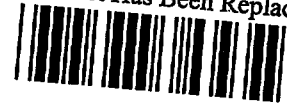


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METAL FRAME FOR SPECTACLES

The present invention pertains to an eyeglass frame containing at least some metallic components such as the temples, the bridge and/or connection bar between the eyewires holding the vision correction lenses, sunglass lenses or safety lenses or
5 directly between the said lenses.

The use of shape memory alloys for making certain components of metallic eyeglass frames has already been known.

Any metal alloy that is able to regain its initial shape by simple heating after having undergone a permanent deformation at a lower temperature is called a shape
10 memory alloy (SMA).

This property is the macroscopic expression of a physical phenomenon involved in the atomic organization of the material: The reversible martensitic transformation.



The martensitic transformation can be described, from a phenomenological viewpoint, by the curve shown in Figure 1, in which the temperature is shown on the abscissa and the transformed fraction is shown on the ordinate.

On cooling (direct martensitic transformation), martensite begins to be formed beginning from the temperature M_s "martensite start", and the sample is completely martensitic at the temperature M_f "martensite finish".

On reheating (inverse transformation), austenite (or β phase) begins to be formed at a temperature A_s "austenite start", and the sample is completely austenitic at the temperature A_f "austenite finish".

The reversible martensitic transformation is the cause of the specific properties of the shape memory alloys:

- one-way memory effect,
- two-way memory effect,
- superelastic effect,
- rubber effect.

The martensitic transformation takes place not only in the case of $T < M_s$, but also at $T > M_s$ by the application of a mechanical stress. If this stress is relieved for an alloy deformed at $T > A_f$, inverse transformation of the martensite into austenite takes place with a transformation hysteresis. This phenomenon is called the superelastic effect. It is illustrated in Figure 2, in which the deformation is shown on the abscissa and the mechanical stress is shown on the ordinate.



The deformation $\epsilon_{\max}$ is the maximum deformation ϵ which a shape memory alloy is able to withstand without irreversible plastic deformation persisting after the shape memory alloy is relieved of any mechanical stress.

The standard NF A 51-080 defines the terminology and the measurements associated with the shape memory alloys. The terms used in this text refer to that standard.

There currently are eyeglass frames containing temples, bridges or bars in which all or part of these components are made of a superelastic shape memory alloy. The shape memory alloy used to prepare these components is an alloy based on titanium and nickel. This results in considerable difficulties in terms of the preparation and the mechanical strength of the eyeglass frames:

- Low fatigue strength of the Ti-Ni alloys, which displays a fragile rupture after some stress cycles.

- Work hardening may be used to palliate the poor fatigue strength of Ti-Ni alloys, but the superelastic deformation $\epsilon_{\max}$ is limited to about 3% to 4% in this case. The rigidity of the Ti-Ni alloy increases rapidly beyond this limit, and the alloy tends to break.

- The Ti-Ni alloys contain a high percentage of nickel and must be coated with nickel for assembly by means of silver solder which is usually used in making eyeglasses. The element nickel may cause allergies in the wearer of the eyeglass frames.



- The assembly of the superelastic components made of Ti-Ni alloy with the components made of conventional metals commonly used in making eyeglasses (Monel, nickel silver, bronzes, cuproberyllium, stainless steels, titanium alloys) cannot be easily performed.

5 Three methods are currently employed to assemble the superelastic components with the conventional components (which lack the property of superelasticity):

- The first method consists of force-fitting the end or ends of the superelastic component into a socket made of a metal that can be soldered with silver. With the superelastic component being fitted into the socket, the socket is then soldered to the
10 conventional components.

It should be noted that a galvanic nickel coating may be used to improve the coupling and the soldering.

- The second method consists of coating the superelastic component with a galvanic nickel layer and subsequently soldering to the conventional component with
15 a silver solder.

- The third method consists of welding the superelastic components to the conventional components with the energy of a laser beam or electron beam. These expensive methods are, however, rarely employed in making eyeglasses.

Other shape memory alloys have also been tested for making superelastic
20 eyeglass frame components. These tests and the patents that may have resulted therefrom mention Cu-Zn-X alloys (in which $X = \text{Al, Sn, ...}$) and Cu-Al-Ni. Such alloys



are described especially in the documents FR-A-2 504 284 and US-A-4 893 917. However, these are polycrystalline alloys. However, compared with the alloys based on Ti-Ni, these alloys cannot withstand $\epsilon_{\max}$ deformations greater than 3% to 4%. Beyond this limit, they are fragile and break because of their coarse grain structure.

5 It is currently desired to improve the mechanical strength and the use of the shape memory alloys used in making eyeglasses, such as Ti-Ni as well as other shape memory alloys.

 The methods used consist of hardening the material in order to increase its yield strength as much as possible.

10 A very fine-grain structure is desirable for this purpose; it is obtained either by recrystallization of the coarse structures generated in the foundry after considerable work hardening, or by structural hardening achieved in the course of heat treatments causing the precipitation of the hard phases, or by cold working.

 The major drawback of these methods is that the deformations associated with superelasticity are greatly limited. The grain boundaries, the precipitates and the work
15 hardening block the martensitic transformation and lead to a great increase in the rigidity of the superelastic alloy.

 The goal of the present invention is to provide a metallic eyeglass frame in which certain components, such as the temples, the bridges or bars, are made of an
20 alloy capable of undergoing deformation under the action of mechanical stresses, while completely resuming their shape once they cease to be subjected to a stress.

In addition, such components should be able to undergo a large number of bending cycles without rupture. Such components should also be able to be easily assembled with other components forming part of the eyeglass frame.

The frame to which the present invention pertains is therefore characterized in that it contains temples and/or a bridge and/or one or more bars made of a monocrystalline shape memory alloy, i.e., an alloy that is formed by a single crystallite or a plurality of crystallites separated by weakly disoriented boundaries and is selected from among the alloys based on Cu or Fe.

The use of a monocrystalline shape memory alloy is advantageous insofar as it makes it possible to benefit from the most homogeneous structure possible from a microscopic viewpoint in order to prevent any local mechanical stress concentration from appearing. The shape memory alloys are selected from among the following copper-based alloys:

Cu-Zn-Al,

Cu-Al-Ni,

Cu-Al-Be,

Cu-Al-Mn,

or from among the following iron-based alloys:

Fe-Mn-Si,

Fe-Mn-Cr,

Fe-Mn-Cr-Si.



A first advantage of these alloys is that they are much less expensive than the Ti-Ni alloys commonly used. In addition, they possess clearly superior deformation characteristics, because the maximum deformation is on the order of magnitude of 11%, at least between -40°C and +80%, or 2 to 3 times that of a Ti-Ni alloy, without
5 any increase in rigidity being observed, which represents a certain advantage for the person wearing the eyeglass frame in the case of an accident such as a shock.

It should be noted that the same Cu-Zn-Al, Cu-Al-Ni, Cu-Al-Be or Cu-Al-Mn and Fe-Mn-Si, Fe-Mn-Cr or Fe-Mn-Cr-Si alloys cannot be deformed by more than 3% to 4% and have a very limited fatigue strength if they have a polycrystalline structure,
10 as opposed to the monocrystalline structure.

Under these circumstances, the frame is deformed and the eyeglass frame resumes its original geometry without residual deformation after the shock.

The fatigue properties of a component made according to the present invention are also advantageous. While a component made of a Ti-Ni alloy runs the risk of
15 breaking after a certain number of stress cycles, the components made of a monocrystalline shape memory alloy according to the present invention are able to withstand several thousand cycles without breaking. It is consequently unnecessary to work harden such a component to confer a better fatigue strength on it. On the contrary, the work hardening of a monocrystalline alloy would run the risk of
20 producing a change in its superelastic characteristics. The components made according to the present invention advantageously preserve their deformability properties in a



broad temperature range spanning at least 120°C. For example, the monocrystalline superelastic components preserve their elastic rebound without any residual deformation in the range of -40°C to +80°C, as opposed to the Ti-Ni alloys, whose use temperatures are between -20°C and +40°C.

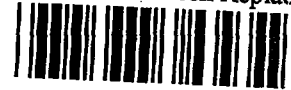
5 It should be noted that the alloys based on Cu-Zn-Al, Cu-Al-Ni, Cu-Al-Mn, Cu-Al-Be, and those based on Fe-Mn-Si, Fe-Mn-Cr or Fe-Mn-Cr-Si can be directly welded or soldered to the other alloys commonly used in making eyeglasses among the shape memory alloys used to prepare the components according to the present invention.

10 It should be noted that the silver solders can be used directly on monocrystalline shape memory copper alloys due to the absence of grain boundaries. In fact, the presence of grain boundaries during soldering is manifested by the formation of intermetallic compounds in these grain boundaries, and these compounds cause an impairment in the mechanical strength of the boundaries.

15 Moreover, as these monocrystalline shape memory alloys do not require work hardening or structural hardening, welding or soldering does not cause any changes in the state of the superelastic shape memory alloy, thus making it possible to use the existing equipment, whose cost of use and depreciation are lower.

20 It is thus possible to directly weld the components according to the present invention to the components forming part of the frame made of the metal alloys commonly used in making eyeglasses. Thus, in particular, the temples can be directly welded to the eyewires of the frame, or each temple can be provided with a torsion bar





intended to be welded to an eyewire of the frame.

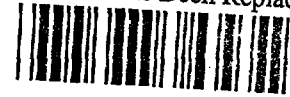
To facilitate bending at the temples [of the frame], it is possible to reduce the thickness of the material acting as the hinges, but without using hinge components as they are commonly known in the area of eyeglass-making. One advantage of this type of articulation of the temples to the body of the frame is that it makes possible the automatic opening of the temples on removal from an eyeglass holder, which makes it possible to put on the eyeglasses with one hand only.

It is also possible to provide other zones of reduced thickness to make it possible to fold up the frame. It is possible in this case to provide zones of reduced thickness on the bridge connecting the two eyewires, on the bar possibly provided between them, as well as in the middle of each temple.

According to another feature of the present invention, a conventional thermomechanical treatment may be carried out locally at the end of each temple to change its behavior from a superelastic behavior to a plastic behavior, which makes it possible to adjust it to the contour of the ear. This treatment can also be easily performed on any part of the bridges and/or of the temples of the frame.

According to another embodiment, the bridge made of monocrystalline shape memory alloy is directly attached to the lenses, and the temples made of monocrystalline shape memory alloy are attached either directly to the lenses or to the hinges, which themselves are directly attached to the lenses.

Another advantageous feature of the components according to the present



invention is that they do not contain nickel in the case of the alloys other than Cu-Al-Ni, which eliminates any risk of allergy resulting from contact with an alloy containing this constituent for the wearer of the eyeglasses.

5 The components made of shape memory alloy according to the present invention are prepared from a wire made of monocrystalline shape memory alloy, whose cross section can be framed in a circle having a diameter of less than 4 mm. This feature permits easy shaping for preparing the components, without requiring considerable deformation resulting from a work hardening, which is harmful for the monocrystalline structure and for the resulting properties.

10 According to another feature of the present invention, the components are made of a monocrystalline shape memory alloy whose transformation temperature A_f , beginning from which the martensite begins to be formed, is between -100°C and -20°C .

15 The present invention will be better understood from the following description with reference to the schematic drawing attached, which shows as nonlimiting examples a number of embodiments of a pair of eyeglasses.

Figure 3 is a diagram showing the deformation of a component according to the present invention as a function of the stress applied to it.

Figure 4 shows a perspective view of a pair of eyeglasses.

20 Figure 5 shows a perspective view of part of a pair of eyeglasses, showing more specifically the articulation of a temple to an eyewire.



Figure 6 is a perspective view of another pair of eyeglasses.

Figure 3 shows a diagram of the deformation of a component made of monocrystalline shape memory alloy according to the present invention as a function of the stress applied to it. As is shown in the left-hand part of the diagram, the elastic deformation of a component made of titanium-nickel does not exceed 4%. On the
5 contrary, the elastic deformation of a component made of a shape memory alloy according to the present invention reaches 11%, and this value of deformation is obtained with a stress lower than that necessary for achieving the maximum deformation of the component made of titanium-nickel.

10 Figure 4 shows a pair of eyeglasses containing two eyewires 2 intended to accommodate the lenses and connected to one another by a bridge 3 and by a bar 4. A temple 6, articulated by means of a hinge 5, is mounted on each eyewire 2. The bridge 3, the bar 4, and the temples 6 may be prepared from a monocrystalline shape memory alloy according to the above provisions.

15 Figure 5 shows an embodiment variant, in which each temple 6 is mounted on the corresponding eyewire 2 by welding, via a torsion bar 7. Consequently, there is no longer a hinge proper, as the alloy permits, considering its possibilities, the pivoting function of the temples toward the closed position to be accomplished. It would be equally possible, without using a bar 7, to provide a section of reduced material
20 thickness facilitating bending on the temple 6 and in the vicinity of its end welded to the eyewire 2.

Figure 6 shows another embodiment of eyeglasses, whose frame is intended to be folded up. In this case, the bridge 3 contains a central zone of reduced thickness 8, the bar 4 has a central zone of reduced thickness 9, and each of the temples 6 contains a central zone of reduced thickness 10 each.

5 It is thus possible first to fold up the two temples 6 over themselves by pivoting around the zones of reduced thickness 10, and then to fold the frame over itself by pivoting around the zones of reduced thickness 8, 9.

10 As is apparent from the above, the present invention brings about a great improvement in the existing technique by providing an eyeglass frame using components made of shape memory alloy, which possess excellent deformability, are not subject to the usual risk of breaking after a certain number of deformations, can be directly welded or soldered to the other components of the eyeglasses made of a conventional alloy, and can be folded without the use of a hinge, which limits the number of components of such a frame.

It is obvious that the present invention is not limited to the embodiments of this frame which are described above as examples; on the contrary, it also encompasses all variants. Thus, the bridge, made of a shape memory alloy, could be directly attached to the lenses, and the temples, made of a monocrystalline shape memory alloy, could be attached either directly to the lenses or to the hinges, which themselves are directly attached to the lenses.





CLAIMS

1. Metal eyeglass frame, characterized in that it contains said temples (6) and/or a said bridge (3) and/or one or more said bars (4) made of a monocrystalline shape memory alloy, i.e., an alloy formed by a single crystallite or a plurality of crystallites separated by boundaries with weak disorientation and selected from among the alloys based on Cu or Fe.

2. Frame in accordance with claim 1, characterized in that the said components (3, 4, 6) made of shape memory alloy are selected from among the following Cu-based alloys: Cu-Zn-Al, Cu-Al-Ni, Cu-Al-Be, Cu-Al-Mn.

3. Frame in accordance with claim 1, characterized in that the said components (3, 4, 6) made of shape memory alloy are selected from among the following Fe-based alloys: Fe-Mn-Si, Fe-Mn-Cr, and Fe-Mn-Cr-Si.

4. Frame in accordance with any of the claims 1 through 3, characterized in that the transformation temperature (A_f) beginning from which the martensite begins to be formed in the shape memory alloy in question is between -100°C and -20°C .





5. Frame in accordance with any of the claims 1 through 4, characterized in that the said components made of shape memory alloy are able to undergo superelastic deformation by 11%, at least between -40°C and $+80^{\circ}\text{C}$.

6. Frame in accordance with any of the claims 1 through 5, characterized in that the said components (3, 4, 6) made of a shape memory alloy are prepared from a wire of monocrystalline shape memory alloy whose cross section can be framed in a circle having a diameter less than 4 mm.

7. Frame in accordance with any of the claims 1 through 6, characterized in that the said components (3, 4, 6) made of a monocrystalline shape memory alloy can be directly welded to other components which form part of the frame and are made of the metal alloys commonly used in making eyeglasses.

8. Frame in accordance with claim 7, characterized in that the said temples (6) are directly welded to the said eyewires (2) of the frame.

9. Frame in accordance with claim 7, characterized in that the said temples (6) are each provided with a said torsion bar (7) intended to be welded to an eyewire of the frame.

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10. Frame in accordance with any of the claims 1 through 9, characterized in that the said components (3, 4, 6) made of a monocrystalline shape memory alloy contain said zones of reduced thickness (8, 9, 10) arranged in the vicinity of the connection zone between a said temple and a said eyewire, and/or at mid-length of the said temples and/or in the middle of the said bridge and of the said connection bar between the said two eyewires of the frame.

11. Frame in accordance with any of the claims 1 through 7, characterized in that the said bridge (3), made of a monocrystalline shape memory alloy, is directly attached to the lenses, and the said temples, made of a monocrystalline shape memory alloy, are attached either directly to the lenses or to the said hinges (5), which in turn are directly attached to the lenses.

12. Frame in accordance with any of the claims 1 through 11, characterized in that the components (3, 4, 6), made of a monocrystalline shape memory alloy, contain one or more zones having subjected to a conventional thermomechanical treatment to change the behavior of the material from a superelastic behavior to a plastic behavior, which makes possible the adjustment of these components.

