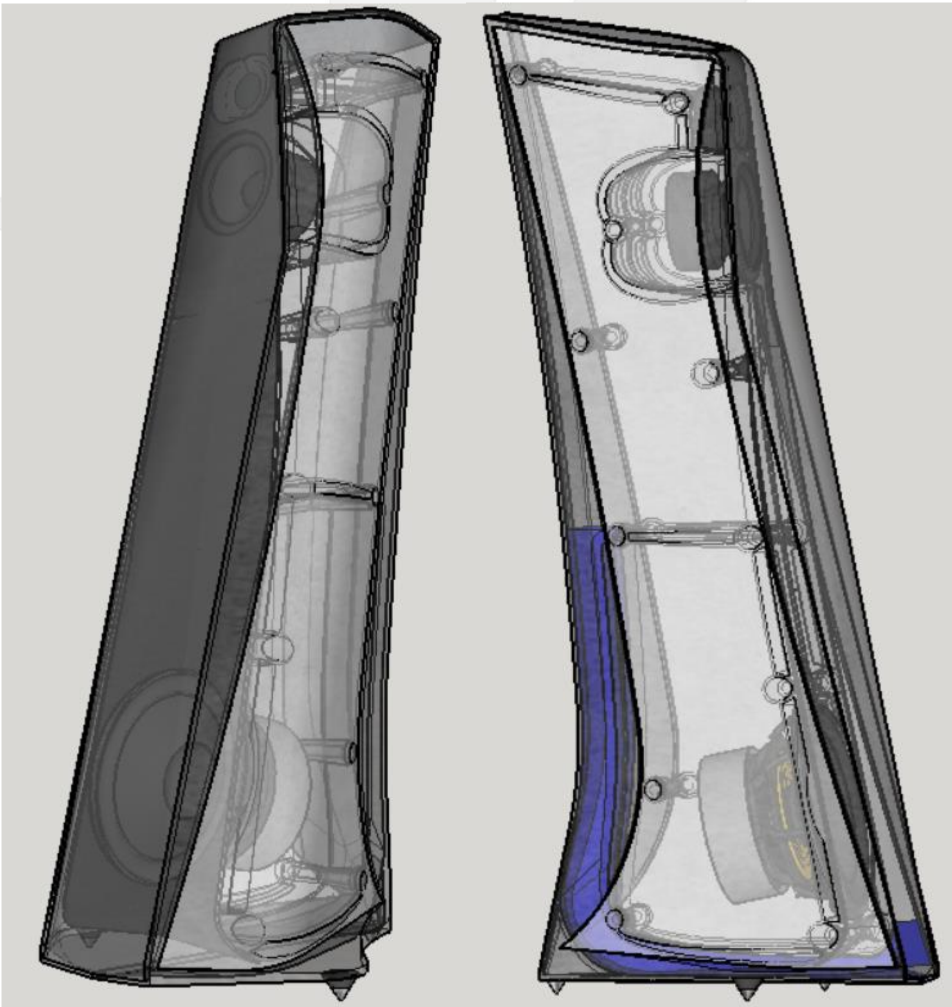
- Custom tailored designs of high quality, developed together with our Danish specialists and production partners, excelling in absolute performance combined with best-in-class consistency.
- Fast, precise, high-res movement combined with well-behaved ringing-free and therefore fatigue-free membranes (enabled by sufficient internal material damping against unwanted resonance).
- Low compression flexible rubber surrounds and spider suspensions, symmetric motor forces and low self-induction at both inward and outward movement, with very high linear excursion reserves.
- Extremely low distortion at low and high listening levels and absolutely minimized at critical frequencies, and a harmonic signature defined by a perfectly balanced even and odd harmonic distortion profile at all frequencies, based on profound understanding of recording and reproduction: a perfect platform to show the sound quality of connected electronics of choice.
- Unique EHDL™ fixed-dome-plus-ring tweeter system that redistributes vertical/horizontal energy in ways most optimal to achieve ultimate sound staging and realistic, fully three-dimensional imaging.



Here's what's new:

The EHDL™ tweeter system of the ADAMANTIS itself is a straight copy of the Ensis tweeter. It excels in resolution over most tweeters found in high-end audio, but is far less resonant than its beryllium counterparts; a feature maintained when compared to the very fast ceramic and diamond specimens found in speakers supplied by Accuton/Thiel. It is faster than the Stilla tweeter but, when looking into the time domain of actual sound reaching the listener, the Stilla does have one advantage over the Ensis: although the front baffle of Ensis is just as slim, there is still some indirect sound bouncing of its smooth surface. And as any indirect sound smears the perceived resolution, Stilla profits from wool felt covering its entire baffle. This makes Stilla's perceived openness and micro detail of almost the same level when comparing it to the Ensis. The ADAMANTIS uses best of both worlds: the super high resolution Ensis tweeter, *plus* a fully compressed wool covered baffle similar to that of Stilla.

The ADAMANTIS is fitted with a bass driver almost identical to the one found in Ensis, and anyone who heard it will tell how awesome it is. This ultra-low distortion woofer with incredible linear excursion needed only some small changes to work with the bigger passive ported enclosure. The addition of this port (highlighted in blue below) is very significant: it adds much higher reserves, almost doubling the maximum dynamic output of the speaker. Tuning it as low as 20hz to effectively keep its aid in the pressure domain, as well as optimizing its air flow and efficiency by horn loading the front directed opening, is something we learned from the Stilla project. It keeps the bass taut and fast, without the delay and booming issues as often encountered with ported speakers. To match the sheer amount of air this woofer can move, the port is much larger than that of the Stilla, to ensure even at extreme decibels it will always remain silent without the slightest cuffing or puffing noise.



Totally new is the speaker's midrange transducer. It was developed from the ground up to meet all possible demands for our new passive speaker. One of the distinct differences from our other midrange drivers was derived from it to be matched to the somewhat limited efficiency of the lower bass driver. To arrive at a higher sensitivity of the whole speaker, we would have to raise the efficiency of that bigger woofer first before looking at the midrange. This would mean fitting this big woofer with a thinner and lighter version of its membrane, or adding magnetic force to its motor. The first would increase cone-induced distortion and would trade in lowest octave output for upper bass efficiency. Adding magnetic force would make for an over-damped motor system, again limiting low frequency output. All considered, we set on this very reasonable efficiency ceiling, and this became the context in which we chose paper pulp over the mineral filled PP mixture as used in our hybrid speakers that excel in their sensitivity especially (which is part of their hybrid-active topology and compact charm).

As explained in the Ensis and Stilla papers, going for a good paper composite cone is hardly a trade-off when being allowed to use a bit more material (and thus sacrifice a bit of sensitivity). Although higher in initial costs, at larger quantities paper cellulose brings better value and this made it clear we should use paper fibres for the double 7 inch bass drivers of the Stilla: these are actively driven by NCore modules, making weight less of an issue. In this paper, in order to benchmark modern paper pulp membranes against other common materials found in high-end transducers, I assembled some examples as published by an independent driver reviewer. These were not assembled by 'cherry picking' and include some very expensive high-end samples from famous brands. I recommend anyone interested in getting more insight in loudspeakers to visit the site's featured domain incorporated in the graphs pictured, to do more exploring among the vast listing of evaluated drivers.

In general, looking at the bulk of reviews from professional magazines as well as DIY sources, it becomes rapidly clear that the implementation of a more rare and expensive membrane material by itself says little about sound quality. The driver's harmonic distortion profile at different sound levels (also available on the same website) can be seen as an overall reflection of the partnership between the motor and the parts it moves, such as voice coil former, suspension and the membrane. To give some insight in differences between membrane materials especially, I chose for this paper to use the step response-graphs that represent the tested driver's pulse behaviour in the time domain.

It basically shows the output of the driver representing its movement as a one-time raise to the signal's full amplitude followed by its decay back to rest position, without filtering. The overall triangle's dimensions described by this movement, rely most on the motor's speed making the one-way push (or pull), and is somewhat affected the connected suspension as well. The ripples along the way down are often very telling, being an almost direct consequence of the membrane's resistance to unwanted resonance. It really depends on the material it is made of. You can filter the main break up nodes out, but in midrange drivers this means that unless you use very steep high order crossover slopes, the harmonics of this resonance still enter the audible domain as unwanted distortion.

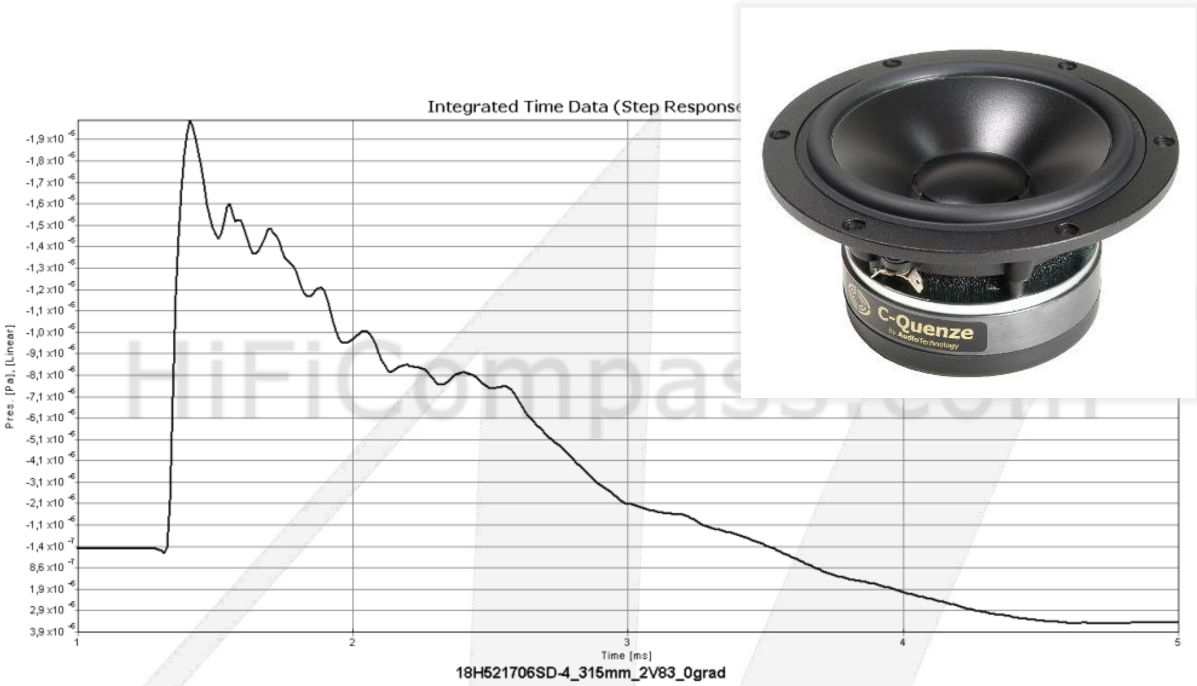
Using steep crossover slopes imply you have to use more than a single filter component (coil or cap) in line with the driver, and this might affect sound quality. More important is this consequence: all these high order crossover topologies suffer from group delay (slowing sound down) in the crossover band. Going super steep (sometimes seen in speakers implementing ceramic drivers) means that a smaller bandwidth will be affected, but in a much more severe way. I found (and I think most audiophiles and sound professionals would agree) that this type of passive filtering can immensely hurt the soundstage and imaging qualities, easily detectable by a set of ears of a demanding listener.

Having explained why the step response behaviour is a good illustration of the acoustic quality of a membrane's material, we can compare some transducer drivers that use the following materials for their moving membranes: ceramic (aluminium oxide), magnesium alloy, mineral filled PP mix, and paper pulp composite (that is also the type of membrane material found in ADAMANTIS).

Up first: an Accuton/Thiel ceramic midrange of the latest cell-type. An impressive and fast neo under-hung motor, but connected to a quite resonant membrane that lacks self-damping of the cone:

Then, a well-made Excel driver from of Seas, Norway, featuring magnesium. Pure magnesium has fair damping, but it's too brittle to use for membranes. After alloying towards more usuable properties, most of its damping is typically immediately lost. Probably as a result, these membranes could not be made very thin, as sensitivity is lower than expected from the lightest of all metals. Also, these drivers need low and steep crossover filters. The first resonance is as high and wide as the initial step:

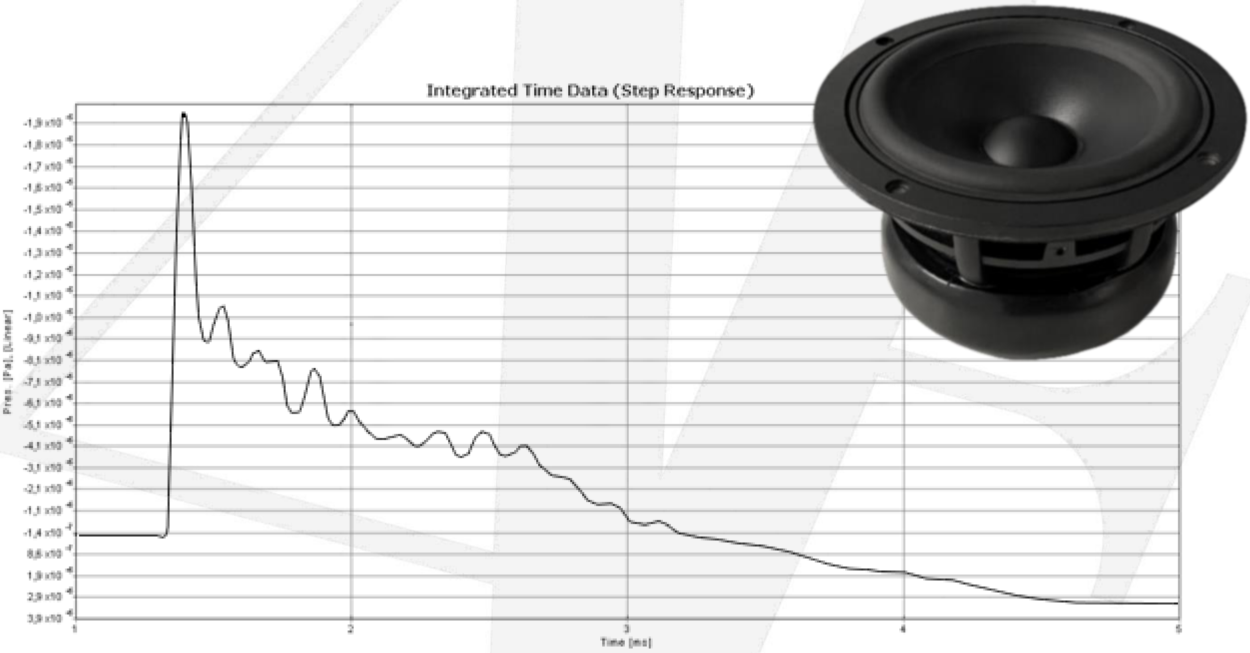
The site also lists a PP-mix driver made by Skaaning. This particular configuration seems to not excel in sheer speed but it was fitted with a well-damped PP-mix cone comparable to Stilla/Ensis:



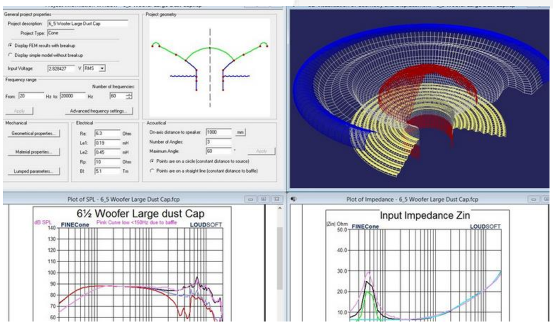
And another Danish design, now by Danisan: a midrange with almost equally well-behaved paper pulp composite membrane and a neo-magnet motor that is in speed more up to our standards:

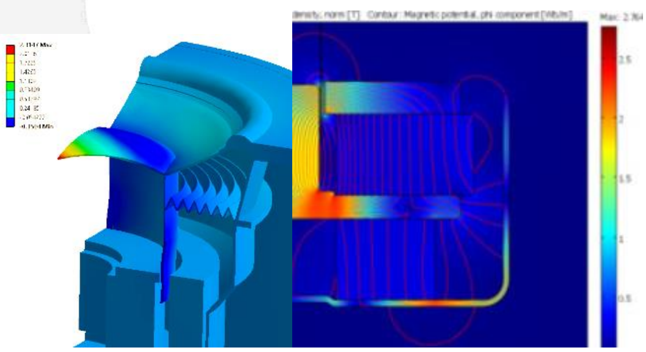
I think the gesture from these examples (and the many independent measurements of other high-end drivers out there) is evident: it clearly confirms that both PP mix as well as well-designed paper pulp composite membranes can provide for excellent performance without ringing. In contrast, just imagine what happens to sound reproduction if the initial pulse is followed by a resonant spike of significant amplitude. If well implemented and filtered, these metal/ceramic cones can perhaps provide for some short term excitement that is perceived in form of extra crisp and ‘detail’. But, soon it will lead to a perception of fatiguing unrealism. It may be a matter of taste, but I feel this approach will not suit the more critical listener looking for long-term genuineness. And don’t forget: such driver needs steep crossover filters (>second order), inflicting group delay. When looking for a midrange with sensitivity below 90dB, a modern paper pulp / cellulose composite membrane can indeed be a more than solid performer and combined with a fast motor it formed the most excellent choice for the ADAMANTIS.

To wrap up the topic of benchmarking membrane materials and their performance, I generated a similar graph, as measured under identical conditions, of the paper-pulp based midrange of the ADAMANTIS. It showcases lightning-speed combined with extremely well-mannered damping:

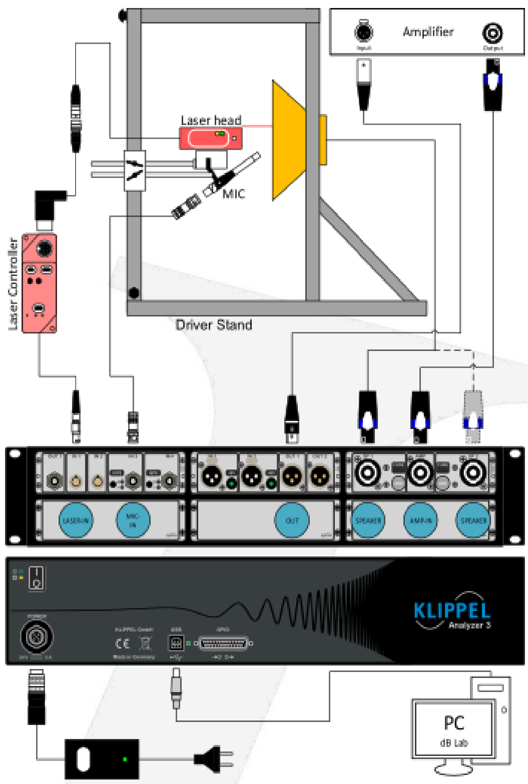


To maximise the midrange-driver’s total performance, the latest software simulations where used for the cone, coil and coil former, combined with surround and suspension, and computing models using Finite Element Analysis to optimise the low eddy-current, low induction (<0.15mh) motor behind it.

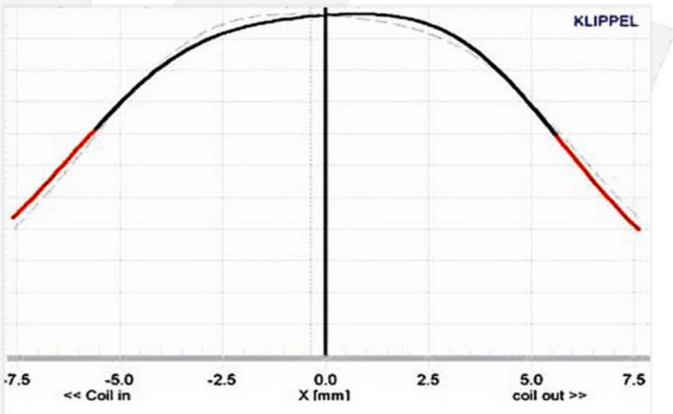




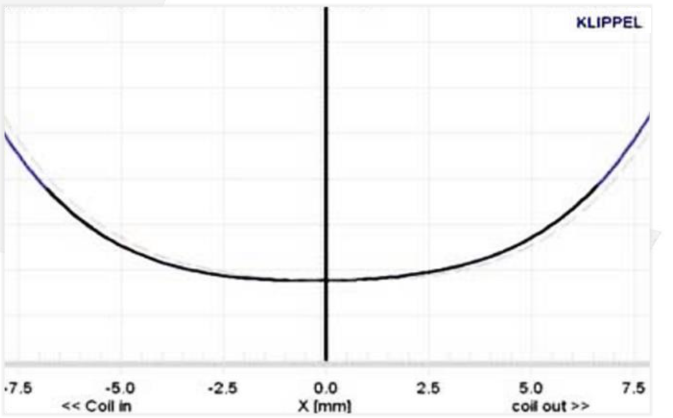
Last but not least, to evaluate and prove the combination of all electrical and mechanical driver parts, it was measured by laser combined with various other sensors (Klippel Analyser). With help of the laser sensor measuring the cone's movement, this setup is used to evaluate the driver's behaviour during its excursion. It shows what happens from rest position till maximum inward and outward excursion and if the sound will likely be compromised by too much variation, or loss, of its magnetic motor force, or inflicted by the mechanical variation of its suspension.



For the midrange we liked to see a linear excursion range potential of 5 or 6mm. In that area we want to keep distortion consistently low. We also want to see identical behaviour for inward and outward movement. Illustrated on the right, there is the amount of magnetic force for coil-in and coil-out movement. Within the -3mm to +3mm area, it has a very nice and constant grip on the moving parts with excellent left to right symmetry.



Then below it, we see the suspension's compliance. The suspension is the spider and the rubber surround that position the moving parts to keep them centred in the driver's structure. Their interference with the excursion movement must be minimal: if the line goes faster up this means the suspension starts to pull more and this can cause distortion and compression. The graph shows an ideal behaviour of this driver with excellent in-out symmetry. This means there is no unwanted interference.



The outcome of these plots is a clear indication of consistently immaculate sound reproduction at all listening levels, without the slightest hint of compression. All factors considered, this midrange is a more than equal match for the low and high frequency drivers. In practise, it simply sounds amazing.

Front cover, top and side panels and their surface finishes

Speakers often come with removeable fronts as some listeners prefer them without while some might better like them covered (and/or keep driver's from harms way). The problem of a removable grill is the fact that the phase response or the tune/voicing of the speaker can be optimum only *with* or *without* that panel attached. Even if the fabric is totally sound-transparant, such as is the case with the Stilla speaker, the dimensional properties, edges etc. will significantly affect sound. This is why the Ensis only comes without a fabric front and why the front of the Stilla is actually a fixed integral part of the cabinet (hence non-removable): compromises are impossible.

For the Adamantis we designed a fixed and extremely open hexagonal mesh front that allows an unobscured view of all three drivers surrounded by compressed wool felt covering the entire baffle. It is even 16% more open than the type of hexagonal mesh found on the famous diamond/ceramic drivers mentioned earlier in this paper and provides magnetic screening to all drivers behind it. To ensure vibration-free operation, it is reinforced by a solid 3mm rod fully along both sides of the front grill panel.

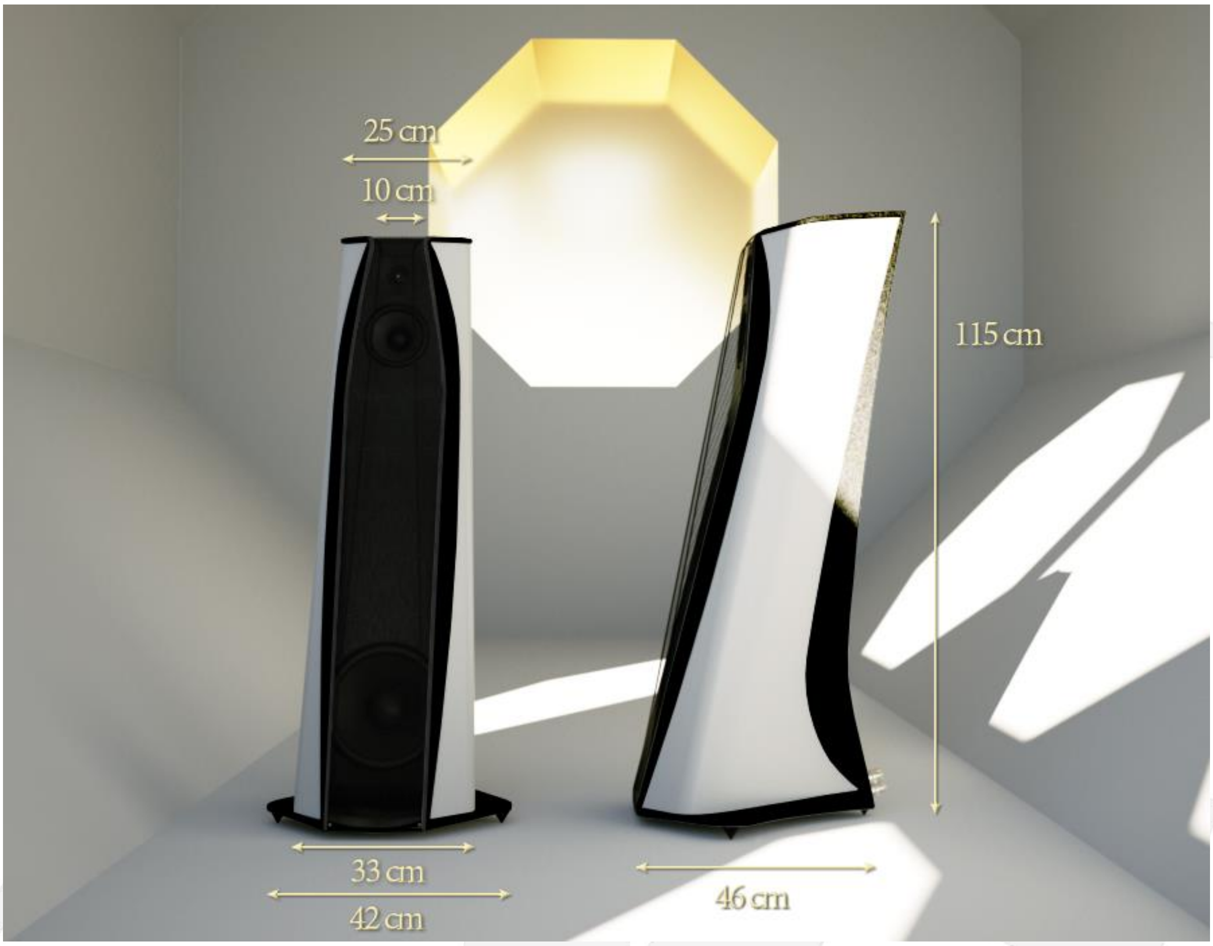
The company logo is flush mounted in the top panel that seals the crossover filter compartment:

Top and side inlay panels are made by multiple layers of different high-damping polymers (based on Epoxy resin, ABS and Acrylic/PMMA) in order to constraint each material's specific vibrational behaviour and they come finished in various high gloss lacquer colours such as white, black and red.

Optional available are metallic versions in white, ice-blue, dark-silver-grey, and beige-golden.

We will also offer some exclusive brushed metal and/or patina finishes as well as a large variety of beautiful real-wood veneers similar to the selection currently available for Ensis and Stilla.

Specifications



Description:	Passive three-way & three-driver floor-standing loudspeaker. Front loaded reflex port.
Drive-units: Low	SF-A-10-BR: Super-Fast 10 inch aluminium, large excursion capability, ported.
Mid	MF-NP-5: Mega-Fast 5 inch coated paper pulp composite, closed.
High	MF-TDR-40: Mega-Fast 40mm doped silk ring + fixed dome, EHDL™ tweeter system
Cabinet:	D I L U V I T E NANOCAST-MMC™ + inserts of D I L U V I T E NANOCAST-PMC™ assembled with eleven big high-tension bolts. Multi-polymer finishing-panels. Totally resonant free operation and perfect time alignment. Horn loaded 20hz reflex port just above the floor.
Front:	Absorbent compressed wool covered curved baffle. Inaudible super-open fixed grill.
Crossover filter:	Low order filter slopes with super wideband phase alignment, made with high quality Danish and German components. Precision value air-coils made on order, in a symmetric layout with audiophile PP (super)-caps and low tolerance super-resistors. Crossover filter is placed in separate enclosure, free from sound and pressure waves.
Wiring, Terminals:	Internal Aequo Audio cables: excellent conductive, dielectric, capacitive and inductive properties. Double set of genuine WBT terminals, suitable for Bi-amping (or Bi-wiring).
Freq. Response:	19hz - 40khz (-3db in-room response)
Sensitivity:	88db at 4 ohm nominal (minimum impedance of ~3 ohm).
Dynamic output:	Max full range linear stereo SPL >116db @ 500 watt (250 watt per speaker).
Recommended amplifier power:	Minimal 20W at 4 ohm nominal. Recommended power >50 watt. Long term maximum power handling of 350 watt, but higher peak-power is allowed.
Weight:	Approximately 80KG per speaker. ~200KG for a pair in wood crate packaging.
Feet:	Three M8 spikes are standard. Front spikes adjustable for tilt and/or uneven flooring.

Anti-vibrational cabinet performance

In order to best explain the cabinet enclosure's performance level, let's take a look at the two most important parameters for each material, stiffness and damping, as standard measured for low frequencies, and then add their density as an additional parameter of importance. Here we go:

Density/weight is already a factor taken into account when looking at energy dissipation, as heavier materials damp more energy on the way back to zero stress & strain at all frequencies. So, density is in effect already part of the damping loss factor. Higher frequencies need less energy to be damped. So, for instance, heavy compressed beech ('tankwood)' provides increased damping compared to plywood, due to increased friction between its cellulose particles, represented by its damping loss factor measured at low frequency. The fact that the difference in performance increases at higher frequencies can be partly explained by the difference in density. Density is however not taken into account of stiffness figures whilst it does influence anti-vibrational performance. Let's take two equally sized materials, with the same stiffness and damping factor, but different in weight. The heavier material of the two requires more energy-input to overcome its inertia and move/vibrate. As a rule of thumb, I use a formula that compensates for the role of weight, in order to make some sense out of all the mentioned properties for the use of solid materials at wide bandwidth frequency:

Wideband Performance Figure (in Gpa) = 2(stiffness x loss) + density x $10^9\ m^2\ s^{-2}$

The factor 2 that doubles stiffness x damping loss factor decreases the relative impact of density, as density is explained to be already part of the damping factor. Don't mind the last part of the formula; it only translates density to units of pressure gigapascal. Although oversimplified, in practise the value that is provided by this calculated performance figure proves to be a reasonable indicator of a material's anti-vibrational performance when considering it for a wideband frequency spectrum.

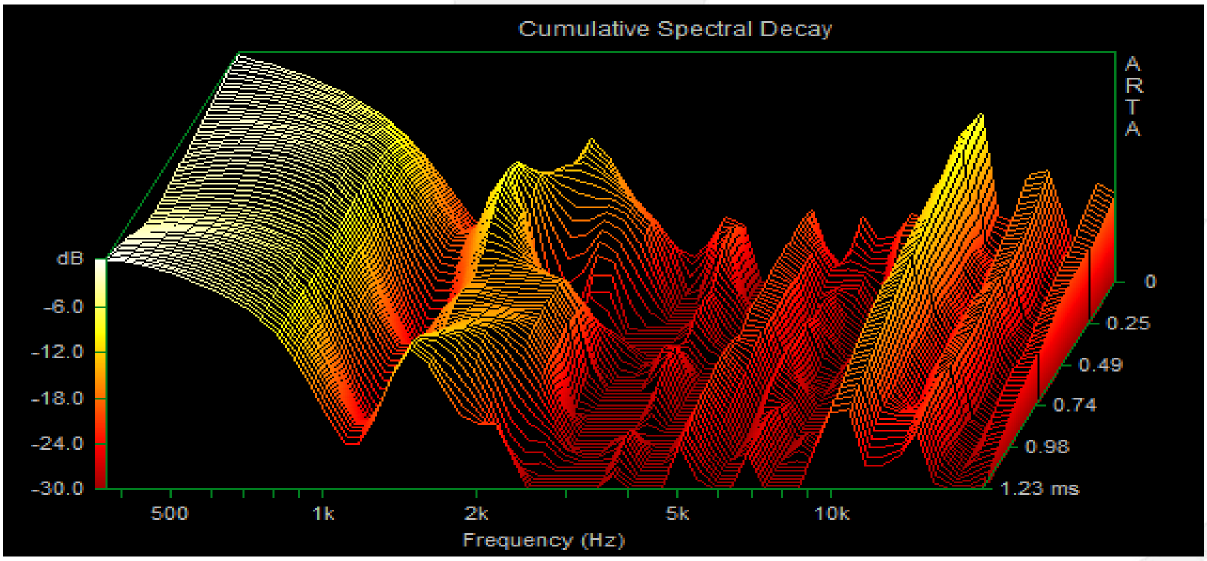
Material	Stiffness in GPa	Damping Factor tan	Density/weight in KG	WPF(performance) in GPa
Birch Plywood	8.0	0.020	0.62	**0.9**
HighCompressedBeech,(Panzer/Tankwood)	16.0	0.100	1.40	**4.6**
Epoxy	3.3	0.030	1.25	**1.4**
Aequo Audio Ensis/Stilla Arteficial Stone	60.0	0.040	1.90	**6.7**
Aluminium 'aerospace' alloy 6061	69.0	0.002	2.70	**3.0**
High quality Carbon Composite	100.0	0.008	1.50	**3.1**
NANOCAST-PMC™	9.0	0.240	1.00	**5.3**
NANOCAST-MMC™	125.0	0.022	7.00	**12.5**

The theoretical performance figure above is useful, but it can't take fully in account what happens at frequencies were resonant ringing, or break-ups, happen. Few of these materials are stiff enough to push such resonance out of the audible spectrum, and almost no material would be able to do so when used for larger structures (in a small tweeter membrane, aluminium still breaks up around 20 kHz). Although density helps to suppress HF vibrations, it's often not enough to overcome severe break ups, especially those of alloys and ceramics. This is important as the quality of an enclosure is limited by any unwanted sound it makes: even a resonance at one single frequency limits the overall performance. For example: if the total cabinet does -60db compared to the overall output level at all frequencies from <20 to >20kHz except at 800Hz where it suffers from a small but high resonance peak of -30db, the overall performance is then only -30db, as this will be the audible noise floor. Even without the resonance itself being in the audible band, its harmonics can spread into the audible band and again limit the noise floor. The D I L U V I T E materials are especially engineered to be free of that kind of resonance regardless of frequency, and perform therefore even better than the table above, based on its generic properties, would suggest. As far as we know, the MMC implemented in the ADAMANTIS is the first resonance-free metal proven by measurements from <1Hz - >100.000Hz.

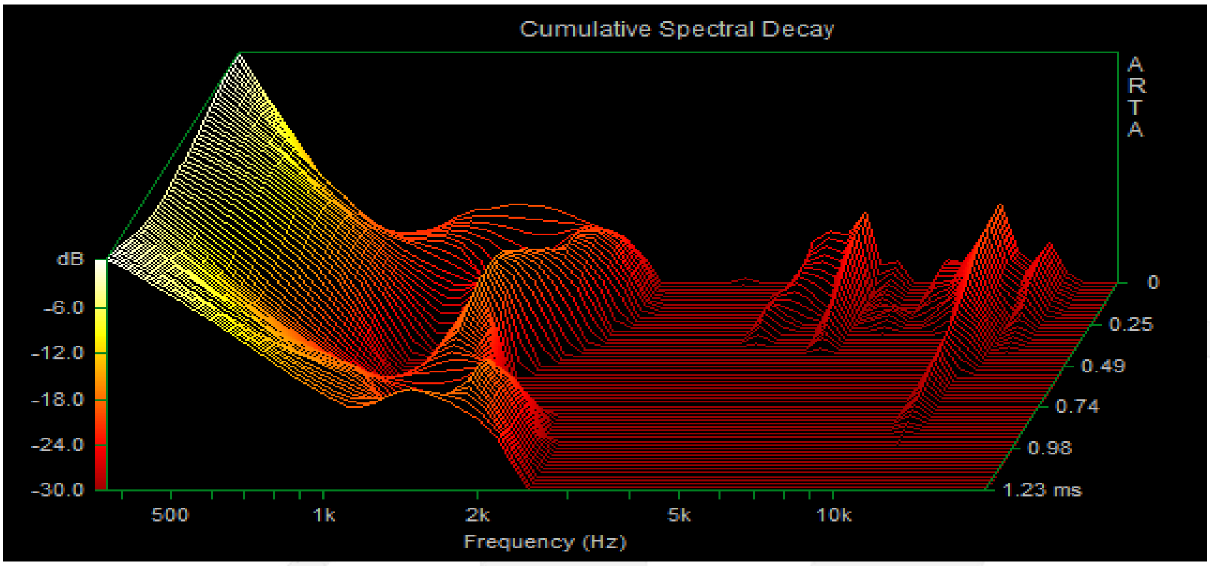
To prevent is better than to cure and our MMC does that very well too. As explained, stiffness and weight together with dimensional parameters make it harder for a cabinet to vibrate, as more energy is needed to move it. By this paraphrase you understand it needs some stiffness and weight before anything else. This can be achieved by a stiffer and heavier material or increased wall thickness. Looking at stiffness and weight of the materials, it is clear which material starts from pole position.

Some might argue it's not so bad if a cabinet allows some sound to be (re-)emitted as long as it is not too delayed (time domain distortion). In that case, to reduce delay, lots of damping is required and somewhat equal over all frequencies. Only then it can become useable as output to add some overall sensitivity. While for some cheaper solid wood speakers this might be satisfactory, most high-end speaker manufacturers will strive for zero cabinet-talk, including us at Aequo Audio. And if for cost reasons we would go this route of using a less stiff but very well damped material, NANOCAST-PMC™ would then surpass any other available material or composite, given its also excellent wideband properties needed to provide instant extra sensitivity, without spoiling the overall sound emission. This could be especially interesting for loudspeakers such as high performance studio monitors. In comparison between ADAMANTIS and earlier high-performing materials of Aequo Audio, the 'WPF' of artificial stone compared to that of MMC suggests that we could go from 10 to 5mm as minimum wall thickness. When applied as such for ADAMANTIS it became clear that then still MMC excels by being totally resonant free regardless of frequency. This makes MMC less in need of extensive bracing or a second material to damp resonance, such as were needed in Ensis and Stilla. Having the brand-new materials at hand we could not resist: we still added the decoupling inserts made of PMC.

What does all this material theory mean in practise? Let's compare two stiff materials suspended in a damping polymer: Aluminium 6061 and NANOCAST-MMC™. I used a pink noise cycle to excite the material sample and measure the resulting amplitude and its decay per frequency using a wideband accelerometer. To evaluate the practical outcome we can look at the area where the small sample plate has its natural break up behaviour. It quite meticulously represents the acoustic material's performance when actually used in high-end speakers featuring some kind of viscoelastic damping enhancement. Measurements were taken under identical circumstances, equal in physical setup and settings, software and graph settings, and the exact same time window in moment and duration, to see what happens in the next 1.23 milliseconds. During this time-window close to the original sound, we can't use our brain to naturally filter out decay/reverbs. It will therefore affect point source perception. After this, the remaining amplitude simply sounds like typical distortion, experienced as delayed ringing, resonance or compromised signal to noise ratio. Up first, aerospace quality billet aluminium 6061 alloy, showing a nasty ringing mode around 10kHz, with slow and lasting decay:



Then, NANOCAST-MMC™, showing much less excitement and amazing levels of damping:



The same applied energy has clearly more trouble putting the NANOCAST-MMC™ sample in motion as represented by the decreased acceleration/movement below 3kHz (thanks to stiffness and weight). We also observe that the plate's natural dimensional resonance has moved up in frequency thanks to additional stiffness. But the real remarkable performance at display, is that it turns dead almost instantly! This was still only a thin flat rectangular plate. When combined with smart physical design that uses curves, variable wall thickness as well variable panel dimensions to prohibit physical resonance, the absence of resonance goes far beyond best-in-class standards of speaker enclosures.

The research also helped to answer an important question: are these new composites significantly different from, and better than, other recent implementations of Nano-materials? I have been following the developments for many years, and for our own projects we looked closely at the latest papers and offerings, especially those using the two most hyped candidates: Graphene and Carbon Nano Tubes (CNT's). Graphene is a layer of carbon atoms, strongly bonded in a hexagonal lattice, with a thickness of about 200 times smaller than a human hair. Although it has some exciting scientific applications, it is so thin that it barely affects the mechanical performance of audio gear (including membranes), if at all. Although some find it a nice marketing statement, the extreme stiffness numbers apply only in-plane of the layer. Graphene can't be strongly bonded in multiple layers and after more than 10 layers it's not even longer considered to be Graphene (transparent), but graphite (grey). CNT's are rolled up and closed layers of Graphene, that have much more interesting three-dimensional properties however, adding them to acoustic materials is mostly a disappointing exercise: stiffness goes impressively up, but with just as (un)impressive decrease of damping capabilities. Also, as the extreme molecular (Van der Waals) forces between the tubes make them to clutter and hard to evenly disperse, it often results in unpredictable structural properties or even in cracks or ruptures.

By this time, countless samples of our composites as well as many materials and composites were tested in a project with the local university. Time over time the outmost remarkable anti-vibrational properties of NANOCAST-MMC™ (that makes up most of the new speaker's cabinet) remain rock-solid and crystal-clear: this could very well change the future's landscape of high-end audio components. In order to facilitate the technological progress in the industry involved in our precious hobby, especially those manufacturing the other components found in the rest of the audio system, we decided to make the ground-breaking anti-vibrational Nano composites available through the D I L U V I T E Company. I expect for this technology to make a significant impact on the whole audio system, providing higher levels of aural bliss for you, me and everyone sharing the same musical passion.

Dynamic performance

At Aequo Audio, we are proud and honoured to see that listeners and hi-fi experts agree on the unparalleled performance of the Stilla loudspeaker at its price and size, with easy amplifier matching on top, providing huge savings on the system's budget. The key feature behind this is the hybrid active/passive technology of our Analogue Room-size and Placement Extension Control (ARPEC™). This device listens in on the signal towards the passive mid/high section, without affecting the easy closed-box 8 ohm nominal impedance curve presented to the user's amplifier for driving the speaker. So without affect or alteration of the signal, it takes this voltage, enables some useful adjustments on it, and then feeds it to two 250W NCore modules. These modules effectively supply the current needed for deep and taut bass delivered by the 7 inch bass drivers. These are the main benefits:

- The active controller lets the bass-driver play as if it is in a big speaker enclosure. How big exactly will depend on adjustments chosen by the listener (and in such way it matches low freq. room-gain).
- Big sound still applies when connecting to smaller power amplifiers, or class A and tube amps.
- Active filtering can be applied on the bass drivers; enabling operation without large and potentially distorting (iron-core) crossover coils, and enables better phase alignment with the midrange.
- The mid-bass driver plays passively in full range with a natural roll off around 100hz, without any caps in line and as low as possible in order to give great transparency and speed in the upper bass.

All that upper bass speed, pure and without crossover parts, is a real delight to experience when listening to music. The 5 inch mid-bass driver developed with Skaaning does simply a great job in low-distortion realism and openness. When switching to the D I L U V I U M concept however, now a 9 inch woofer takes care of the upper bass area, opening new registers of immense dynamic power. In that prototype we use an additional driver-specific amplifier to provide for coil-free active filtering (fully analogue and without DSP, as is our custom). For the new passive speaker, we wanted to keep that dynamic air shuffle, especially in the upper bass regions, without losing too much of the qualities specific for our hybrid-active approached loudspeakers. So, not much unlike other speakers in the most exclusive corner of best-performing and large-sized passive three-ways, we filter the bass driver with a low-pass around 200 Hz. In order to achieve perfect time and phase alignment, we put extra attention into aligning the lower woofer with the other drivers by designing the cabinet in such ways that this bass driver is positioned much (!) more forward toward the listener. By doing so, we entirely removed the typical blur as often suffered from with many tall passive and multi-way floor-standers.

A bit higher crossover point than the 100hz found in Stilla and Ensis, requires less induction by the coils as are necessary for the now passively filtered woofer. It also enables the ADAMANTIS to move large quantities of air in the upper bass region, much like the D I L U V I U M, and matched only by some of the world's most famous contenders. For listening music, this adds a feel of luscious thrill and a more 'live' experience. At the same time, relieving the midrange of bass duties made it possible to optimize it instead for speed and detail in ways these would have otherwise compromised the upper bass area. This higher level of specialization for midrange frequencies, allowed us to vastly improve musical reproduction qualities in terms of openness, resolution and natural cleanliness. To complete the driver-trio, we could not decide for anything else but the Ensis tweeter to complement the overall potential of ADAMANTIS. And did I already mention our new passive loudspeaker with horned port at 20 Hz plays up to twice as loud in the lowest registers as the already impressive Ensis does?

The new speaker profits from every step up in connected amplifiers and other electronics. It does need some current to fully benefit from the almost limitless dynamic reserves (reached from around 200 watts and up), but when connected to proper supplies of power, and after some effort in the speaker's placement setup and its environment, it really shines. It can even take listeners passed some specific qualities offered by Stilla and Ensis, especially when comparing it on sheer enthusiasm of live-concerts at real live listening levels. It came out to be one heck of a mighty speaker indeed.

Summary and conclusion

Since the start of Aequo Audio in 2012, we have been looking for ways to use better performing material combinations in our loudspeakers. Straight from the beginning we have developed and implemented new composites with superb properties such as Grey Matter Compound™ (a high damping tungsten-based composite) and our artificial stone (a ceramic composite with stiffness and weight comparable to granite, but much better damping loss). The big breakthrough came in form of our inventions using Nano technology to push the combination of stiffness and damping loss to new heights. The great price proposition is something just as significant when looking at the cost of some other Nanotech implementations out there and the ADAMANTIS is the first fine example of that.

In this paper I tried to give an idea of the unique properties of the new exciting materials at hand, but also on the work spent on the three-dimensional cabinet design and optimization of all structural and acoustic parameters. Within our company we clearly have committed to a strategy where we are not only ahead in speaker technology, but also shift the centre of gravity in workload towards engineering and design, rather than production labour. On the long term, it means we can keep production and assembly in-house and keep strong focus on quality and impeccable craftsmanship.

As for the drivers, we took readily available technology from the more expensive Ensis and Stilla loudspeakers were possible, and made the necessary alterations for the ADAMANTIS without any holdback or constraint. In case of the midrange, this meant an all-new driver. Although its paper composite membrane may hint to being something less fancy than beryllium or carbon, its actual properties are state-of-the art and its performance is among the best found in high-end audio. This approach is a clear indication of our fact-driven and value-driven approach in use of technology.

Rather than being limited by a lower price than that of Ensis and Stilla, ADAMANTIS has profited from various upgrades where possible. That does not only count for cabinet materials, but includes the implementation of the mega-fast Ensis tweeter in combination with the compressed wool baffle and horn loaded port features similar to those found in Stilla. It's clearly bigger and heavier than those other two speaker products and we'll leave it up to you to decide if that's a good or bad thing. Probably more important is that its increase in size does not come at the cost of soundstage and imaging. This new speaker is again at the top of the food chain in that area. In general, we don't position this speaker below Ensis or Stilla, but in a different category altogether. It is by definition a loudspeaker that suits the vast amount of audiophiles that don't mind to use bigger speakers and paired electronics, or the fact that they will have no active placement adjustments to their disposal.

Nonetheless, it has the Aequo Audio signature written all over it. In the fully passive-loudspeaker domain, I feel that the ADAMANTIS can in fact be considered to be more graceful, smart and uncompromised in performance than any of its counterparts. Its elegant form-follows-function enclosure has much more internal volume than anyone seeing it would suspect. Both human as well as computing intelligence helped to design the Nano-composites and the totally resonant-free cabinet made of them. The use of low diffraction edges on the slim, variable-width baffle, the EHDL™ tweeter and the special low frequency tuned front port, will make in fact for an excellent proposition of extreme high fidelity in a variety of listening-rooms, without the need of excessive room-treatment.

Anyone deciding to stay or go fully passive, will benefit from the unique features of this new powerhouse and its performance potential at levels never possible before at this price point. All those seeking deep-sea bass, a wide open transparent sound, and densely palpable projections in an extended full-venue landscape, have to look no further. They will be in for a bold, thrilling, but never fatiguing experience in which they are fully transported to where the music originally happened. Our whole team feels gratitude for taking part in the journey to deeper musical connection, and perhaps enabling an additional -and very important- group in the global audio community their progress in it.