

NEW DIAPHRAGM FLAX SANDWICH

Patent
N° W02014/106713 A1



 **FOCAL**[®]
THE SPIRIT OF SOUND

THE SEARCH FOR THE HOLY GRAIL OF DIAPHRAGM TECHNOLOGIES

DIAPHRAGM TECHNOLOGIES

More than 30 years of Focal tradition

The drive unit is at the very heart of Focal's work. For more than 30 years we have been exploring the possibilities offered by revolutionary new materials in order to develop the ideal loudspeaker diaphragm. The list is long: Polyglass, "K2" sandwich, "W" sandwich, Kevlar, titanium, Tioxid, beryllium, aluminium-magnesium.

The diaphragm is the critical interface for the transducer; it is what sets the air molecules in motion, and the fidelity of the transfer depends on the intrinsic qualities of the material used. Ideally, a diaphragm should satisfy three key but contradictory criteria:

- it must be light so that it will accelerate quickly.
- it must be rigid so that it functions like a piston,
- it must be well damped so that it does not colour the sound.

Across our whole Home, Car and Pro ranges we currently use two different diaphragm technologies for mid-woofers: Polyglass for the less costly ranges, "W" and Kevlar sandwich, with their outstanding qualities, for our top of the range products. (The "K2" sandwich is derived from and very similar to the "W" sandwich). Because the "W" sandwich has to be manufactured by hand, its range of application remains limited for reasons of cost.

Glass sandwich for rigidity

In the course of the last few years, many innovations have appeared as a result of engineers revisiting **natural materials and combining them with modern composites**, thus creating new types of hybrid material. There are very few solutions using a single homogeneous material that satisfy the three key criteria set out above. Solutions using a mixture of materials offer a much wider range of possibilities. Sandwich construction using thin skins of fiberglass, with which we are totally familiar thanks to the "W" sandwich,

remains the supreme method of controlling rigidity.

What material for the core?

The core of a sandwich material provides the mechanical damping, which is responsible for the sonic neutrality of the diaphragm. We wanted to make use of non-woven fibers which could be formed into a sandwich cone by a stamping process in order to automate the forming process. This would make sandwich construction, which has hitherto been reserved for top of the range applications, available to a wider range of products. With the "W" sandwich the only way to form the core in Plexiglas foam and to apply the fiberglass skin is by hand.

Flax very quickly became a serious candidate. France is the main cultivator in Europe of fiber flax, principally in Flanders, Picardy, Normandy and the Pas-de-Calais region. French flax is considered the best in the world.

Flax is one of the oldest textile fiber, which has been cultivated since the 4th Century BC and which was used by the Egyptians as a protective cloth for mummies. A bundle (called "technical fiber" in spinning) is composed of ten to forty fibers. Each fiber is a single, very elongated cell, 6 to 10 centimetres in length and with a diameter of 7 to 40 µm, composed of 70 to 80 per cent cellulose.



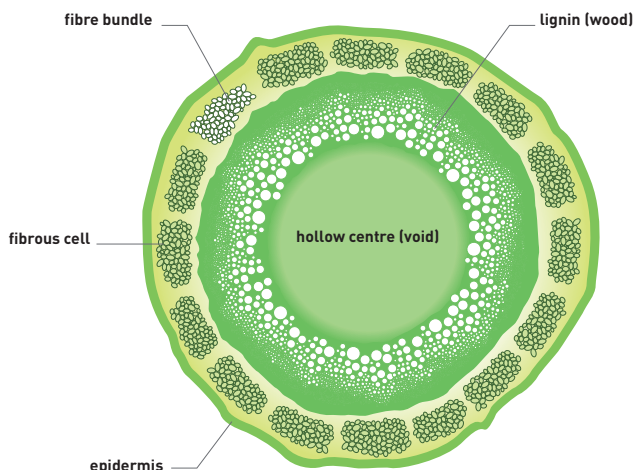
The unique qualities of flax Composite materials have properties suitable for applications where both rigidity and low mass are required. However, their disadvantage is that they lack damping, which leads to very poor control of vibrations. Often, as in the case of sports equipment, it is necessary to apply damping materials to absorb the intrinsic vibration of the material. It is clear that this is a particularly critical issue for loudspeaker diaphragms, one which requires us to ensure that there is sufficient internal damping within the structure of the material. Recent developments in this field combining composites and natural fibers have brought unexpected opportunities. **Flax is twice as light as fiberglass, because the fiber is hollow.** It also has very low elasticity which makes it ideal



PS 165FX (high-end powerful new Car Audio 2-way component).

to increase the flexural rigidity of our sandwich. Moreover, it can be obtained in non-woven bundles of considerable diameter and it can therefore produce the thickness required for a sandwich. Synthetic fibers or foams originating from petrochemical resources are subject to inflation linked to the sharp rise in crude oil

prices. Organic or ecological textiles, like flax, are thus becoming more and more price-competitive. Flax combines the three key factors required of the core of a sandwich material for loudspeakers: it has low density, a high tensile (Young's) modulus of elasticity of up to 60GPa, and excellent internal damping.



Flax offers unique qualities: light because it is hollow and very low elasticity. It constitutes a choice suitable for the manufacture of the core of a sandwich structure.



France is the largest producer of flax in Europe. French flax fiber is considered one of the worlds best. Cropped in Flanders, Picardy and Normandy it enjoys very favorable climatic conditions.

Performance comparison of various solutions

Many prototypes have been developed by Focal in the course of the last two years using diaphragms made from single materials (including metals and thermoplastics), composites (with thermosetting, thermoplastic and acrylic matrices) and even in coated paper. We very quickly restricted our choice to composite/sandwich structures: single-skin structures with a pre-impregnated glass fiber face and a rear woven or non-woven linen face, and sandwich structures with internal and external skins in pre-impregnated glass fiber on a core of braided or non-braided flax, with straight or semi-exponential cone profiles. A measurement report was developed internally to make

our research less empirical. At each stage test samples were produced to assess the mechanical performance of the new structures. To provide reference data, test samples of Polyglass and "W" sandwich in different thicknesses, as well as aluminium and glass fiber, were also produced so that we could validate our experiments with reference to known materials. Five criteria were analysed, with results that are shown in the graphs which follow. The designations for the sandwich structures are:

- "W" sandwich/Focal patent: introduced in 1995, this is a sandwich with glass fiber on both sides of a core of acrylic/Plexiglass foam.
- "F" sandwich/Focal patented in 2013 (N° 1350116): this is a

sandwich with glass fiber on both sides of a core of flax. It will be used in Focal products from 2013.

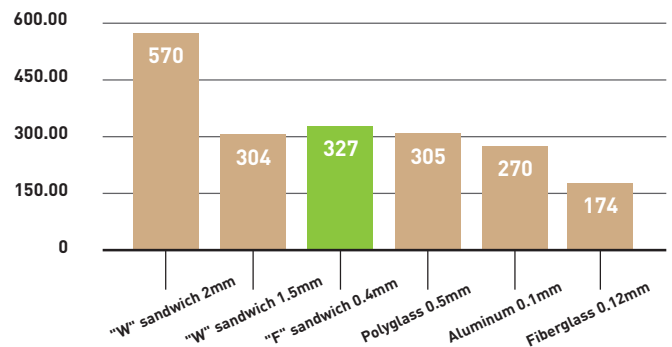
Low mass – a guarantee of high dynamic performance

[Graph 1] For a 165mm mid-woofer, the mass of the diaphragm required to conserve good sensitivity is of the order of 10 grams. This corresponds to an ideal surface mass of the order of 300g/m². The diagram opposite shows that a 2 mm thick "W" sandwich due to its mass is more suitable for application in pure woofer. Aluminium needs to be used in a very fine thicknesses of 0.1mm, which is completely impractical. It appears in the list only to validate the coherence of our tests.

Flax sandwich
Details for midrange driver



Graph 1: Surface Mass in g/m²





Car Audio "Flax" component kits: 100% Focal technology for the new high end of Performance Expert range.

High tensile modulus – a guarantee of extended frequency response

[Graph 2] Young's modulus represents the mechanical load which would cause elongation of 100 per cent of the initial length of a material, if it were possible to apply it. In reality, the material is permanently deformed or breaks well before this value is attained. If the Young's modulus of a material is high it is said to be rigid. It is easy to understand that the higher the Young's modulus of the core of a sandwich

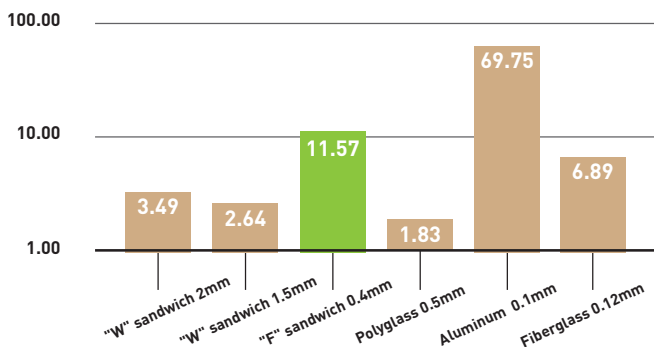
material, the more resistant to bending it will be and the better a loudspeaker diaphragm made from the material will function as rigid piston. Flax has a high Young's modulus of 60GPa, of the same order of magnitude as the glass or Kevlar fibers or aluminum.

High internal damping – a guarantee of neutrality

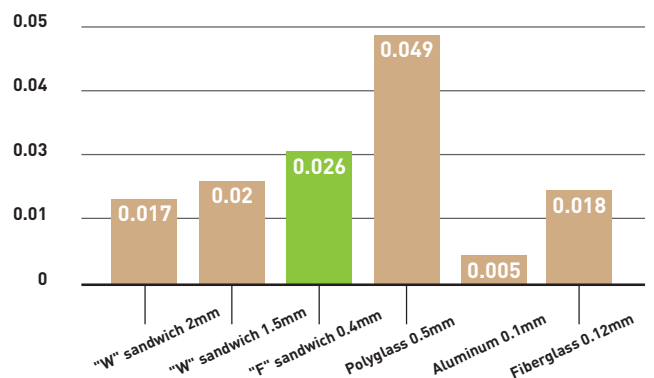
[Graph 3] Internal damping is characterised by a coefficient known as the dissipation factor. At the diaphragm's "breakup" frequency, the

higher the dissipation factor, the less severe the resonance as surplus energy is dissipated within the material. This is a guarantee of low coloration, of true tonality. Aluminium has very poor damping qualities, which disqualifies it irretrievably. Polyglass, with its cellulose pulp base, is excellent in this respect (the reputation of 'paper' diaphragms is already well known to loudspeaker designers); "F" sandwich performs very well too.

Graph 2: Young's modulus in GPa (logarithmic scale)



Graph 3: Dissipation factor tan delta



High speed of sound in the diaphragm – a guarantee of definition

[Graph 4] An important criterion, the speed of sound propagation in a diaphragm is directly proportional to its breakup frequency. The speed of sound of the flax sandwich is on a par with that of the "W" sandwich, with a value double that of Polyglass. High velocity of sound is also a

guarantee of high definition in the midrange. Polyglass, which was introduced nearly 30 years ago, now falls far short of the hybrid materials developed by Focal in the interim.

High flexural stiffness – a guarantee of well controlled bass

[Graph 5] This parameter defines how stiff the diaphragm is in bending. High bending stiffness is an essential criterion for a diaphragm working at bass frequencies, where significant differences in the air pressure on either face can otherwise cause deformation. High flexural rigidity brings a material close to the theoretical ideal of a diaphragm functioning as a rigid piston over its entire passband.

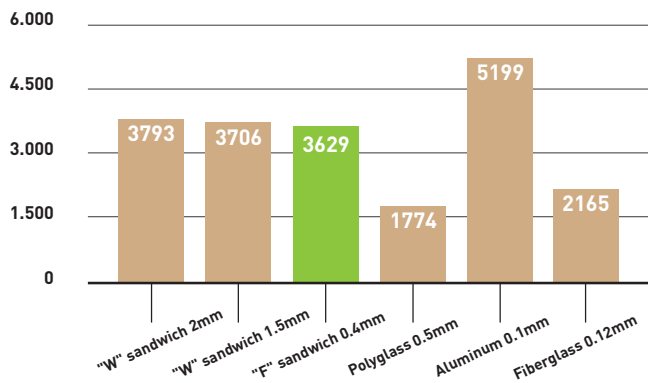
The advantage of sandwich construction is obvious here since flexural rigidity increases with diaphragm thickness. As the lower graph shows, the "W" sandwich is without rival in this regard. Despite its relative thinness, the flax sandwich is nearly three times stiffer than the thicker Polyglass alternative.

Summary

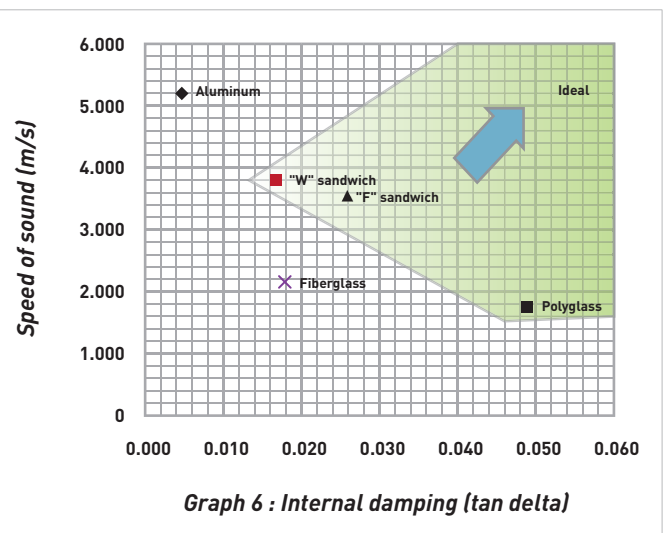
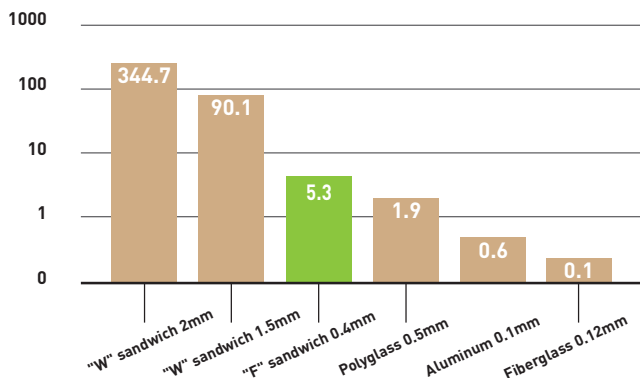
To design a high performance diaphragm you have to optimise a complex set of criteria, which are for the most part contradictory. The composite solution using flax in a sandwich structure with fiberglass skins is a very harmonious way of combining low mass with high internal damping, high velocity of sound and high flexural rigidity.

[Graph 6]

Graph 4: Speed of sound in m/s



Graph 5: Flexural rigidity index (logarithmic scale)



Graph 6: Internal damping (tan delta)



2013 new product - Aria 948 Black High Gloss
Between Chorus and Electra, the Aria 900 line will be the first to be equipped with "Flax" cones.

Based on these analyses, the diaphragms were manufactured to evaluate, in full scale, their performance in a blind listening trial. We decided to conduct the tests using a Chorus 806V and a Chorus 806W. Focal has a long tradition and recognised expertise in designing two-way bookshelf speakers, which require a mid-woofer whose diaphragm must satisfy all the contradictory demands already identified: high rigidity for good bass combined with high internal damping to avoid coloration in the midrange. All the prototypes not using sandwich construction were rejected because their bass

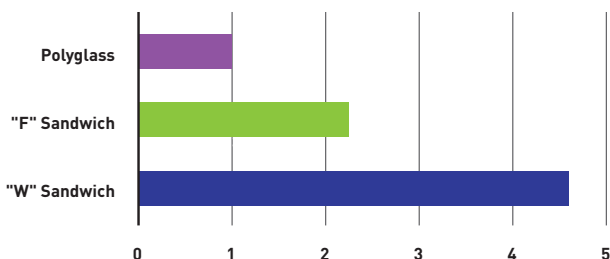
performance was inferior to that of Polyglass. Flexural rigidity can also be improved by adjusting the geometry of the cone. The semi-exponential profiles give very good results, for example, with Polyglass because we reinforce the stiffness. With the sandwich structures, which are intrinsically stiffer, we have favoured straight cones as they deliver tighter bass.

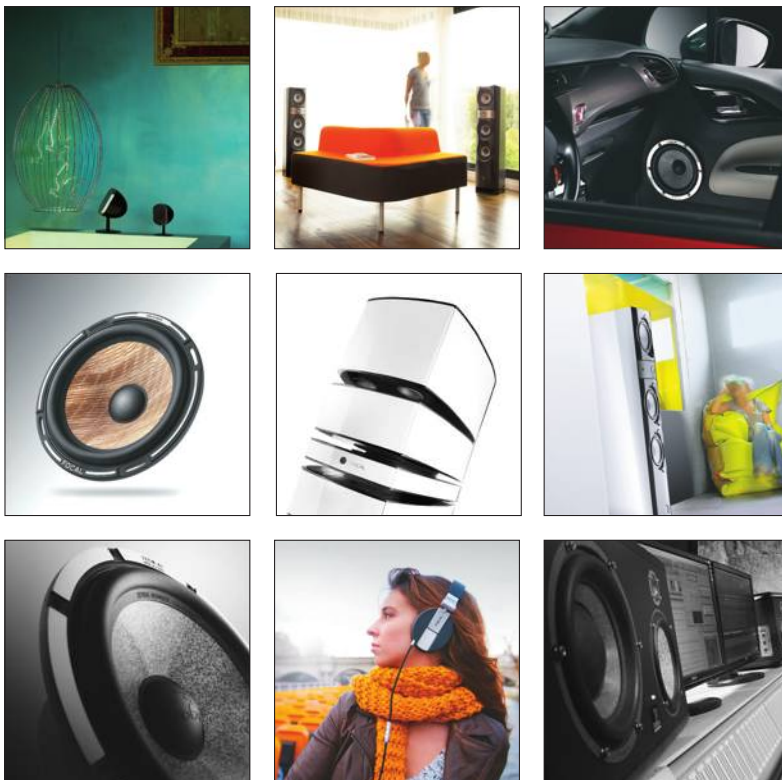
richness of reproduction in the midrange register. Moreover, the industrial process developed to manufacture this material bring it within reach of product ranges such as Aria 900 for the home or Performance Series for the car, very price-competitive ranges which could not aspire to the "W" sandwich for reasons of cost. [Graph 7]

The "F" sandwich based on flax has a promising future: its qualities in the midrange are in total accord with our brand values, since Focal sound is characterised in particular by the



Graph 7: Relative cost / Polyglass base










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