

March 10, 1964

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3,124,428

HIGH STRENGTH STRUCTURAL MATERIAL

Filed Nov. 23, 1959

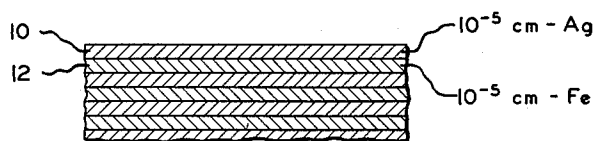


FIG. 1

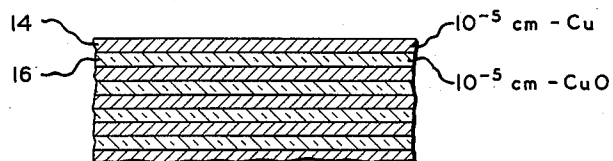


FIG. 2

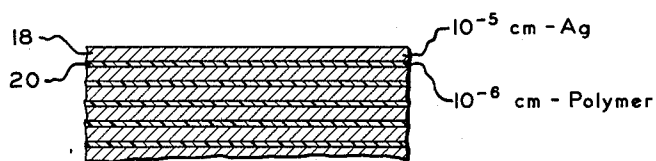


FIG. 3

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Filed Nov. 23, 1959, Ser. No. 854,905

4 Claims. (Cl. 29—183.5)

The present invention relates to structural materials and, more particularly, to structural materials characterized by unusual strength.

The primary object of the present invention is to provide, in the fabrication of sheet, wire, tube and the like, a novel structural material possessing unusual tensile, compressive and shear strength by virtue of a multiplicity of discrete strata of different materials, of which at least 50 discrete strata are composed of an inorganic material and range in thickness from 10^{-7} to 10^{-4} centimeters. It is believed that such a structural material possesses extremely high strength by virtue of the physical nature of thin solids and bonded interfaces.

Other objects of the present invention will in part be obvious and will in part appear hereinafter.

For a fuller understanding of the nature and objects of the present invention, reference should be had to the following detailed description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a broken away, exaggerated cross-sectional view of a structural material embodying the present invention;

FIG. 2 is a broken away, exaggerated cross-sectional view of another structural material embodying the present invention; and

FIG. 3 is a broken away, exaggerated cross-sectional view of a further structural material embodying the present invention.

The extraordinarily high strength of materials embodying the present invention is believed to result from the following two strengthening effects.

The first strengthening effect is based upon the following considerations. Under the influence of tensile, compressive or shear forces, a metal deforms first elastically and then plastically. Usually plastic flow begins under applied stresses at least ten times smaller than theoretically should be required to cause whole atomic planes in a perfect metal crystal to move relative to one another. The discrepancy between the calculated and observed values of the stresses required to initiate plastic flow has been attributed to the movement, under applied stress, of imperfections or "dislocations" existing in most metals. When the dislocations of a metal crystal are eliminated or alternatively are locked so that they cannot move readily, the stresses required to produce plastic flow are increased enormously. Apparently, a locked condition of dislocations is attained by forming the metal in sufficiently thin condition.

The second strengthening effect is based upon the following considerations relating to the interfacial surface between two materials. It is known that metals at room temperature have surface energies of the order of 3,000 ergs/cm². This energy normally is negligible in reference to any possible effect on mechanical properties. Thus, let us assume a one centimeter cube of a material like steel stressed in tension to its elastic limit of about 6×10^9 dynes/cm², at which point its maximum elastic strain will be 3×10^{-3} . The total elastic energy required to raise this cube to its elastic limit is about 9×10^6 ergs. Since during straining, the sides of the cube will be lengthened by 3×10^{-3} cm. in the direction of the tension, and shortened by 10^{-3} cm. at right angles to this direction (poisson ratio is about one third), we have a total increase of area of 8×10^{-3} cm², which requires

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24 ergs of energy. The latter amount is a negligible proportion of the total energy. The foregoing indicates that normally the elastic properties of a metal are not effected by its surface energy properties. With a technique to substantially increase the ratio of surface or interfacial area to volume, it is possible to increase the ratio of surface to volume energy.

In accordance with the present invention the foregoing two effects are combined by laminating a multiplicity of discrete strata of different materials, of which at least 50 discrete strata are composed of a metallic or hard nonmetallic material and range in thickness from 10^{-7} to 10^{-4} cm. These strata, for example, may be separated from each other by strata of like or different thickness composed of other materials, be they metallic, inorganic or organic compounds. The alternate may be produced by vacuum deposition under which evaporation from a molten source occurs at a pressure no greater than 10^{-5} mm. Hg or vapor deposition under which reduction from a vapor occurs by displacement or decomposition. Other methods which might be used are the electroplating of alternative layers of metals or the rolling down to the correct thickness of a thicker material built up of a pile of foils. Preferably, adjacent strata should be composed of incompatible materials which ensure their discrete characteristics. This incompatibility might be inferred from the low solubility (preferably less than 1.0%) of the atoms or molecules of one material in a solid lattice of the other, or by the inability of the contiguous materials to form chemical compounds. Such incompatibility would make it easier to manufacture the multi-layer material. Alternatively, interdiffusion of adjacent strata may be prevented even in the case of soluble contiguous materials by controlling deposition conditions. However, it should be emphasized that soluble as well as insoluble layer lattice materials should show the strengthening effect. These strata may be disposed, for example, in various geometrical configurations including sheets, tubes and wires.

Various products embodying the present invention are illustrated in FIGS. 1, 2 and 3. The product of FIG. 1 is of a type comprising alternate strata 10 and 12 of different metals such as silver and iron or different non-metals such as glass and lithium fluoride. Each of strata 10 and 12 is approximately 10^{-5} cm. thick. The product of FIG. 2 is of a type comprising alternate strata 14 and 16 of a metal such as copper and an inorganic compound such as copper oxide. Stratum 14 and stratum 16 are approximately 10^{-5} cm. thick. Stratum 16 is formed by oxidizing the outer layer of a deposited stratum 14. The product of FIG. 3 is of a type comprising alternate strata 18 and 20 of a metal such as silver and an organic compound, for example, a high polymer such as methyl methacrylate. Each stratum 18 is approximately 10^{-5} cm. thick and each stratum 20 is approximately 10^{-6} cm. thick. It is to be expressly understood that, in addition to the requisite multiplicity of strata within the thickness range of from 10^{-7} to 10^{-4} cm., a product of the present invention may include strata of other thicknesses covering faces of the product or interspersed within the product.

Since certain changes may be made in the above described process without departing from the scope of the present invention, all matter disclosed in the foregoing description or shown in the accompanying drawing shall be interpreted in an illustrative and not in a limiting sense.

What is claimed is:

1. A structural product comprising a multiplicity of discrete sequential strata bonded together, each adjacent pair of discrete sequential strata including a first stratum composed of a first material and a second stratum composed of a second material, said first material and

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said second material being incompatible, the boundary between said first material and said second material being sharp, at least fifty of said discrete sequential strata each being composed of an inorganic material and ranging in thickness from 10^{-7} to 10^{-4} centimeters, said inorganic material being metallic.

2. A structural product comprising a multiplicity of discrete sequential strata bonded together, each adjacent pair of discrete sequential strata including a first stratum composed of a first material and a second stratum composed of a second material, said first material and said second material being incompatible, the boundary between said first material and said second material being sharp, at least fifty of discrete sequential strata each being composed of an inorganic material and ranging in thickness from 10^{-7} to 10^{-4} centimeters, said first stratum being composed of silver that is 10^{-5} centimeters thick and said second stratum being composed of iron that is 10^{-5} centimeters thick.

3. A structural product comprising a multiplicity of discrete sequential strata bonded together, each adjacent pair of discrete sequential strata including a first stratum composed of a first material and a second stratum composed of a second material, said first material and said second material being incompatible, the boundary between said first material and said second material being sharp, at least fifty of discrete sequential strata each being composed of an inorganic material and ranging in thickness from 10^{-7} to 10^{-4} centimeters, said first stratum being composed of copper that is 10^{-5} centimeters

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thick and said second stratum being composed of copper oxide that is 10^{-5} centimeters thick.

4. A structural product comprising a multiplicity of discrete sequential strata bonded together, each adjacent pair of discrete sequential strata including a first stratum composed of a first material and a second stratum composed of a second material, said first material and said second material being incompatible, the boundary between said first material and said second material being sharp, at least fifty of discrete sequential strata each being composed of an inorganic material and ranging in thickness from 10^{-7} to 10^{-4} centimeters, said first stratum being composed of silver that is 10^{-5} centimeters thick and said second stratum being composed of an organic polymer that is 10^{-6} centimeters thick.

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