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COMPOSITE FUEL PIPES
ZUSAMMENGESETZTE KRAFTSTOFFROHRE
TUYAX À CARBURANT EN COMPOSITES

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Description

TECHNICAL FIELD

[0001] The application relates generally to fuel pipes and, more particularly, to aircraft fuel pipes.

BACKGROUND OF THE ART

[0002] Fuel pipes in aircraft must typically be designed such as to limit the definition of a path of conduction for the electrical charge created in case of lightning strike. In addition, fuel pipes must meet certain flammability requirements.
[0003] It has been known to provide metallic fuel pipes in composite wing structures in order to meet the flammability requirements; such pipes are generally wrapped with isolators to avoid current transfer through the pipes, however such isolators may increase the cost and weight of the aircraft.

SUMMARY

[0004] In one aspect, there is provided a fuel pipe for an aircraft, the fuel pipe comprising a wall made of a material including: a matrix composed of an epoxy copolymer obtained through the reaction of a resin of the bisphenol A diglycidyl ether type with an amine hardener, and from 3 to 5 % of an organically modified nanoclay by weight of the epoxy copolymer, the nanoclay including layered magnesium aluminum silicate platelets; and reinforcing fibers embedded in the matrix.
[0005] The resin may be a bisphenol A epichlorohydrin based resin.
[0006] The resin may be a phenol, 4,40 - (1-methylethylidene) bis-polymer with (chloromethyl) oxirane.
[0007] The resin may include or is composed of C60H64O8•C12H20Cl4O4.
[0008] The resin may include or is composed of (C15H16O2·C3H5ClO)x, where x may be from 2 to 10.
[0009] The resin may include, may be composed of or may be derived from
[0010] The matrix may include 4% of the organically modified nanoclay by weight of the epoxy copolymer.
[0011] The nanoclay may be an organically modified montmorillonite.
[0012] The nanoclay may be a natural montmorillonite modified with a quaternary ammonium salt and treated with MT2EtOH (methyl, tallow, bis-(2-hydroxyethyl) quaternary ammonium).
[0013] The tallow may include about 65% C18, about 30% C16 and about 5% C14.
[0014] The nanoclay may be a surface modified montmorillonite treated with ODA (octadecyl amine).
[0015] The fibers may be woven fibers.
[0016] The fibers may be selected from the group consisting of glass fibers, aramid fibers, flax fibers, carbon fibers and combinations thereof.
[0017] The fibers may be glass fibers selected from the group consisting of E-glass (alumino-borosilicate glass with less than 1% w/w alkali oxides), A-glass (alkali-lime glass without a significant proportion of boron oxide), E-CR-glass (alumino-lime silicate with less than 1% w/w alkali oxides), C-glass (alkali-lime glass with boron oxide), D-glass (borosilicate glass), R-glass (alumino silicate glass without MgO and CaO), S-glass (alumino silicate glass with high MgO and without CaO), and combinations thereof.
[0018] The hardener may be an amidoamine.
[0019] The hardener may include triethylenetetramine.
[0020] A weight proportion of the resin to the hardener may be from 35% to 100%.
[0021] The weight proportion of the resin to the hardener may be about 2:1
[0022] The wall may be made of a single layer of the material.

DESCRIPTION OF THE DRAWINGS

[0023] Reference is now made to the accompanying figures in which:

Fig. 1 is a schematic view of a fuel pipe according to a particular embodiment; and
Fig. 2 is a graph of flammability test results for an epoxy/glass composite with and without the addition of nanoclays.

DETAILED DESCRIPTION

[0024] Composite fuel pipes, in particular when used in a composite aircraft structure, may present several advantages over metal pipes, for example with respect to weight and cost. Because of the low conductivity nature of the composite pipes as compared with metallic pipes, the possibilities of coupling of magnetic field as well as transfer of direct current are generally reduced. However, composite pipes have a higher level of flammability because of the hydrocarbon nature of the pipes.

[0025] It has been found that the addition of an appropriate type of nanoclay to an appropriate epoxy/glass composite advantageously reduces the flammability of the material and provides for a material suitable for use in fuel pipes in compliance with flammability certification requirements.

[0026] Referring to Fig. 1, a pipe 12 forming part of a fuel distribution system 10, which in a particular embodiment is located in an aircraft, is shown. The pipe 12 is defined by a tubular wall 14 which in the embodiment shown is made of a single layer of material; alternately, multiple layers may be used. The wall 14 is made of a material including a polymer matrix and reinforcing fibers.

[0027] The material includes an epoxy copolymer, which is formed by the reaction of a resin and a hardener. Suitable types of epoxy resins include glycidyl-ether, glycidyl-ester and glycidyl-amine epoxy resins as well as the non-glycidyl epoxy resins like aliphatic or cycloaliphatic epoxy resins. In a particular embodiment, the resin is EPON™ 828, a liquid bisphenol A epichlorohydrin based epoxy resin with the chemical designation of Phenol, 4,40 - (1-methylethylidene) bis-polymer with (chloromethyl) oxirane. EPON™ 828 is a resin of the DGEBA (bisphenol A diglycidyl ether) type.

[0028] In a particular embodiment, the resin includes or is composed of C60H64O8•C12H20Cl4O4.

[0029] In a particular embodiment, the resin includes or is composed of (C15H16O2•C3H5ClO)x, where x is from 2 to 10, and preferably 4.

[0030] In a particular embodiment, the resin includes, is composed of or is derived from the following compound:

\[
\text{CH}_2\text{CH}_2\text{OH} \quad \text{CH}_3 - \text{N}^+ - \text{T} \quad \text{CH}_2\text{CH}_2\text{OH}
\]

[0031] In a particular embodiment, the hardener added to the liquid resin to obtain the epoxy is an amine hardener, more particularly EPIKURE™ 3046, a polyamidoamine containing triethylene tetramine from Resolution Performance Products LLC. Other types of suitable hardeners may alternately be used, including but not limited to EPIKURE™ 3271 (a modified aliphatic amine), EPIKURE™ 3140 (a polyamide, high imidazoline, moderate molecular weight hardener based on dimerized fatty acid and polyamines), EPIKURE™ 3300 (a cycloaliphatic amine), EPIKURE™ 3125 (a polyamide hardener based on dimerized fatty acid and polyamines) and EPIKURE™ 3370 (a cycloaliphatic amine).

[0032] In a particular embodiment, the quantity of hardener is from 35% to 100% that of the resin by weight; in another particular embodiment, the weight ratio of resin to hardener is 2:1.

[0033] The matrix of the material of the wall 14 also includes an appropriate type of nanoclay mixed with the resin before reaction with the hardener. For the nanoclay, a platelet structure such as montmorillonite was selected over a nanotube structure such as halloysite. Because of the structure of the montmorillonite, polymer chains of epoxy can be intercalated into the interlayer of layered silicate of montmorillonite to form epoxy/montmorillonite nanocomposites with flame-retardant properties.

[0034] In a particular embodiment, the nanoclay is Cloisite® 30B from Southern Clay Products, a natural montmorillonite modified with a quaternary ammonium salt, treated with MT2EiOH (methyl, tallow, bis-(2-hydroxyethyl) quaternary ammonium). Typical properties include a concentration of MT2EiOH of 90 meq/100g clay, less than 2% moisture, 30% weight loss on ignition and a d-spacing (d001) of 1.85nm. Cloisite® 30B may be defined as

\[
\text{CH}_2\text{CH}_2\text{OH} \quad \text{CH}_3 - \text{N}^+ - \text{T} \quad \text{CH}_2\text{CH}_2\text{OH}
\]
where T is Tallow (∼65% C18; ∼30% C16; ∼5% C14); anion: chloride

[0035] In another particular embodiment, the nanoclay is Nanomer® 1.30E from Nanocor Inc., a surface modified montmorillonite treated with ODA (octadecyl amine), a primary amine base. Typical properties include a cation exchange capacity of 1.45, less than 3% moisture, and d-spacing (d001) of 2.38nm.

[0036] In a particular embodiment, the reinforcing fibers are TG-06-P fibers, E-glass fibers from JB Martin Texitek Division E-glass fibers. Other types of glass fibers may alternately be used, including other E-glass (alumino-borosilicate glass with less than 1% w/w alkali oxides), A-glass (alkali-lime glass with little or no boron oxide), E-CR-glass (alumino-lime silicate with less than 1% w/w alkali oxides), C-glass (alkali-lime glass with high boron oxide content), D-glass (borosilicate glass with high dielectric constant), R-glass (alumino silicate glass without MgO and CaO), S-glass (alumino silicate glass without CaO but with high MgO content); other types of fibers such as aramid (e.g. Kevlar®) fibers, flax fibers and carbon fibers may also be used.

[0037] In a particular embodiment, the fibers are woven; other fiber structures may alternately be used.

[0038] Flammability tests were performed on different materials with and without the nanoclay additives, as set forth below. The epoxy/glass samples with nanoclay were manufactured by first dispersing the montmorillonite nanoparticles in the resin by using a mechanical mixer (high speed around 10000 rpm for 10 minutes, temperature control below 120°C). The composites with 1 layer of woven glass fibers were prepared using the mixed resin and nanoclay as the matrix. The hardener was added into the mixture of resin and nanoclay and the resulting resin, nanoclay and hardener mixture was impregnated to the glass fibers using hand layup method. The composites were cured at room temperature for 2 days with subsequent post curing for 2 hours at 100°C.

[0039] All samples had a thickness below 0.120 in (3.05 mm). The material was considered compliant if for the samples tested the speed of combustion did not exceed 3.0 in/min (76.2 mm/min) or if the combustion stopped before the flame reached the 4 in (101.6 mm) mark.

[0040] All samples where conditioned at 23°C for 48 hours, at a humidity level of 50 % before the tests.

Test 1: Epoxy/glass

[0042] Samples were cut from an epoxy/glass composite without nanoclay. The resin was EPON™ 828 and the hardener was Epikure™ 3046 described above. The weight proportion of resin to hardener was 2:1, and the material included one layer of plain weave E-glass fibers TG-06-P. The thickness of the samples was approximately 1.5mm. The results are set forth in the table below.

<table>
<thead>
<tr>
<th>No.</th>
<th>1 in</th>
<th>2.5 in</th>
<th>4 in</th>
<th>5 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>74</td>
<td>117</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>74</td>
<td>118</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>83</td>
<td>124</td>
<td>157</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
<td>71</td>
<td>120</td>
<td>149</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>70</td>
<td>118</td>
<td>150</td>
</tr>
<tr>
<td>Mean</td>
<td>26.6</td>
<td>74.4</td>
<td>119.4</td>
<td>151.2</td>
</tr>
<tr>
<td>Inch/min</td>
<td>2.26</td>
<td>2.01</td>
<td>2.01</td>
<td>1.98</td>
</tr>
</tbody>
</table>

[0043] The samples are compliant since the burn rate is below 3 in/min.

Test 2: Epoxy/glass with 2% Cloisite® 30B

[0044] Samples were cut from an epoxy/glass composite with a 2% weight addition of nanoclay, the 2% weight ratio being defined with respect to the weight of epoxy (resin and hardener). The resin, hardener and glass fibers were the
same as that in Test 1. The nanoclay was Cloisite® 30B, described above. The thickness of the samples was approximately 1.5mm. The results are set forth in the table below.

<table>
<thead>
<tr>
<th>Seconds to reach burn length, epoxy/glass, 2% Cloisite® 30B</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Inch/min</td>
</tr>
</tbody>
</table>

[0045] The samples are compliant since the burn rate is below 3 in/min. A comparison of the curves of Figure 2 shows that the results obtained with 2% Cloisite® 30B (Test 2) are similar to those obtained with the epoxy/glass without nanoclay (Test 1): the sample takes longer to burn to the 1 inch mark in Test 2, but the time taken to reach the 5 inch length is similar.

Test 3: Epoxy/glass with 4% Cloisite® 30B

[0046] Samples were cut from an epoxy/glass composite with a 4% weight addition of nanoclay. The resin and hardener were the same as that in Tests 1-2 and the nanoclay the same as that in Test 2, Cloisite® 30B. The thickness of the samples was approximately 1.5mm. The results are set forth in the table below.

<table>
<thead>
<tr>
<th>Seconds to reach burn length, epoxy/glass, 4% Cloisite® 30B</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Inch/min</td>
</tr>
</tbody>
</table>

[0047] The samples are compliant since the burn rate is below 3 in/min. A comparison of the curves of Figure 2 shows that the 4% Cloisite® 30B (Test 3) provides for a lower level of flammability than the epoxy/glass without nanoclay (Test 1) and with 2% Cloisite® 30B (Test 2): the sample takes longer to burn to all the marks in Test 3, with the difference being more pronounced at the beginning (1 inch mark).

Test 4: Epoxy/glass with 2% Nanomer® I.30E

[0048] Samples were cut from an epoxy/glass composite with a 2% weight addition of another nanoclay. The resin and hardener were the same as that in Tests 1-3. The nanoclay was Nanomer® I.30E, described above. The thickness of the samples was approximately 1.5mm. The results are set forth in the table below.

<table>
<thead>
<tr>
<th>Seconds to reach burn length, epoxy/glass, 2% Nanomer® I.30E</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>
The samples are compliant since the burn rate is below 3 in/min. A comparison of the curves of Figure 2 shows that the 2% Nanomer® I.30E (Test 4) provides for a lower level of flammability than the epoxy/glass without nanoclay (Test 1): the sample takes longer to burn to all the marks in Test 3, with the difference being more pronounced at the end (5 inch length). Although the samples of Test 4 initially burn more quickly than those with 4% Cloisite® 30B (Test 3) up to the 1 inch mark, over the complete length of the samples the 2% Nanomer® I.30E (Test 4) performs slightly better.

Test 5: Epoxy/glass with 4% Nanomer® I.30E

Samples were cut from an epoxy/glass composite with a 4% weight addition of nanoclay. The resin and hardener were the same as that in Tests 1-4 and the nanoclay the same as that in Test 4, Nanomer® I.30E. The thickness of the samples was approximately 1.5mm. The results are set forth in the table below.

Seconds to reach burn length, epoxy/glass, 4% Nanomer® I.30E

<table>
<thead>
<tr>
<th>No.</th>
<th>1 in</th>
<th>2.5 in</th>
<th>4 in</th>
<th>5 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
<td>86</td>
<td>140</td>
<td>178</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>92</td>
<td>146</td>
<td>183</td>
</tr>
<tr>
<td>3</td>
<td>34</td>
<td>84</td>
<td>137</td>
<td>168</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>90</td>
<td>148</td>
<td>188</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>79</td>
<td>135</td>
<td>170</td>
</tr>
<tr>
<td>Mean</td>
<td>35.0</td>
<td>86.2</td>
<td>141.2</td>
<td>177.4</td>
</tr>
<tr>
<td>Inch/min</td>
<td>1.71</td>
<td>1.74</td>
<td>1.70</td>
<td>1.69</td>
</tr>
</tbody>
</table>

The samples are compliant since the burn rate is below 3 in/min. A comparison of the curves of Figure 2 shows that the 4% Nanomer® I.30E (Test 5) provides for a significantly lower level of flammability than the epoxy/glass without nanoclay (Test 1), with 2% Nanomer® I.30E (Test 4), and with 2% and 4% Cloisite® 30B (Tests 2-3): the sample takes longer to burn to all the marks in Test 5, with the difference becoming more pronounced at the end (5 inch length).

Test 6: Polyamide-6

Samples were cut from a polyamide-6 material, without nanoclay. Two rounds of tests were performed. The five samples of the first round had a thickness of between 1.31 mm and 1.38 mm. The five samples of the second round had a thickness of between 1.27 mm and 1.35 mm. All samples burned up to the first mark (at 1 in) before the 30 seconds of application of the flame were over, and are considered as non compliant.

Test 7: Polyamide-6 with 2% Cloisite® 15A

Samples were cut from a polyamide-6 material with a 2% weight addition of nanoclay. The polyamide was the same as that in Test 6. The nanoclay was Cloisite® 15A. Three rounds of tests were performed. The five samples of the first round had a thickness of between 1.17 mm and 1.26 mm. The five samples of the second round had a thickness of between 1.18 mm and 1.22 mm. The five samples of the third round had a thickness of between 1.19 mm and 1.24 mm. All samples but one in the second round and one in the third round burned up to the first mark (at 1 in) before the 30 seconds of application of the flame were over, and are considered as non compliant. In the first two rounds there
was a lot less bubbles that in Test 6. The samples did not instantly melt but the portion exposed to the flame became transparent and fell in one piece. In the third round, the samples melted and fuelled combustion; a lot of bubbles were produced.

[0054] The results for the samples that did not burn up to the first mark (at 1 in) before the 30 seconds of application of the flame were over are shown in the table below. These samples are considered as non compliant because they burned completely and melted.

<table>
<thead>
<tr>
<th>Seconds to reach burn length, polyamide-6, 2% Cloisite® 15A</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
</tr>
<tr>
<td>Round 2-1</td>
</tr>
<tr>
<td>Round 3-3</td>
</tr>
</tbody>
</table>

Test 8: Polyamide-6 with 4% Cloisite® 15A

[0055] Samples were cut from a polyamide-6 material with a 4% weight addition of nanoclay. The polyamide was the same as that in Tests 6-7 and the nanoclay was the same as that in Test 7, Cloisite® 15A. The thickness of the samples was between 1.21 mm and 1.29 mm. All samples burned completely before reaching the 5 in mark and as such are considered non compliant. The results are set forth in the table below.

<table>
<thead>
<tr>
<th>Seconds to reach burn length, polyamide-6, 4% Cloisite® 15A</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Test 9: Polyamide-6 with 2% ME100

[0056] Samples were cut from a polyamide-6 material with a 2% weight addition of another nanoclay. The polyamide was the same as that in Tests 6-8 and the nanoclay was the synthetic nanoclay ME100 (from Somasif CBC chemical Co.). The thickness of the samples was between 1.26 mm and 1.36 mm. These samples are considered as non compliant because all samples burned under the applied flame. More bubbles were produced than in Test 6 (polyamide-6 without nanoclay). White smoke was been observed. The samples did not melt immediately but the portion exposed to the flame became transparent and dropped.

Test 10: Polyamide-6 with 4% ME100

[0057] Samples were cut from a polyamide-6 material with a 4% weight addition of nanoclay. The thickness of the samples was between 1.27 mm and 1.31 mm. The polyamide was the same as that in Tests 6-9 and the nanoclay was the same as that in Test 8, ME100. These samples are considered as non compliant because all samples melted and burned under the applied flame, similarly to Test 9.

Test 11: Polyethylene

[0058] Samples were cut from a polyethylene material, without nanoclay. The thickness of the samples was between 1.22 mm and 1.27 mm. With the horizontal test the combustion stopped immediately. A test was performed with the samples extending vertically, and the samples melted and ran like water. The samples are considered as non compliant because of the very high rate of flammability observed.

Test 12: Polyethylene with 2% Cloisite® 15A

[0059] Samples were cut from a polyethylene material with a 2% weight addition of nanoclay. The polyethylene was
the same as that in Test 9. The nanoclay was Cloisite® 15A. The thickness of the samples was between 1.24 mm and 1.32 mm. The samples burned very quickly vertically, ran and continued to burn on the ground. A lot of smoke was produced. The samples are considered as non compliant because of the very high rate of flammability observed.

During the tests, it was found that the addition of the montmorillonite to the epoxy/glass composite increased the burning time and the char of the sample was less deformed after the test. In addition, the presence of montmorillonite in the epoxy/glass composite reduced falling fragments during combustion. As such the presence of montmorillonite in the epoxy/glass composite may help limit the spread of the flame during combustion, which may be a consideration for structural materials.

It has been found that nanoclays suitable for inclusion in the fuel pipe material may be described as organically modified, nanometer scale, layered magnesium aluminum silicate platelets. In the present application, "organically modified" refers to the modification of the substantially inorganic nanoclay (i.e. generally free of carbon and hydrogen groups) to make it organophilic. In a particular embodiment, the organically modified clay includes covalently linked organic moieties that have been modified with a C₂₅C₁₂ alkylamine, preferably a quaternary amine with a C₈C₁₀ alkyl, to make it organophilic. Recommended clays include Cloisite® 30B and Nanomer® I.30E and also other types of montmorillonite such as Cloisite® 20A, Cloisite® Na, Nanomer® 1.44P, Cloisite® 25A, and Cloisite® 15A.

With the epoxy/glass composite tested, both montmorillonites provided for better results with the 4% weight concentration than with the 2% weight concentration.

As such, it is concluded that a composite material including a matrix composed of an epoxy copolymer obtained through the reaction of a resin of the bisphenol A diglycidyl ether type with an amine hardener, and between 3 to 5% of an organically modified nanoclay by weight of the epoxy copolymer with the nanoclay including layered magnesium aluminum silicate platelets, and reinforcing fibers embedded in the matrix, provides for a material particularly suitable for the manufacture of composite fuel pipes in an aircraft, with respect to flammability requirements. The resin is preferably a bisphenol A epichlorohydrin based resin, and preferably a phenol, 4,4’-(1-methylethylidene) bis-polymer with (chloromethyl) oxirane. The nanoclay is preferably provided in a 4% weight proportion to the epoxy copolymer, and is preferably a montmorillonite. The amine hardener is preferably an amidoamine.

In a particular embodiment, the addition of the nanoclay also improves the stability of the composite fuel pipes. The added particles may participate in maintaining the form of the structure even in case of fire, and minimize dropping of the polymer phase. As such the possibility of spreading the fire to other parts may be reduced.

Claims

1. A fuel pipe for an aircraft, the fuel pipe comprising a wall made of a material including:

   a matrix composed of

   an epoxy copolymer obtained through the reaction of a resin of the bisphenol A diglycidyl ether type with an amine hardener, and from 3 to 5% of an organically modified nanoclay by weight of the epoxy copolymer, the nanoclay including layered magnesium aluminum silicate platelets; and

   reinforcing fibers embedded in the matrix.

2. The fuel pipe as defined in claim 1, wherein the resin is a bisphenol A epichlorohydrin based resin.

3. The fuel pipe as defined in claim 1, wherein the resin is a phenol, 4,4’ - (1-methylethylidene) bis-polymer with (chloromethyl) oxirane.

4. The fuel pipe as defined in claim 1, wherein the resin includes or is composed of C₆₀H₆₄O₈•C₁₂H₂₀Cl₄O₄.

5. The fuel pipe as defined in claim 1, wherein the resin includes or is composed of (C₁₅H₁₀O₂•C₃H₅ClO)x, where x is from 2 to 10.

6. The fuel pipe as defined in claim 1, wherein the resin includes, is composed of or is derived from
7. The fuel pipe as defined in any one of claims 1 to 6, wherein the matrix includes 4% of the organically modified nanoclay by weight of the epoxy copolymer.

8. The fuel pipe as defined in any one of claims 1 to 7, wherein the nanoclay is an organically modified montmorillonite.

9. The fuel pipe as defined in any one of claims 1 to 8, wherein the nanoclay is a natural montmorillonite modified with a quaternary ammonium salt and treated with MT2EtOH (methyl, tallow, bis-(2-hydroxyethyl) quaternary ammonium).

10. The fuel pipe as defined in claim 9, wherein the tallow includes about 65% C18, about 30% C16 and about 5% C14.

11. The fuel pipe as defined in any one of claims 1 to 8, wherein the nanoclay is a surface modified montmorillonite treated with ODA (octadecyl amine).

12. The fuel pipe as defined in any one of claims 1 to 11, wherein the fibers are woven fibers.

13. The fuel pipe as defined in any one of claims 1 to 12, wherein the fibers are selected from the group consisting of glass fibers, aramid fibers, flax fibers, carbon fibers and combinations thereof.

14. The fuel pipes as defined in claim 13, wherein the fibers are glass fibers selected from the group consisting of E-glass (alumino-borosilicate glass with less than 1% w/w alkali oxides), A-glass (alkali-lime glass without a significant proportion of boron oxide), E-CR-glass (alumino-lime silicate with less than 1% w/w alkali oxides), C-glass (alkali-lime glass with boron oxide), D-glass (borosilicate glass), R-glass (alumino silicate glass without MgO and CaO), S-glass (alumino silicate glass with high MgO and without CaO), and combinations thereof.

15. The fuel pipe as defined in any one of claims 1 to 14, wherein the hardener is an amidoamine.

**Patentansprüche**

1. Kraftstoffleitung für ein Luftfahrzeug, wobei die Kraftstoffleitung eine Wand umfasst, die aus einem Material besteht, das folgendes aufweist:

   eine Matrix, die sich zusammensetzt aus:

   einem Epoxid-Copolymer, das durch die Reaktion eines Harzes vom Typ Bisphenol A Diglycidylether mit einem Amin-Härter erhalten wird; und

   3 bis 5% des Gewichts des Epoxid-Copolymers eines organisch modifizierten Nanotons, wobei der Nanoton geschichtete Magnesiumaluminiumsilikat-Plättchen aufweist; und

   in die Matrix eingebettete Verstärkungsfasern.

2. Kraftstoffleitung nach Anspruch 1, wobei das Harz ein Harz auf der Basis von Bisphenol A Epichlorhydrin ist.

3. Kraftstoffleitung nach Anspruch 1, wobei das Harz ein Phenol, 4,40-(1-Methylethyliden)bis-polymer mit (Chlormethyl)oxiran ist.

4. Kraftstoffleitung nach Anspruch 1, wobei das Harz C_{60}H_{64}O_{5}·C_{12}H_{20}Cl_{2}O_{4} aufweist oder daraus besteht.

5. Kraftstoffleitung nach Anspruch 1, wobei das Harz (C_{10}H_{16}O_{2}·C_{3}H_{6}ClO)_{x} aufweist oder daraus besteht, wobei x zwischen 2 und 10 liegt.
6. Kraftstoffleitung nach Anspruch 1, wobei das Harz folgendes aufweist, daraus besteht oder davon hergeleitet ist:

7. Kraftstoffleitung nach einem der Ansprüche 1 bis 6, wobei die Matrix 4% des Gewichts des Epoxid-Copolymers des organisch modifizierten Nanotons aufweist.

8. Kraftstoffleitung nach einem der Ansprüche 1 bis 7, wobei der Nanoton ein organisch modifiziertes Montmorillonit ist.

9. Kraftstoffleitung nach einem der Ansprüche 1 bis 8, wobei der Nanoton ein natürliches Montmorillonit ist, modifiziert mit einem quartären Ammoniumsalz und behandelt mit MT2EtOH (Methyl, Talg, bis-(2-Hydroxyethyl) quartäres Ammonium).

10. Kraftstoffleitung nach Anspruch 9, wobei der Talg etwa 65% C18, etwa 30% C16 und etwa 5% C14 aufweist.

11. Kraftstoffleitung nach einem der Ansprüche 1 bis 8, wobei der Nanoton ein oberflächenmodifiziertes Montmorillonit, behandelt mit ODA (Octadecylamin) ist.

12. Kraftstoffleitung nach einem der Ansprüche 1 bis 11, wobei die Fasern Webfasern sind.

13. Kraftstoffleitung nach einem der Ansprüche 1 bis 12, wobei die Fasern ausgewählt sind aus der Gruppe bestehend aus Glasfasern, Aramidfasern, Flachfasern, Kohlefasern und Kombinationen davon.

14. Kraftstoffleitungen nach Anspruch 13, wobei die Fasern Glasfasern sind, ausgewählt aus der Gruppe bestehend aus E-Glas (Alumino-Borosilikatglas mit weniger als 1% w/w Alkalioxid), A-Glas (Alkalikalkglas ohne signifikanten Anteil von Boroxid), E-CR-Glas (Alumino-Kalkglas mit weniger als 1% w/w Alkalioxid), C-Glas (Alkalikalkglas mit Boroxid), D-Glas (Borosilikatglas), R-Glas (Aluminosilikatglas ohne MgO und CaO), S-Glas (Aluminosilikatglas mit hohem MgO-Anteil und ohne CaO) und Kombinationen davon.

15. Kraftstoffleitung nach einem der Ansprüche 1 bis 14, wobei der Härter ein Amidoamin ist.

Revendications

1. Tuyau à carburant pour avion, le tuyau à carburant ayant une paroi constituée d'un matériau comprenant :

   une matrice composée

   d'un copolymère époxy résultant de la réaction d'une résine de type éther diglycidylique de bisphénol A avec un durcisseur aminé, et

   de 3 à 5 % d'une nanoargile organiquement modifiée en poids du copolymère époxy, la nanoargile comprenant des plaquettes de silicate d'aluminium et de magnésium stratifiées ; et

   des fibres de renfort noyées dans la matrice.

2. Tuyau à carburant selon la revendication 1, la résine étant une résine à base d'épichlorhydrine de bisphénol A.

3. Tuyau à carburant selon la revendication 1, la résine étant un phénol 4,40-(1-méthyléthylidène)bis-polymère avec du (chlorométhyl)oxirane.

4. Tuyau à carburant selon la revendication 1, la résine comprenant ou étant constituée de C₆₀H₆₄O₈·C₁₂H₂₀Cl₄O₄.

5. Tuyau à carburant selon la revendication 1, la résine comprenant ou étant constituée de (C₁₉H₁₆O₂·C₇H₃ClO)ₓ, x étant compris entre 2 et 10.
6. Tuyau à carburant selon la revendication 1, la résine comprenant, étant constituée de ou étant dérivée de

![Diagramme]

7. Tuyau à carburant selon l’une quelconque des revendications 1 à 6, la matrice comprenant 4 % de la nanoargile organiquement modifiée en poids du copolymère époxy.

8. Tuyau à carburant selon l’une quelconque des revendications 1 à 7, la nanoargile étant une montmorillonite organiquement modifiée.

9. Tuyau à carburant selon l’une quelconque des revendications 1 à 8, la nanoargile étant une montmorillonite naturelle modifiée par un sel d’ammonium quaternaire et traitée avec du MT2EtOH (méthyl, suif, bis-(2-hydroxyethyl) ammonium quaternaire).

10. Tuyau à carburant selon la revendication 9, le suif comprenant environ 65 % de C18, environ 30 % de C16 et environ 5 % de C14.

11. Tuyau à carburant selon l’une quelconque des revendications 1 à 8, la nanoargile étant une montmorillonite à surface modifiée traitée avec de l’ODA (octadécyl amine).

12. Tuyau à carburant selon l’une quelconque des revendications 1 à 11, les fibres étant des fibres tissées.

13. Tuyau à carburant selon l’une quelconque des revendications 1 à 12, les fibres étant choisies dans le groupe constitué par les fibres de verre, les fibres d’aramide, les fibres de lin, les fibres de carbone et leurs combinaisons.

14. Tuyau à carburant selon la revendication 13, les fibres étant des fibres de verre choisies dans le groupe constitué de verre E (verre alumino-borosilicate avec moins de 1 % en poids d’oxydes alcalins), du verre A (verre sodo-calcique sans proportion significative d’oxyde de bore), de verre E-CR (silicate alumino-calcique avec moins de 1 % en poids d’oxydes alcalins), de verre C (verre sodo-calcique avec l’oxyde de bore), de verre D (verre borosilicate), de verre R (verre alumino-silicate sans MgO ni CaO), de verre S (verre alumino-silicate à teneur élevée en MgO et sans CaO) et leurs combinaisons.

15. Tuyau à carburant selon l’une quelconque des revendications 1 à 14, le durcisseur étant une amidoamine.