

Adhesion promoter for piezoceramic hydrophone

The invention relates to a piezoceramic hydrophone, to a passive sonar, to a surface vessel or underwater vehicle comprising the passive sonar according to the invention, to a process for producing a piezoceramic hydrophone and to the use of the piezoceramic hydrophone.

Underwater location systems such as SONAR (sound navigation and ranging) systems have been used for more than a hundred years, especially in military applications. Here, a fundamental distinction has to be made between active and passive (sonar) location systems. Whereas active systems, for example the ASDIC system (Anti Submarine Detection Investigation Committee) developed during the second world war, transmit and receive soundwaves, in passive systems only the signals emitted from the surroundings are received and subsequently evaluated. The advantage of passive systems is that they do not emit any self-locatable signals. However, the precise spatial location of underwater objects by passive systems alone becomes more difficult. It is therefore usual for many surface vessels and underwater vehicles to employ both passive and active sonar systems, depending on their task profile.

In known hydrophones, two hollow sphere halves are joined to form a hollow sphere. DE 102 12 291 C1 and US 6 029 113 A disclose hollow sphere halves consisting of a piezoceramic material. The hollow sphere halves have opposite polarities and from each hollow sphere an inner and outer electrode is connected via a resistor to an inverted voltage amplifier. An illustrative structure of a hydrophone is also described in DE 10 2008 029 269 A1, [0002], [0007]-[0008] and [0018]-[0024].

The hollow sphere itself is frequently shielded against external influences such as moisture and dirt by means of a polymer jacket. This polymer jacket has to be matched in terms of sound velocity and the long-term stability of the material to the use in conjunction with a hydrophone.

The effectiveness and shielding of the polymer jacket depends largely on the bonding to the ceramic surface of the hollow sphere. Owing to the differing material properties of the ceramic surface and the surface of the polymer jacket, an additional bonding agent is necessary in many cases. Such a bonding agent has to ensure a reliable, resistant and firm join between the ceramic surface and the polymer jacket. Owing to the use in a moist, saltwater-containing environment which can also have significant temperature fluctuations, the bonding agent must also have high long-term stability in respect of chemical and mechanical stresses.

Various bonding agents, e.g. "Passirex" (may be registered trademark), especially ones based on Cr(VI) compounds, are known for the specified purpose. The carcinogenic potential of Cr(VI) compounds has already been known for a relatively long time. Especially in the production of the hydrophone, exposure of employees to Cr(VI) compounds cannot be ruled out entirely. In addition, release of the Cr(VI) compound is also possible during use or maintenance. Appropriate later disposal is also made more complicated and more expensive by Cr(VI) compounds. The expression "Cr(VI) compounds" relates to compounds of chromium in the oxidation state plus six. This includes salts, complexes, melts and solutions.

Regulation (EC) No. 1907/2006, "REACH regulations", stresses clearly the requirements in the area of the use of commonly used materials that are hazardous to health. On the basis of the risk assessment required in approval proceedings, many compounds have to be replaced by less critical compounds.

US 6 029 113 A discloses the structure of a differential hydrophone comprising a ceramic sphere made up of two piezoelectric hemispheres. The arrangement makes it possible to register acoustic signals caused by changes in water pressure and to convert them into electrical signals.

DE 102 12 291 C1 discloses an underwater antenna having at least one hydrophone and a symmetrical, electrical amplification circuit assigned to the hydrophone.

DE 10 2008 029 269 A1 discloses a hydrophone for an underwater antenna, which comprises two hemispherical shells which are composed of radially polarized piezoelectric material and are assembled to form a hollow sphere and which have electrodes covering the inner and outer shell surfaces. The hemispherical shells are fastened at their shell edges in a mirror-symmetrical manner to the underside and upper side of a support side.

EP 0 099 643 A2 discloses highly damping polymer compositions comprising a segmented block polymer of polyurethane and an elastomer having a glass transition temperature in the range from -40°C to +15°C. Furthermore, a towed array sonar comprising a tube consisting of the abovementioned polymer composition is disclosed. A plurality of hydrophones are arranged within the tube.

It is an object of the present invention to provide a bonding agent for a hydrophone, which allows safe and reliable adhesion of the polymer jacket to the ceramic surface of the sphere. At the same time, no components which present a hazard to health should be present.

The object of the invention is surprisingly achieved by a piezoceramic hydrophone as claimed in claim 1. Further advantageous embodiments may be found in the dependent claims.

The invention further comprises a passive sonar comprising the piezoceramic hydrophone of the invention.

The invention encompasses a surface vessel or underwater vehicle comprising the passive sonar according to the invention.

The invention additionally encompasses a process for producing a piezoceramic hydrophone.

The invention additionally encompasses the use of the piezoceramic hydrophone of the invention in warships and research ships, preferably submarines, ASW (antisubmarine warfare) helicopters, sonar buoys, frigates, destroyers, corvettes, speedboats and/or diving robots.

The piezoceramic hydrophone of the invention comprises at least the following elements. A first hemispherical shell and a second hemispherical shell are assembled to form a hollow sphere. For the purposes of the invention, the expression “hemispherical shell” preferably encompasses a hemisphere having an internal hollow space. The internal hollow space preferably encompasses/forms from 10% to 90% of the volume of the hemisphere, for example based on a wall thickness of from 0.5 mm to 4 mm, preferably from 0.8 mm to 2 mm. An illustrative structure of a hydrophone may be found, inter alia, in DE 10 2008 029 269 A1, paragraph [0018] to [0022]. The first hemispherical shell and the second hemispherical shell comprise a radially polarized, piezoelectric material, for example lead zirconate titanate (PZT). The first hemispherical shell and the second hemispherical shell have an outer layer. For the purposes of the invention, the expression “outer layer” preferably encompasses an at least partial coating of the hemispherical shell surfaces. For the purposes of the invention, the expression “partial” refers to a coating over preferably at least 30%, particularly preferably at least 75%, of the hemispherical shell surface areas. To avoid short-circuiting, individual sections of the hemispherical shell areas of the first hemispherical shell and of the second hemispherical shell may be designed without an outer layer (coating) or may be provided with an intermediate insulating layer or an insulating element. This preferably encompasses, for example, the area of bonding of the two hemispherical shells to one another. For the purposes of the invention, the expression “outer layer” preferably refers to a coating on the surface of the hemispherical shell, particularly preferably the inner and outer shell surfaces of the respective hemispherical shell. The outer layer comprises silver and/or silicon compounds, in

other words it “contains” silver and/or silicon compounds. Furthermore, the hydrophone according to the invention includes electrical contacting of the first hemispherical shell and the second hemispherical shell. A polymer jacket surrounds the hollow sphere and prevents or slows the penetration of moisture or dirt. The hydrophone of the invention is characterized in that the outer layer is joined to the polymer jacket by a bonding agent. The bonding agent (preferred definitions also as described in “Römpf Chemie Lexikon, 9th edition, vol. 3, p. 1704, 1995”) comprises/contains a compound of the formula $(M^1)_2[(M^2)F_6]$, where $M^1 = H, NH_4, Li, Na, K, Rb, Cs$ and $M^2 = Ti, Zr$. The bonding agent according to the invention thus makes it possible to dispense with Cr(VI) compounds while maintaining comparable or better durability.

In a preferred embodiment, the radially polarized, piezoelectric material comprises lead zirconate titanate (PZT).

The polymer jacket preferably comprises silicones, polyesters, polyethers, polyamides, particularly preferably polyurethanes. The polymer jacket particularly preferably comprises preservatives, stabilizers (for example oxidation and UV stabilizers) and/or plasticizers.

In a preferred embodiment, the bonding agent comprises corrosion inhibitors.

The electrical contacting of the first hemispherical shell and the second hemispherical shell is preferably effected by solder joints.

The invention further comprises a passive sonar comprising an inventive piezoceramic hydrophone as described above. The passive sonar or electroacoustic underwater antenna is preferably used in underwater vehicles and surface vessels. Examples of such a structure, e.g. as a side antenna fastened to the outer skin or else an electroacoustic underwater antenna, may be found in DE 10 2004 037 987 A1 in paragraph [0013] to [0022].

In a further embodiment, the invention comprises a surface vessel or underwater vehicle comprising an inventive passive sonar as described above. Examples of preferred surface vessels or underwater vehicles are submarines, submarines having AIP (air-independent propulsion), ASW (antisubmarine warfare) helicopters, sonar buoys, frigates, destroyers, corvettes, speedboats and/or diving robots.

The invention additionally encompasses a process for producing a piezoceramic hydrophone, comprising at least the following steps. In a first step, an outer layer comprising silver and/or silicon compounds is applied to a first hemispherical shell and to a second hemispherical shell.

Application can, for example, be carried out by application by means of brushing, spray processes, dipping processes or else PVD (physical vapor deposition) or CVD (chemical vapor deposition). In a subsequent step, the outer layer is sintered and/or calcined. A bonding agent comprising a compound of the formula $(M^1)_2[(M^2)F_6]$, where $M^1 = H, NH_4, Li, Na, K, Rb, Cs$ and $M^2 = Ti, Zr$, is subsequently applied to the outer layer before or after joining the first hemispherical shell and the second hemispherical shell to form a hollow sphere. The application of the bonding agent, for example in the form of an aqueous solution, can, for example, be carried out by means of brushing, spray processes, dipping processes or else by PVD (physical vapor deposition) or CVD (chemical vapor deposition).

The bonding agent is preferably dried after application. Furthermore, the electrical contacting of the first hemispherical shell and the second hemispherical shell is effected before or after joining the first hemispherical shell and the second hemispherical shell to form a hollow sphere. A polymer jacket, for example composed of polyurethane, is subsequently applied around (preferably completely around), the hollow sphere. Application can, for example, be carried out by introducing and curing a 2-component polyurethane, for example by pouring a 2-component system.

The surface of the first hemispherical shell and/or of the second hemispherical shell and/or of the entire hollow sphere is preferably abrasive-blasted before application of the outer layer. The surface of the first hemispherical shell and/or of the second hemispherical shell is particularly preferably abrasive-blasted with corundum before the application. It has surprisingly been found that abrasive-blasting, in particular with corundum, significantly improves and increases the adhesion of the polymer jacket to the bonding agent and to the outer layer.

In a preferred embodiment, the application of the bonding agent is carried out by spray processes, dipping processes and/or brushing processes.

The invention also encompasses the use of the above-described piezoceramic hydrophone of the invention and/or passive sonar of the invention in warships and research ships, preferably submarines, submarines having AIP (air-independent propulsion), ASW (antisubmarine warfare) helicopters, sonar buoys, frigates, destroyers, corvettes, speedboats and/or diving robots.

The invention will additionally be elucidated with reference to the following figure. The figure does not restrict the scope of protection of the invention, but merely serves for illustrative explanation. The figure is not true to scale.

In the figure:

Figure 1 shows a schematic cross section of a hydrophone according to the invention.

Figure 1 shows the piezoceramic hydrophone of the invention. A first hemispherical shell (1) and a second hemispherical shell (2) comprising a radially polarized, piezoelectric material (for example lead zirconate titanate (PZT)) are assembled to form a hollow sphere (3). The first hemispherical shell (1) and the second hemispherical shell (2) comprise an outer layer (4). The outer layer (4) comprises (contains) silver and/or silicon compounds. To avoid short-circuiting, individual sections of the hemispherical shell areas of the first hemispherical shell (1) and of the second hemispherical shell (2) may be designed without an outer layer (4). The polymer jacket (6) surrounds the hollow sphere (3) with hollow sphere interior (5) and prevents or slows the penetration of moisture or dirt. The hydrophone of the invention is characterized in that the outer layer (4) is joined to the polymer jacket by a bonding agent (7). The bonding agent (7) comprises/contains a compound of the formula $(M^1)_2[(M^2)F_6]$, where $M^1 = H, NH_4, Li, Na, K$ and $M^2 = Ti, Zr$. The bonding agent (7) of the invention thus makes it possible to dispense with $Cr(VI)$ compounds while maintaining comparable or better durability.

List of reference numerals

- (1) First hemispherical shell
- (2) Second hemispherical shell
- (3) Hollow sphere
- (4) Outer layer
- (5) Hollow sphere interior
- (6) Polymer jacket
- (7) Bonding agent
- (10) Support plate
- (11) Conductor tracks

Claims

1. A piezoceramic hydrophone comprising at least the following elements:
 - a first hemispherical shell (1) and a second hemispherical shell (2) which are assembled to form a hollow sphere (3);
wherein the first hemispherical shell (1) and the second hemispherical shell (2) comprise a radially polarized, piezoelectric material (9) and the first hemispherical shell (1) and the second hemispherical shell (2) have an outer layer (4), and the outer layer (4) comprises silver and/or silicon compounds;
 - an electrical contact (5) of the first hemispherical shell (1) and the second hemispherical shell (2); and
 - a polymer jacket (6) around the hollow sphere (3);
characterized in that the outer layer (4) is joined to the polymer jacket (6) by a bonding agent (7) and wherein the bonding agent (7) comprises a compound of the formula $(M^1)_2[(M^2)F_6]$, where $M^1 = H, NH_4, Li, Na, K, Rb, Cs$ and $M^2 = Ti, Zr$.
2. The piezoceramic hydrophone as claimed in claim 1, **characterized in that** the radially polarized, piezoelectric material (9) comprises lead zirconate titanate (PZT).
3. The piezoceramic hydrophone as claimed in either of claims 1 or 2, **characterized in that** the polymer jacket comprises polyurethanes, silicones, polyesters, polyethers, polyamides, preferably polyurethanes.
4. The piezoceramic hydrophone as claimed in any of claims 1 to 3, **characterized in that** the polymer jacket (6) comprises preservatives, stabilizers and/or plasticizers.
5. The piezoceramic hydrophone as claimed in any of claims 1 to 4, **characterized in that** the bonding agent (7) comprises corrosion inhibitors.
6. The piezoceramic hydrophone as claimed in any of claims 1 to 5, **characterized in that** the electrical contacting (5) of the first hemispherical shell (1) and the second hemispherical shell (2) is effected by solder joints.
7. A passive sonar comprising a piezoceramic hydrophone as claimed in any of claims 1 to 6.

8. A surface vessel or underwater vehicle comprising a passive sonar as claimed in claim 7, preferably in submarines, submarines having AIP (air-independent propulsion), ASW (antisubmarine warfare) helicopters, sonar buoys, frigates, destroyers, corvettes, speedboats and/or diving robots.
9. A process for producing a piezoceramic hydrophone, comprising at least the following steps:
 - applying an outer layer (4) comprising silver and/or silicon compounds to a first hemispherical shell (1) and a second hemispherical shell (2);
 - sintering and/or calcining the outer layer (4);
 - applying a bonding agent (7) comprising a compound of the formula $(M^1)_2[(M^2)F_6]$, where $M^1 = H, NH_4, Li, Na, K, Rb, Cs$ and $M^2 = Ti, Zr$, to the outer layer (4) before or after joining the first hemispherical shell (1) and the second hemispherical shell (2) to form a hollow sphere (3);
 - electrically contacting the first hemispherical shell (1) and the second hemispherical shell (2) before or after joining the first hemispherical shell (1) and the second hemispherical shell (2) to form a hollow sphere (3); and
 - applying a polymer jacket (6) around the hollow sphere (3).
10. The process as claimed in claim 9, **characterized in that** the surface of the first hemispherical shell (1) and/or of the second hemispherical shell (2) and/or of the hollow sphere (3) are abrasive-blasted, preferably with corundum, before application of the outer layer (4).
11. The process as claimed in claim 9 or 10, **characterized in that** the application of the bonding agent (7) is carried out by spray processes, dipping processes and/or brushing processes.
12. The use of the piezoceramic hydrophone as claimed in any of claims 1 to 6 and/or passive sonar as claimed in claim 7 in warships and research ships, preferably submarines, submarines having AIP (air-independent propulsion), ASW (antisubmarine warfare) helicopters, sonar buoys, frigates, destroyers, corvettes, speedboats and/or diving robots.