they both have a carbon coating which is 0.1–5 μm thick.

**Advanced composites with thermoplastic particles at the interface between the layers**
Maranci, A., Peake, S.L. and Kaminski, S.S. (American Cyanamid Company, Stamford, CT, USA) *US Pat 5 057 353 (15 October 1991)*
A fibre-reinforced thermosetting resin prepreg has an outer thermoplastic resin layer that contains no reinforcing fibres. This layer comprises particles 2–100 μm in diameter that are soluble in the thermosetting resin upon curing of the prepreg to form the composite.

**Ceramic matrices reinforced with SiC, $Si_3N_4$ or SiAlON fibres having a coating of C, B or BN containing SiC or $Si_3N_4$**
Sakamoto, H. and Miyoshi, T. (Hitachi Ltd, Tokyo, Japan) *US Pat 5 057 465 (15 October 1991)*
A ceramic composite with a matrix of SiC, $Si_3N_4$ or $Si_{6-z}Al_zO_zN_{8-z}$, where $0<z\leq4$, contains fibres or whiskers of SiC, $Si_3N_4$ or $Si_{6-z}Al_zO_zN_{8-z}$, where $0<z\leq4$. The fibres are 10–200 μm in diameter and the whiskers are 0.5–5 μm, and they both have a coating of C, B or BN containing 10–50 mol% of SiC or $Si_3N_4$ which is 0.1–5 μm thick.

**Metal–ceramic composites containing complex ceramic whiskers**
Brupacher, J.M., Christodoulou, L. and Nagle, D.C. (Martin Marietta Corporation, Bethesda, MD, USA) *US Pat 5 059 490 (22 October 1991)*
A composite comprises *in situ* precipitated complex boride whiskers in a solvent metal matrix. The whiskers have an aspect ratio of greater than 10:1.

**Alumina–titanium carbide–silicon carbide composition**
Mehrotra, P.K. and Billman, E.R. (Kennametal Inc, Latrobe, PA, USA) *US Pat 5 059 564 (22 October 1991)*
An alumina matrix has 1–30 volume% silicon carbide whiskers and 5–40 volume% titanium carbide particles or whiskers dispersed in it. The silicon carbide whiskers have an average diameter of 0.3–0.7 μm, while the titanium carbide particles and whiskers both have average diameters of 1–10 μm.

## PROCESSES

**Processing of carbon/carbon composites using supercritical fluid technology**
Berneberg, P.L. and Krukonis, V.J. (The Babcock and Wilcox Company, New Orleans, LA, USA) *US Pat 5 035 921 (30 July 1991)*
A polycarbosilane, polysilane or n-hexylcarborane ceramic precursor dissolved in a supercritical fluid is infiltrated into a carbon/carbon composite. The pressure is reduced so that precursor precipitates within the porosity of the composite. The impregnated composite is pyrolysed, thereby improving the oxidation resistance of the original composite.

**Carbon-coated reinforcing fibres and composite ceramics made therefrom**
Stempin, J.L. and Wexell, D.R. (Corning Incorporated, Corning, NY, USA) *US Pat 5 039 635 (13 August 1991)*
An inorganic fibre reinforcement material is coated with a pyrolytic carbon and then formed into a preform with powdered glass or glass ceramic. The preform is consolidated at temperatures of up to 1300°C under pressure such that full densification of the matrix is achieved but so that the pyrolytic carbon coating is not destroyed.

**Resin transfer moulding process**
Johnson, C.F. and Chavka, N.G. (Ford Motor Company, Dearborn, MI, USA) *US Pat 5 041 260 (20 August 1991)*
Random chopped fibre reinforcements are sprayed onto a forming member whilst a vacuum is drawn through the member. A resin-soluble web is applied over the reinforcements on the member and the reinforcements are compressed. The resulting preform is removed and placed in a resin transfer mould; the mould is then closed and resin is introduced to produce an FRP part.

**Filament-containing composite**
Singh, R.N. and Morrison, W.A. (General Electric Company, Schnectady, NY, USA) *US Pat 5 043 303 (27 August 1991)*
Carbon-containing filaments are coated with boron nitride and enveloped with an infiltration-promoting material containing elemental carbon to produce a preform with 25–85 volume% open porosity and containing largely parallel filaments. This preform is heated and infiltrated with a molten infiltrant comprising boron and silicon and containing at least 0.1 weight% elemental boron by weight of elemental silicon in solution in silicon. The whole is then cooled to produce the composite.

**Process for forming ceramic matrix composites**
Allaire, R.A. and Coppola, F. (Corning Incorporated, Corning, NY, USA) *US Pat 5 049 329 (17 September 1991)*
A preform containing long reinforcing fibres and a finely-divided ceramic matrix is heated to a temperature of 500–1500°C. Consolidation pressure is applied in a direction normal to the fibre direction via a softened glass pressurizing medium whilst the preform is supported against a rigid shaping surface.

**Method of curing composite parts**
Brustad, V.G., Phillips, R.V. and Rodman, W.L. (The Boeing Company, Seattle, WA, USA) *US Pat 5 051 226 (24 September 1991)*
Uncured fibre-reinforced resin on a former is passed through a fluid bath which exerts compressive pressure on it for a sufficient time to cure the composite, whilst the composite is heated rapidly enough that resin flow occurs before curing.

**Method for fabrication of superplastic composite material having metallic aluminium reinforced with silicon nitride**
Imai, T. and Mabuchi, M. (Agency of Industrial Science and Technology and Ministry of International Trade and Industry, Tokyo, Japan) *US Pat 5 051 231 (24 September 1991)*
Silicon nitride whiskers or sub-50 μm powder is wet mixed with sub-50 μm aluminium powder. The solvent is removed and the resultant mixture pressure sintered under a vacuum. It is further treated, pressed and hot extrusion moulded to form a superplastic composite of silicon nitride reinforced aluminium.

**Method of preparing carbon fibre-reinforced carbon modules**
Takahashi, S. (Kanto Yaking Kogyo KK, Kanagawa, Japan) *US Pat 5 055 243 (8 October 1991)*
Carbon fibres are packed in plastic bags and impregnated with resinous binders, after which the bags are hermetically sealed under vacuum. The bags are confined in a predetermined space and the contents released from vacuum so that the fibres expand and fill the space. The modules are heat treated to make the resin binders infusible and then carbonized by further heating to produce carbon fibre-reinforced carbon modules.

**Method of making carbon–carbon composites**
(Engle, G.B. of Poway, CA, USA) *US Pat 5 061 414 (29 October 1991)*
A green composite of graphitizable carbon fibres woven in three dimensions and a fine graphitizable pitch powder is heated until the pitch powder softens when the composite is pressed. It is then heated to at least 500°C so that the pitch carbonizes and a carbon matrix is formed which shrinks and cracks. Pyrolytic carbon is then deposited by infiltration with a hydrocarbon gas, after which it is covered with additional graphitizable pitch at 200°C or greater and pressure applied to infiltrate the pitch. The whole is then heated to at least 900°C. The last two steps are repeated at least once and then the composite is heated to between 2400 and 3100°C to graphitize the fibres and the matrix. After this, it is infiltrated with a hydrocarbon gas at between 982 and 1490°C which deposits pyrolytic carbon in the pores and cracks.