The invention provides a sports helmet having a forehead end and a neck end and a longitudinal direction connecting said forehead end and said neck end. Said sports helmet comprising an impact attenuation layer comprising a layer of expanded material comprising an expanded polymer material, and an outer shell of a fibre-reinforced material selected from self-reinforced polyethylene and self-reinforced polypropylene, said layer of expanded material having a thickness of 0.5-3.0 cm and a density of 20-100 kg/m³, and said outer shell having a thickness of 0.2-0.95 mm. Such a sports helmet is light weight and flexible and can be used as a multi-sports helmet.
Flexible sports helmet

Field of the invention

The invention relates to a flexible sports helmet.

Background of the invention

Many types of sports helmets are known. Usually, each sport requires its own helmet, for instance for skiing, (ice)skating, and cycling.

US20080172774 discloses in its abstract an in-mould helmet, comprising a shell and a blow-moulded layer of shock absorbing material inside the shell. The in-mould helmet is provided with penetration protection, at least partially, between the shell and the shock absorbing layer. The invention also concerns a method to produce an in-mould helmet, comprising the steps of vacuum forming a shell, arranging penetration protection inside the shell, and blow-moulding shock absorbing material inside the shell.

Summary of the invention

The invention seeks to provide a sports helmet that is comfortable to wear and use. Furthermore, the invention seeks to provide a sports helmet that can be used for several sports.

The invention provides a sports helmet having a forehead end and a neck end and a longitudinal direction connecting said forehead end and said neck end, said sports helmet comprising an impact attenuation layer comprising a layer of expanded material comprising an expanded polymer material, and an outer shell of a self-reinforced polymer material, said layer of expanded material having a thickness of 0.5-3.0 cm and a density of 20-100 kg/m³, and said outer shell having a thickness of 0.2-0.95 mm.

It was found that such a helmet can be made thin, flexible and lightweight, which is comfortable to wear and use, in particular in sport activities. It was found that a sports helmet can be provided that can be used for several sports. Such a helmet should comply with various formal requirements set out in various official requirements. It was found that a helmet could be made that complies with requirements, like for
instance EN 1077 and/or EN 1078. Furthermore, the sports helmet complies with ASTM F1849. In particular, it was found possible to make a sports helmet that is lighter than 350 gr for a sports helmet of size "large" or "L". Usually, the size "L" is made to fit a head with a circumference of 57,0 - 59,5 cm. In particular, it was possible to provide such a sports helmet for skiing, ice skating and/or cycling that weighs less than 310 gr, and still complies with the above-referenced requirements.

A further advantage is that the sports helmet can be flexible. The shell material thickness allows bending by hand. And yet, the sports helmet complies with all the requirements of strength and impact resistance. The flexibility allows temple sides to be folded towards each other. This makes the helmet more adaptable to the shape of the head of the wearer/user.

Thus, the invention allows producing a multi-sports helmet, i.e., a sports helmet that complies with different requirements for different sports. In particular, the multi-sports helmet fulfils the user requirements and formal requirements for at least cycling, ice skating and skiing.

In an embodiment, the outer shell and the attenuation layer can be separable form one another. Thus, the outer shell may be removed from the attenuation layer to be replaced, cleaned, or stored.

Self-reinforced in the context of the invention refers to fibre-reinforced material in which the fibres and matrix material are from the same polymer type. For instance, the fibres can be polyethylene (PE) and the matrix material can be polyethylene (PE), or the fibres can be polypropylene (PP) and the matrix material can be polypropylene. These materials are light weight and can be recycled easily. Other polymer materials that may be used are polyamide (PA), for instance nylon. Further alternative include polyester, for instance polyethylene terephthalate (PET). This in general does not mean that the polymer of both components is exactly identical.

A suitable material in an embodiment is for instance disclosed in EP1787790. This material is suitable for the sports helmet of the invention. Self-reinforced in this context refers to a thermoplastic composite, wherein the thermoplastic composite comprises a matrix and a reinforcement, both issued of a semi-crystalline polymer, which are preferably of the same class.

In an embodiment, both the matrix and the reinforcement are issued from a semi-crystalline polymer of the same class. So far, these materials have been thermoformed...
in a non-isothermal process, similar to the traditional composites. Highly oriented semi-crystalline polymer molecules can serve as reinforcement for a non-oriented matrix of the same class of semi-crystalline polymer. The result is a single type 'self-reinforced' material the melting point of the matrix, generally indicated by the DSC melting point as defined in ISO 11357-3, is lower than the melting point of the reinforcements.

The term "same class" in an embodiment means that both matrix and reinforcement are based on polymers comprising the same majority of monomeric units. For instance in case a polypropylene reinforcement is used, the matrix of the same class will also be formed by a polypropylene and that if the reinforcement is a polyethylene, the matrix of the same class will be formed by a polyethylene.

In an embodiment, in case of the use of polypropylene as the material for the composite, the material for the reinforcement will preferably be a homopolypropylene, preferably having a relatively high molecular weight, such as an average molecular weight of at least 250000 and a melting temperature of at least 160 °C. It is to be noted that the reinforcement preferably consists of one material only, but that in case of recycle of production scrap, minor amounts of the material of the matrix may also be present in the reinforcement. This will generally not exceed 10 wt.%.

The material of the matrix in this embodiment is, as indicated above, also a polypropylene, preferably a copolymer of propylene with ethylene or another a-olefin. It is preferred to use a propylene ethylene copolymer, having an ethylene content of between 1 and 25 mol % and a propylene content of between 75 mol % and 99 mol %, as the material for the matrix, in particular if the central layer is a polypropylene. It is also possible to use blends of two of these materials.

In an embodiment in case of the use of polyethylene, basically the same considerations apply. As reinforcement an HDPE is preferably used, i.e. a polyethylene having a density of at least 950 kg/m3. The weight average molecular weight is preferably at least 250000 and the melting point is 130 °C or higher. It is to be noted that the reinforcement preferably consists of one material only, but that in case of recycle of production scrap, minor amounts of the material of the matrix may also be present in the reinforcement. This will generally not exceed 10 wt.%. 


The matrix is preferably also a polyethylene, but now with a lower melting point, the difference being at least 10 °C. Suitable polyethylenes are random or block ethylene copolymers, LLDPE, LDPE, VLDPE and the like.

The impact attenuation layer comprises a layer of expanded material. Nowadays, usually these materials are expanded polymer material. Known expanded polymer materials are expanded polystyrene (EPS), expanded polyethylene (EPE) and expanded polypropylene (EPP). Often, these materials are also referred to as foam. In general in order to be usable and be suited as "impact attenuation layer", they should be able to withstand a compression force without being completely compressed.

The expanded polymer material can be expanded polyethylene (EPE), expanded polypropylene (EPP). These materials are very suitable, for instance due to their elastic properties. Another suitable material is expanded polystyrene (EPS). Although less elastic, it often is cheaper to produce.

In an embodiment, the expanded polymer material is a closed cell foam. This has good impact properties and may provide elastic properties.

In an embodiment, the expanded polymer material is selected from expanded polyethylene and expanded polypropylene. These materials provide excellent recyclability, in articular with the material of the outer shell. In another embodiment, the expanded polymer material is polystyrene (EPS). Usually, the expanded material is provided in the form of expanded beads. These beads are provided in a mould and subjected to hot air or steam treatment.

In an embodiment, the impact attenuation layer has a thickness selected from the range of between 1.5 and 3.0 cm. In particular said expanded polymer material has a thickness selected from the range of between 1.5 and 2.5 cm. In order to comply with all the requirements, it was found that a thickness selected from the range of between 1.5 and 2.5 cm provided a balance between weight and protection. Usually, the thickness is selected from the range of between 1.75 and 2.5 cm. The thickness of a layer of one sports helmet may vary within the boundaries.

In an embodiment, the outer shell has a thickness selected from the range of 0.4-0.95 mm. It was found that with this thickness, it was possible to comply with requirements, and produce a light eight and flexible helmet. It was found that in particular the outer shell has a thickness selected from the range of 0.6-0.9 mm.
In an embodiment, the outer shell is produced from a single sheet of fibre-reinforced SRPP or SRPE material that is thermoformed.

In an embodiment, the outer shell is produced from a functionally planar sheet of said fibre-reinforced material that is formed into a curved sport helmet outer shell by thermoforming said functionally planar sheet in a mould, wherein in said thermoforming said functionally planar sheet undergoes a shrinkage in its largest two dimensional directions that is less than 10%. In an embodiment, the rate is less than 5%. In particular, the shrinkage is less than 2%. The low shrinkage provided an optimal strength/flexibility ratio. In particular a low shrinkage ensures that the mechanical properties, e.g. stiffness and strength of the reinforcing polymer fibre, are retained after thermoforming. It requires, however, careful material handling. In an embodiment, the material is slidably clamped in a mould during heating and shaping, balancing shrinkage due to heating and stretching due to closing the mould.

In an embodiment, the layer of expanded material comprises longitudinal or transversal cuts through the layer of expanded material, allowing said layer of expandable material to be bent along said longitudinal axis. In combination with the flexible outer shell, a sports helmet can be provided that is strong, but can be bent. The two temple ends can be pressed together by hand. Thus, when strapped to the head of a user, it forms around the shape of the head which adds to a comfortable wearing.

In an embodiment, the longitudinal cuts in said layer of expanded material comprising longitudinal zig-zag cuts. In particular, the cuts comprising a series of substantially longitudinal cuts, alternatingly starting from the forehead end and running up to a distance from the neck end, and starting from the neck end and running up to a distance from the forehead end. Often, the attenuation layer is about part of a sphere, and the cuts will follow a somewhat curved path, maintain a distance between cuts. This provides flexibility and yet maintains strength.

In an embodiment, the helmet further comprises a chin straps for securing under chin of a user when wearing said helmet for holding said sport helmet onto the head of the user, wherein said chin straps are attached to said shell. It was found that the strength of the material of the shell allows direct attachment of the chin straps in a sufficiently safe way even when the shell is thin.

In an embodiment, the sports helmet further comprises an attachable neck part that comprises attachment parts at or near one side that are connectable to
corresponding attachment parts at or near said neck end of said sports helmet. Using
the neck part, additional protection can be added, allowing a use for more different
sports, for instance ice skating and skiing.

In an embodiment said neck part attachment parts are lips that are insertable
between said attenuation layer and said shell.

In an embodiment, the neck part is made from the same fibre-reinforced material
as the outer shell.

In an embodiment, the outer shell at said neck end comprises said corresponding
attachment parts, in particular extending to an inside of said outer shell, and said
attachable neck part comprises said attachment parts extending at its outer surface, said
attachable neck part when attached to said sports helmet extending around an edge of
outer shell at said neck end and running around a neck of a user when wearing said
sports helmet. This allows secure attachment.

In an embodiment, the attachable neck part comprises strap attachment parts for
attaching to complementary strap attachment parts on said straps near said neck end.
This provides secure fixation of the neck part.

In an embodiment, the outer shell comprises at least two longitudinal slits in said
outer shell and extending through said outer shell, in particular said slits extending in
longitudinal direction at least 1.5 cm, and having a width of at least 1 mm. In particular,
the slits have a length of 1-3.5 cm end a width of 1-6 mm. More in particular, the slits
or through openings have a length of 1.5-3 cm and a width of 2-5 mm. It was found that
these slits or openings, in particular in combination with the material selection, comply
with the "thorn test".

In an embodiment, the layer of expanded material comprises at least two slits
extending through said expandable material, said slits positioned in line with said slits
in said outer shell for providing ventilation when said helmet is worn by a user.

In an embodiment, the attenuation layer comprises an indentation at the forehead
end and in an inner surface which in use is directed towards a user's head and is
opposite to an outer surface interfacing the shell, in use providing a space between the
attenuation layer and the forehead of the user. This indentation, in particular when in
fluid communication with the slits or through openings, can provide ventilation. The
indentations form depressions. Usually, such a depression does not reach trough the
attenuation layer.
In an embodiment, the sports helmet comprises ventilation means. In an embodiment, said ventilation means comprising an air inlet provided near the forehead end, through openings in said attenuation layer and through said shell, and air channels connecting said air inlet and said through openings. In an embodiment, the air channels opening towards a users head such that air travelling from said air inlet to said through openings for leaving said sports helmet is guided over a users head. When having speed, air travels over the helmet and provides an under pressure at the through openings. Thus, it was found that air will be sucked in at the air inlet, travel trough the air channels inside the helmet, and leave through the through openings or slits. This stream of air will contact a users head and provide ventilation and cooling.

In an embodiment, the air channels are formed by indentations in said attenuation layer at an inner surface which in use is directed towards a users head and is opposite to an outer surface interfacing the shell.

In an embodiment, the air channels are formed by pads provided as part of said attenuation layer at an inner surface which in use is directed towards a users head and is opposite to an outer surface interfacing the shell, said pads in use contacting the users head and providing said air channels between then. In this way, padding pads or pads provide a comfortable wear and create ventilation channels.

In an embodiment, the air inlet comprises an indentation in said attenuation layer at the forehead end and in an inner surface which in use is directed towards a users head and is opposite to an outer surface interfacing the shell. Thus, additional cooling can be provided at the front of the head or forehead of the user.

In an embodiment, the air channels run substantially in a direction from the forehead end toward the neck end.

In an embodiment, the sports helmet furthermore comprises detachable ear parts, wherein said ear parts comprise an attachment end with attachment means for attaching to complementary attachment means on said shell.

The invention further relates to an outer shell for a sports helmet, obtainable by thermoforming a single sheet of fibre-reinforced SRPP or SRPE material.

The invention further or in combination relates to an outer shell for a sports helmet, obtainable by thermoforming a functionally planar sheet of fibre-reinforced material into a curved sport helmet outer shell in a mould, wherein in said
thermoforming said functionally planar sheet undergoes a shrinkage in its largest two dimensional directions that is less than 10%.

In an embodiment said thermoforming said functionally planar sheet undergoes a shrinkage in its largest two dimensional directions that is less than 5%.

In an embodiment said thermoforming said functionally planar sheet undergoes a shrinkage in its largest two dimensional directions that is less than 2%.

The invention further relates to a sports helmet having a forehead end and a neck end and a longitudinal direction connecting said forehead end and said neck end, said sports helmet comprising an impact attenuation layer comprising a layer of expanded material comprising an expanded polymer material, and an outer shell of a self-reinforced polymer material.

This sports helmet can further comprise any of the features or combination of features described in this application. This may be part of a divisional application.

The person skilled in the art will understand the term "substantially" in this application, such as in "substantially encloses" or in "substantially extends up to". The term "substantially" may also include embodiments with "entirely", "completely", "all", etc. Hence, in embodiments the adjective substantially may also be removed. Where applicable, the term "substantially" may also relate to 90% or higher, such as 95% or higher, especially 99% or higher, even more especially 99.5% or higher, including 100%. The term "comprise" includes also embodiments wherein the term "comprises" means "consists of."

Furthermore, the terms first, second, third and the like if used in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "to comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or
"an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device or apparatus claims enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

The invention further applies to a sports helmet or parts thereof comprising one or more of the characterising features described in the description and/or shown in the attached drawings. The invention further pertains to a method or process comprising one or more of the characterising features described in the description and/or shown in the attached drawings.

The various aspects discussed in this patent can be combined in order to provide additional advantages. Furthermore, some of the features can form the basis for one or more divisional applications.

**Brief description of the drawings**

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, showing an embodiment of a sports helmet, and showing in:

- Figures 1A-1C a side view of a sports helmet in a several exemplary configurations, in figure 1A for instance for cycling, in figure 1B a neck part is attached for instance for ice skating, and in figure 1C an ear part is further added, for instance for skiing:
  - Figure 2 the ear part for figure 1c;
  - Figure 3 a view on the inside of the sports helmet, and
  - Figure 4 the attenuation layer of the sports helmet of figures 1A-1C seen from the outside.

The drawings are not necessarily on scale.

**Description of preferred embodiments**
Figures 1A-1C show a side view of a sports helmet 1 in several exemplary configurations, in figure 1A shows a basic configuration for instance for cycling, in figure 1B a neck part 10 is attached to the basic configuration of figure 1A for instance for ice skating. In figure 1C an ear part 12 is further added to the configuration of figure 1B, for instance for skiing. The ear part 12 can also be used without the neck part 10, i.e., in the configuration of figure 1A. The drawings may comprise and show design features that may also be protectable via other rights, like design rights or copyright.

The sports helmet 1 has a forehead end 2 and a neck end 3 that are connected via a longitudinal line 1. Usually, a plane of symmetry can be defined with line 1 in this plane, defining a longitudinal direction connecting forehead end and neck end.

The sports helmet 1 has an impact attenuation layer 5 and an (outer) shell 4. The materials of these parts are already explained above. In an embodiment, these two parts can be disassembled, allowing the impact attenuation layer 5 to be removed from the shell. In this way, they can be dried and cleaned separately after use.

As explained above, the shell can remain relatively thin. In this way, the shell 4 will be flexible. In fact, it can easily be folded together by hand, allowing the temple ends to touch. The outer shell 4 can be so flexible that it can even be rolled up. The shell 4 can for instance be between 0.3 and 0.9 mm. Furthermore, some features of the attenuation layer can be added that allow the complete sports helmet to be flexible, in that the temple ends of the complete sports helmet 1 can be hand-folded to touch one another. This will be explained when discussing figures 3 and 4.

The sports helmet 1 further comprises a retention system comprising one or more chin straps 8 that in use hold the sports helmet 1 on the head of a user. Here, the chin straps 8 are attached to the shell 4. It was found that the material of the shell allows connecting of the chin straps 8 directly to the shell 4. The connection is much stronger than a connection to the impact attenuation layer 5. The chin straps 8 are connected via attachment means 9, often via rivets for permanent attachment, or a snap fastener of popper in case removability of the chin strap 8 is desired. Here, one attachment means 9 is applied near the neck end. In this way, only one attachment means 9 is sufficient.

The sports helmet of figures 1A-1C further comprises a ventilation means. To that end, provisions are made to allow air to flow inside the helmet and in contact with a user's head. The shell 4 here comprises through openings 7 divided over the helmet 1.
In another embodiment, more openings may be provided and/or at other positions. The
impact attenuation layer 5 is provided with corresponding through openings in
connection with the openings in the shell 4. This allows a fluid communication between
the outside air and the head of a user. When the user has a certain speed, air flowing
around the sports helmet and over the through openings will create a lowered pressure
in the through openings.

To allow air to flow through the sports helmet 1 via the inside of the sports
helmet 1 and to contact the head of the user, an air inlet 6 is provided at the forehead
end of the sports helmet.

Furthermore, air channels connecting the air inlet and the through openings are
provided. In an embodiment, the air channels are open at the users head. In figure 3,
showing the inside of the sports helmet 1, it can be seen that here the interior surface of
the impact attenuation layer, i.e., the surface that in use will be directed toward the heat
of a user, is provided with air channels running from the air inlet 6 near the forehead
end 2 to the through openings 7. Here, the air channels are established using padding
pads 20 provided on the inner surface of the attenuation layer 5, thus providing a
comfortable wear and air channels between the padding pads 20. Alternatively or in
combination, the inner surface of the attenuation layer may be provided with
depressions defining the air channels.

The through openings 7 can be in longitudinal direction, as indicated in the
drawings and/or in transversal direction, or a combination. It was found that openings 7
having a length of up to 3 cm and a width of up to 0.7 mm are big enough to provide
sufficient ventilation, and still comply with the requirements, like the "thorn test". The
shape and positioning of the openings 7 may also be part of design features.

The air inlet 6 in the embodiment of the drawings is provided by a depression in
the inner surface of the attenuation layer 5 at the forehead end 2, in figure 3 indicated
with hatched lines. When a user wears the helmet 1, a space (indicated with dotted lines
in figures 1A-1C) remains between (part) of the users forehead end the attenuation
layer 5. In figure this air inlet 6 is in fluid communication with the air channels.

The sports helmet lean be provided with an additional, removable neck part 10 to
provide additional neck protection. This neck part 10 is attached to the rest of the sports
helmet 1 at the neck end 3 of the shell 4, in fact for the total sports helmet 1 further
removing the neck end 3 from the forehead end 2. The neck part comprises extension
ends that are indicated with dotted lines in figure 1C. These extension ends are pressed
between the shell 4 and the attenuation layer 5. Here, the extension ends comprise
notches or cut-away parts that hook behind attachment means 9 near the neck end 3 of
the shell 4. Here, the attachment means also attach the chin strap to the shell 4. The
neck part 10 further comprises an attachment means for attaching the neck part 10 to
the chin strap 8. In particular, the chin strap 8 end the neck part 10 comprise
complementary attachment means parts. In an embodiment, the neck part 10 is
removable from the chin strap 8. The attachment means may comprise a snap fastener,
a popper, or even Velcro.

The sports helmet may also be provided with a removable ear part 12, as
indicated in figure 1C. The ear part 12 is shown in more detail in figure 2. The ear part
12 may also be used without the neck part 10.

The ear part 12 comprise a flexible layer 14 that usually from a flexible, polymer
material, and is about as flexible as the shell 4. In an embodiment, it may be from the
same material as the shell 4. The ear part 12 may comprise a first padding 17 at the
surface that is in use directed towards the ear of the wearer. The ear part 12 may
comprise a further padding at the outer surface, for instance for design purposes. The
ear part comprises extensions 15 that in use are pressed between the attenuation layer
and the shell in order to fix the position of the ear parts 12 with respect to the further
sports helmet 1. The ear part 12 here further comprises a loop 13, usually from a fabric,
having an opening for in use leading the chin strap 8 through. In this way, the ear part
is properly fixed. Additionally, the ear part can be provided with additional attachment
means 13a, like buttons, push buttons, Velcro or snap fittings for attachment to
complementary provisions on the chin strap 8.

As can be seen, the retention system of the sports helmet 1 further comprises a
neck strap 18, which in general is known in the art. It comprises a knob for adapting the
circumference of the sports helmet and adapting it to the head size of the wearer.

The attenuation layer 5 here has longitudinal cuts 19. Here, the longitudinal cuts
19 are partly starting from the forehead end 2 and run to near the neck end and there are
longitudinal cuts that start at the neck end 3 and run up to near the forehead end 2. In
this embodiment, the cuts alternatingly start at the forehead end 2 and the neck end 3.
Thus, in fact, the attenuation layer 5 can be pulled apart into a zigzag pattern. Figure 4
shows an exterior view of only the attenuation layer 5. These longitudinal cuts 19 allow
the impact attenuation layer 5 to be folded to some extend with the temple ends toward each other, i.e., along the longitudinal line 1 shown in figure 3. This contributes to a wearing comfort, but still provide a safe sports helmet that complies to the relevant requirements. In particular, the longitudinal cuts 19 are a little curved

The use of in particular SRPP as shell 4 provides in particular for the penetration test in EN1077 and the kerbstone test in EN1078 an advantageous effect. It was found that the force of an impact is spread over a larger area. This was found to allow a thinner impact attenuation layer, adding to a further weight reduction.

The chin straps 8 are attached to the shell 4. It was found that in particular the SRPP allows a thinner shell and yet allows attachment of the chin straps to the shell. It still complies with the requirements, like the retention test in all the formal specifications.

It was found that an attenuation layer having a density as low as 80 kg/m$^3$ provides a sports helmet that complies with official requirements. The impact attenuation layer can have a density as low as 60 kg/m$^3$ and still complies. Density may even be as low as 40 kg/m3 and still comply.

Furthermore, with a thickness of the shell of between 0.1-0.95 mm, it is possible to provide a sports helmet which complies with EN1077 and EN1078 and more specifically with the test norms and protected areas described in these standards. Said helmet in the construction of said expanded foam and said outer shell, including an ear pad and the neck part, have a total weight of max. 350 g. A sports helmet of size L - head circumference of 57.0 to 59.5 - without the neck part and ear part can have a weight of 300 g and still comply with the above-referenced regulations.

The use of SRPP material as (outer) shell allows in particular in the penetration test of EN 1077 (ski) to provide the sports helmet with ventilation openings, to have a thickness of 20-22 mm and a low weight. It complies with the "thorn-test" or penetration test.

It will also be clear that the above description and drawings are included to illustrate some embodiments of the invention, and not to limit the scope of protection. Starting from this disclosure, many more embodiments will be evident to a skilled person. These embodiments are within the scope of protection and the essence of this invention and are obvious combinations of prior art techniques and the disclosure of this patent.
Reference numbers

1 sports helmet
2 forehead end
3 neck end
4 shell
5 impact attenuation layer
6 front ventilation provision in the attenuation layer
7 ventilation slit(s)
8 chin strap
9, 9’ attachment means for chin strap
10 neck part
11 attachment part on neck part for chin strap
12 ear part
13 attachment means on ear part for chin strap
14 ridged ear part
15 attachment parts
16 soft outer layer
17 ear part inner padding
18 rear strap
19 impact attenuation layer cut-in
20 inner padding parts
1 longitudinal line
Claims

1. A sports helmet having a forehead end and a neck end and a longitudinal direction connecting said forehead end and said neck end, said sports helmet comprising
(a) an impact attenuation layer comprising a layer of expanded material comprising an expanded polymer material, and
(b) an outer shell of a self-reinforced polymer material,
wherein said layer of expanded material has a thickness of 0.5-3.0 cm and a density of 20-100 kg/m³, and said outer shell has a thickness of 0.2-0.95 mm.

2. The sports helmet according to claim 1, wherein said outer shell has a thickness of 0.4-0.95 mm.

3. The sports helmet according to claim 1 or 2, wherein said expanded polymer material is selected from the group consisting of expanded polyethylene (EPE), expanded polypropylene (EPP) and expanded polystyrene (EPS).

4. The sports helmet according to any one of the preceding claims, wherein said impact attenuation layer has a thickness between 1.5 and 2.5 cm, in particular said layer of expanded polymer material has a thickness between 1.5 and 2.5 cm.

5. The sports helmet according to any one of the preceding claims, wherein said self-reinforced polymer material is selected from self-reinforced polyethylene (SRPE) and self-reinforced polypropylene (SRPP).

6. The sports helmet of any one of the preceding claims, wherein said outer shell is produced from a single sheet of fibre-reinforced SRPP or SRPE material that is thermoformed.

7. The sports helmet according to any one of the preceding claims, wherein said outer shell is produced from a functionally planar sheet of said fibre-reinforced material that is formed into a curved sport helmet outer shell by thermoforming said
functionally planar sheet in a mould, wherein during said thermoforming said
functionally planar sheet undergoes a shrinkage in its largest two dimensional
directions that is less than 10%, in particular less than 5%, more in particular less than
2%.

8. The sports helmet according to any one of the preceding claims, wherein said
layer of expanded material comprises longitudinal or transversal cuts through the layer
of expanded material, allowing said layer of expandable material to be bent along said
longitudinal axis.

9. The sports helmet of the previous claim, wherein said longitudinal cuts in said
layer of expanded material comprising longitudinal zig-zag cuts, in particular
comprising a series of substantially longitudinal cuts, alternatingly starting from the
forehead end and running up to a distance from the neck end, and starting from the
neck end and running up to a distance from the forehead end.

10. The sports helmet according to any one of the preceding claims, wherein said
helmet further comprises a chin straps for securing under chin of a user when wearing
said helmet for holding said sport helmet onto the head of the user, wherein said chin
straps are attached to said outer shell.

11. The sports helmet according to any one of the preceding claims, wherein said
sports helmet further comprises an attachable neck part that comprises attachment parts
at or near one side that are connectable to corresponding attachment parts at or near
said neck end of said sports helmet, especially wherein said neck part attachment parts
are lips that are insertable between said attenuation layer and said shell.

12. The sports helmet according to the previous claim, wherein said neck part is
made from the same fibre-reinforced material as the outer shell.

13. The sports helmet according to any one of the previous two claims, wherein said
outer shell at said neck end comprises said corresponding attachment parts, in
particular extending to an inside of said outer shell, and said attachable neck part
comprises said attachment parts extending at its outer surface, said attachable neck part when attached to said sports helmet extending around an edge of outer shell at said neck end and running around a neck of a user when wearing said sports helmet.

14. The sports helmet according to any one of claim 11-13 and claim 10, wherein said attachable neck part comprises strap attachment parts for attaching to complementary strap attachment parts on said straps near said neck end.

15. The sports helmet according to any one of the preceding claims, wherein said outer shell comprises at least two longitudinal slits in said outer shell and extending through said outer shell, in particular said slits extending in longitudinal direction at least 1.5 cm, and having a width of at least 2 mm.

16. The sports helmet according to claim 15, wherein said layer of expanded material comprises at least two slits extending through said expandable material, said slits positioned in line with said slits in said outer shell for providing ventilation when said helmet is worn by a user.

17. The sports helmet according to claim 15, wherein said attenuation layer comprises an indentation at the forehead end and in an inner surface which in use is directed towards a users head and is opposite to an outer surface interfacing the shell, in use providing a space between the attenuation layer and the forehead of the user.

18. The sports helmet according to any one of the preceding claims, comprising ventilation means, said ventilation means comprising an air inlet provided near the forehead end, through openings in said attenuation layer and through said shell, and air channels connecting said air inlet and said through openings, said air channels opening towards a users head such that air travelling from said air inlet to said through openings for leaving said sports helmet is guided over a users head.

19. The sports helmet according to claim 18, wherein said air channels are formed by indentations in said attenuation layer at an inner surface which in use is directed
towards a user's head and is opposite to an outer surface interfacing the shell.

20. The sports helmet according to claim 18 or 19, wherein said air channels are formed by pads provided as part of said attenuation layer at an inner surface which in use is directed towards a user's head and is opposite to an outer surface interfacing the shell, said pads in use contacting the user's head and providing said air channels between them.

21. The sports helmet according to claim 17, 18 or 19, wherein said air inlet comprises an indentation in said attenuation layer at the forehead end and in an inner surface which in use is directed towards a user's head and is opposite to an outer surface interfacing the shell.

22. The sports helmet according to any one of claims 17-21, wherein said air channels run substantially in a direction from the forehead end toward the neck end.

23. The sports helmet according to any one of the preceding claims, wherein said sports helmet is a multi-sports helmet.
Fig. 3
**A. CLASSIFICATION OF SUBJECT MATTER**

INV. A42B3/06 A42B3/12 A42B3/28

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

A42B

Documented searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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**Date of the actual completion of the international search**

21 September 2015

**Name and mailing address of the ISA**

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**Date of mailing of the international search report**

29/09/2015

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Gui san, Thi erry

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