



METHOD FOR THE PRODUCTION OF POROUS CARBON-BASED MOULDED BODIES, AND USE THEREOF AS CELL CULTURE CARRIER SYSTEMS AND CULTURE SYSTEMS

The present invention relates to methods for producing carbon-based moulded bodies. In particular, the present invention relates to methods for producing porous carbon-based moulded bodies by carbonising organic polymer materials mixed with non-polymeric fillers and subsequently dissolving the fillers out from the carbonised moulded bodies. In a further embodiment the present invention relates to methods for producing porous carbon-based moulded bodies by carbonising organic polymer materials mixed with non-polymeric fillers which are substantially completely decomposed during the carbonisation. The present invention further relates to a method for producing porous carbon-based moulded bodies by carbonising organic polymer materials, the carbon-based moulded bodies being partially oxidised following carbonisation so as to produce pores. In addition, the present invention relates to porous moulded bodies produced according to one of said methods and the use thereof, especially as cell culture carriers and/or culture systems.

As a result of the variability of its properties, carbon is a versatile material in all areas of materials engineering. Carbon-based materials are used in mechanical engineering, vehicle construction, and also in medical engineering and process engineering. Described in DE 35 28 185 is a method for producing high-strength, high-density carbon materials from special powdered carbon-containing raw materials without using a binder.

DE 198 23 507 describes methods for producing carbon-based shaped bodies by carbonising biogenic raw materials of natural vegetable fibres or wood product. DE 100 11 013 and EP 0 543 752 describe methods for producing carbon-



containing materials by carbonisation or pyrolysis of foamed initial polymers such as polyacrylnitrile or polyurethane. The carbon foams thus obtained are used as high-temperature insulators in furnace installations or reactor construction or for sound damping in high-temperature operation. US 3,342,555 also describes a method for producing light porous carbon by carbonising foamed polymers based on phenolaldehyde resins of the resol or novolac type.

Said prior-art methods for producing porous carbon moulded bodies have the disadvantage that the moulded bodies obtained by carbonising foamed polymers frequently exhibit very low mechanical stability which makes it almost impossible to use these under mechanical loading conditions. Further, pore size and pore volume in these moulded bodies cannot be adjusted sufficiently accurately for these to be usable for example for biotechnological applications, such as orthopaedic implants.

There is thus a continuous need for new and improved methods for producing porous carbon-containing moulded bodies.

It is thus an object of the present invention to provide a simple method for producing porous carbon-based moulded bodies which can be implemented under economical conditions.

A further object of the present invention is to provide a method for producing porous carbon-based moulded bodies which allows the porosity, especially the pore volume and the pore diameter, to be specifically adjusted in a reproducible manner by varying simple process parameters.

A further object of the present invention is to provide methods for producing porous carbon-based moulded bodies

which can be used for the tailored production of corresponding moulded bodies in a plurality of shapes and dimensions.

It is further an object of the present invention to provide fields of use and applications of the carbon-based moulded bodies according to the invention.

The objects according to the invention are solved by the methods and moulded bodies which can be produced thereby as well as the uses according to the independent claims. Preferred embodiments are specified in the respective dependent claims.

In general, the present invention provides methods whereby porous carbon-based moulded bodies are produced by carbonising semi-finished moulded parts of organic polymer materials, the porosity of the moulded body being produced during or following the pyrolysis.

In a first embodiment of the present invention a method is provided for producing porous carbon-based moulded bodies which comprises the following steps:

- mixing organic polymer materials which can be carbonised to carbon with non-polymeric fillers;
- producing a semi-finished moulded part from the mixture;
- carbonising the semi-finished moulded part in a non-oxidising atmosphere at elevated temperature, wherein a carbon-based moulded body is obtained;
- dissolving the fillers out from the carbonised moulded body using suitable solvents.

According to this embodiment of the method according to the invention, in this first step the organic polymer materials which can be carbonised to give carbon are mixed or blended with non-polymeric fillers. In principle, this can be carried out using suitable mixing methods known to the person skilled in the art, such as for example dry mixing of polymer pellets with filler powders or granules, mixing fillers into the polymer melt or mixing fillers with polymer solutions or suspensions.

Suitable as non-polymeric fillers are all substances which are substantially stable under carbonisation conditions and which can be removed from the carbon-based moulded bodies after carbonisation by using suitable solvents. Furthermore, non-polymeric fillers which are converted to solvent-soluble substances under carbonisation conditions are suitable as fillers.

Preferred fillers are selected from inorganic metal salts, especially salts of alkali and/or alkaline earth carbonates, sulphates, sulphites, nitrates, nitrites, phosphates, phosphites, halides, sulphides, oxides and mixtures thereof. Further suitable fillers are selected from organic metal salts, preferably those of alkali, alkaline-earth and/or transition metals, especially their formates, acetates, propionates, maleates, malates, oxalates, tartrates, citrates, benzoates, salicylates, phthalates, stearates, phenolates, sulphonates, amine salts, and mixtures thereof.

Suitable solvents for dissolving out the fillers from the carbonised moulded bodies are water, especially hot water, diluted or concentrated inorganic or organic acids, alkalis and the like. Suitable inorganic acids are, in diluted or concentrated form, hydrochloric acid, sulphuric acid, phosphoric acid, nitric acid as well as diluted hydrofluoric acid.

Suitable alkalis are, for example, sodium hydroxide solution, ammonia solution, carbonate solutions but also organic amine solutions.

Suitable organic acids are formic acid, acetic acid, trichloromethanoic acid, trifluoromethanoic acid, citric acid, tartaric acid, oxalic acid and mixtures thereof.

The fillers can be substantially completely or partially dissolved out from the carbonised moulded body, according to the type and duration of usage of the solvent. The substantially complete dissolution of the fillers is preferred.

The fillers can be used in suitable grain sizes depending on the intended application and desired porosity or pore dimension. Especially preferred are powder or granular fillers having average particle sizes of 3 Angstrom to 2 mm, especially preferably 1 nm to 500 μ m and particularly preferably 10 nm to 100 μ m.

The person skilled in the art will select suitable particle sizes of non-polymeric fillers depending on the desired porosity and the desired pore dimensions of the ready-carbonised moulded body.

In addition, suitable solvents for dissolving out the fillers are organic solvents such as methanol, ethanol, N-propanol, isopropanol, butoxydiglycol, butoxyethanol, butoxyisopropanol, butoxypropanol, n-butyl alcohol, t-butyl alcohol, butylene glycol, butyl octanol, diethylene glycol, dimethoxydiglycol, dimethylether, dipropylene glycol, ethoxydiglycol, ethoxyethanol, ethyl hexanediol, glycol, hexanediol, 1,2,6-hexanetriol, hexylalcohol, hexylene glycol, isobutoxypropanol, isopentyl diol, 3-methoxybutanol, methoxydiglycol, methoxyethanol, methoxyisopropanol, methoxymethylbutanol, polypropylene

glycol, methylal, methyl hexylether, methylpropanediol, neopentyl glycol, polyethylene glycol, pentylene glycol, propanediol, propylene glycol, propylene glycol butylether, propylene glycol propylether, tetrahydrofuran, trimethylhexanol, phenol, benzene, toluol, xylol; and also water, optionally mixed with dispersion adjuvants as well as mixtures of the aforesaid.

In certain embodiments of the present invention, mixtures of organic solvents with water and/or inorganic and/or organic acids can also be used to dissolve out the non-polymeric fillers from the carbonised moulded bodies.

In a second embodiment of the invention, a method for producing porous carbon-based moulded bodies is provided, comprising the following steps:

- mixing organic polymer materials which can be carbonised to carbon with non-polymeric fillers;
- producing a semi-finished moulded part from the mixture;
- carbonising the semi-finished moulded part in a non-oxidising atmosphere at elevated temperature, wherein the polymeric fillers are substantially completely decomposed.

According to this embodiment of the invention, the pores in the carbon-based moulded body are produced during carbonisation such that polymeric fillers are incorporated in the organic polymer materials to be carbonised, said polymeric fillers substantially being decomposed under carbonisation conditions.

Without wishing to be committed to a specific theory, it has been shown that certain polymeric fillers, especially

saturated aliphatic hydrocarbons under the conditions of carbonisation, i.e. high temperatures and exclusion of oxygen, can be decomposed substantially completely by way of methods similar to cracking to give volatile hydrocarbons such as methane, ethane and the like which then escape from the porous carbon framework of the carbonised moulded body during the pyrolysis or carbonisation.

Suitable polymeric fillers can be selected from saturated, branched or unbranched aliphatic hydrocarbons which can be homo- or copolymers. Preferred here are polyolefins such as polyethylene, polypropylene, polybutene, polyisobutene, polypentene as well as their copolymers and mixtures thereof.

In a first step the polymeric fillers are mixed with the carbonisable polymer materials. In principle, this can be carried out using suitable mixing methods known to the person skilled in the art, such as for example mixing of polymer pellets or granules, mixing polymeric fillers into melts of carbonisable organic polymer materials or suspensions or solutions of these polymer materials, coextrusion of the polymeric fillers with the carbonisable organic polymer materials and the like.

The pores produced in the carbonised moulded bodies can be suitably dimensioned or varied within wide limits by a suitable choice of molecular weight, chain length and/or degree of branching of the polymeric fillers. The polymeric fillers can also be used in the form of thin fibres which form suitably dimensioned pore passages during carbonisation. The porosity can be adjusted by selecting the fibre diameter and the fibre length, larger fibre diameters and lengths producing greater porosity. In this case, desired intermediate effects can also be achieved by

suitable mixing of the fibres used or asymmetrical porosity distributions and textures of the moulded bodies.

This embodiment of the method according to the invention using polymeric fillers as pore formers is especially suitable for porous moulded bodies having small pore sizes in the nano- to micrometer range, especially having pore sizes of 3 Angstrom to 2 mm, particularly preferably 1 nm to 500 μm and especially preferably 10 nm to 100 μm .

In a preferred embodiment of this method, after carbonisation the carbonised moulded body is treated with suitable oxidising and/or reducing agents to further modify the pore sizes. A subsequent compaction or closure of the pores, for example by CVD/CVI methods whilst separating suitable organic or inorganic precursors can also be used according to the invention to "tailor make" moulded bodies having desired properties.

According to a third embodiment of the method according to the invention, a method for producing porous carbon-based moulded bodies is provided, comprising the following steps:

- producing a semi-finished moulded part from carbonisable organic polymer materials;
- carbonising the semi-finished moulded part in a non-oxidising atmosphere at elevated temperature, wherein a carbon-based moulded body is obtained;
- partial oxidation of the carbonised moulded body to produce pores.

According to this embodiment of the method according to the invention, a moulded body is formed by carbonising suitable polymer materials and after carbonisation, porosity is produced and/or enlarged in the carbonised moulded body by

means of suitable oxidising agents, by pores being "burnt" into the carbon-based moulded bodies by partial oxidation of the carbon.

The treatment of the carbonised moulded body preferably takes place at elevated temperatures in oxidising gas atmospheres. Suitable oxidising agents for partial oxidation in an oxidising gas phase are air, oxygen, carbon monoxide, carbon dioxide, nitrogen oxide and similar oxidising agents. These gaseous oxidising agents can be mixed with inert gases such as noble gases, especially argon or also nitrogen and suitable volume concentrations of the oxidising agent can be exactly adjusted. Holes or pores are burnt into the porous moulded body by reaction with these oxidising agents by way of partial oxidation.

The partial oxidation is preferably carried out at elevated temperatures, especially in the range of 50°C to 800°C.

In an especially preferred method of this embodiment, the partial oxidation is carried out by treating the moulded body with, optionally flowing, air at room temperature or thereabove.

In addition to the partial oxidation of the moulded body using gaseous oxidising agents, liquid oxidising agents can also be used, such as for example concentrated nitric acid which is applied to the moulded body in a suitable manner. In this case, it can also be preferable to bring the concentrated nitric acid in contact with the carbonised moulded body at temperatures above room temperature to ensure superficial or deeper pore formation.

The aforementioned methods for producing pores can also be combined with one another according to the invention. Thus, in addition to soluble fillers, it is possible according to the invention to additionally use polymeric fillers which

are volatile under carbonisation conditions or are decomposed to give volatile substances. In this way, the coarser pores produced from the fillers can be linked to the micro- or nanopores of the polymeric fillers to give anisotropic pore distributions. Furthermore, in addition to the pore formation using fillers and/or polymer solids, the existing pores can also be expanded, interlinked or modified by partial oxidation.

In addition, it is possible to close the pores, for example, by treatment with liquid-crystal tar pitch and optionally subject them to renewed temperature treatment. High-ordered crystalline zones can thus be achieved by carbonisation. Asymmetric and symmetrical graded materials, for example, can be obtained by combining the methods according to the invention.

ORGANIC POLYMER MATERIAL

In all three said embodiments of the method according to the invention, the materials used as the organic polymer material which can be carbonised to form carbon are those which remain carbon materials from amorphous, partially crystalline and/or crystalline symmetrical or asymmetrical material under carbonisation conditions i.e. at elevated temperature and in a substantially oxygen-free atmosphere.

Without wishing to be committed to a specific theory, it has been shown that unsaturated, branched aliphatic hydrocarbons, branched or unbranched, cross-linked or non-cross-linked aromatic or partially aromatic hydrocarbons, and substituted derivatives thereof are especially suitable for this purpose. Unsaturated hydrocarbons, especially aromatic hydrocarbons are generally built into graphite-like cross-linked six-ring structures under carbonisation conditions which form the basic framework of the carbonised moulded body.

Saturated aliphatic and/or aromatic hydrocarbons with heteroatom fractions such as ether, urethanes, amides and amines and the like are suitable as carbonisable organic polymer materials or in mixtures with other aliphatic or aromatic unsaturated hydrocarbons in the method according to the invention.

In the method according to the invention the carbonisable organic polymer materials are preferably selected from: polybutadiene; polyvinyls such as polyvinylchloride or polyvinyl alcohol, poly(meth)acrylic acid, polyacryl cyanoacrylate; polyacrylnitrile, polyamide, polyester, polyurethane, polystyrene, polytetrafluoroethylene; polymers such as collagen, albumin, gelatin, hyaluronic acid, starch, celluloses such as methylcellulose, hydroxypropylmethyl cellulose, carboxymethyl cellulose phthalate; casein, dextran, polysaccharide fibrinogen, poly(D,L-lactide), poly(D,L-lactide-co-glycolide), polyglycolide, polyhydroxybutylate, polyalkylcarbonate, polyorthoester, polyester, polyhydroxyvaleric acid, polydioxanone, polyethylene terephthalate, polymalic acid, polytartaric acid, polyanhydride, polyphosphazene, polyamino acids; polyethylenevinyl acetate, silicone; poly(ester urethane), poly(ether urethane), poly(ester urea), polyether such as polyethylene oxide, polypropylene oxide, pluronics, polytetramethylene glycol; polyvinyl pyrrolidone, poly(vinyl acetate phthalate), alkyd resin, chlororubber, epoxy resin, acrylate resin, phenol resin, amine resin, melamine resin, alkylphenol resins, epoxided aromatic resins, tar, tar-like materials, tar pitch, liquid-crystal tar pitches, bitumen, starch, cellulose, shellac, organic materials of renewable raw materials as well as their copolymers, mixtures and combinations of these homo- or copolymers.

The carbonisable polymer materials can furthermore contain usual additives such as fillers, softeners, lubricants,

flame retardants, glass, glass fibres, carbon fibres, cotton, fabric, metal powder, metal compounds, metal oxides, silicon, silicon oxide, zeolites, titanium oxide, zirconium oxide, aluminium oxide, aluminosilicate, talc, graphite, soot, clay materials, phyllosilicates and the like. In particular, in preferred embodiments of the present invention fibrous materials of cellulose, cotton, textile fabrics, glass fibres, carbon fibres and the like are suitable as polymer additives for improving the mechanical properties of the porous moulded bodies produced.

The semi-finished moulded parts according to the method of the present invention can be produced by means of usual shaping methods for polymer materials, known to the person skilled in the art. Suitable shaping methods are casting methods, extrusion methods, pressing methods, injection moulding methods, co-extrusion blow moulding or other usual shaping methods, for example winding methods or strand winding methods using flat starting materials.

CARBONISATION

In the method according to the invention, carbonisation is carried out in a substantially oxygen-free or oxidising-agent-free atmosphere. Suitable carbonising atmospheres, for example, are protective gas, preferably nitrogen and/or argon, inert gases, SiF_6 and mixtures of these protective gases. Optionally, these protective gas atmospheres can be used at underpressure or overpressure. Carbonisation in vacuum can also advantageously be used in the methods according to the invention.

Furthermore, it can be preferable to add reactive gases to the inert gas atmosphere. Preferred reactive gases for this purpose are non-oxidising gases such as hydrogen, ammonia,

C₁-C₆ saturated aliphatic hydrocarbons such as methane, ethane, propane, butane, mixtures of these and the like.

Suitable temperatures for the carbonisation step lie in the range of 200°C to 4000°C or more. Depending on the selected temperature in the carbonisation step and depending on the type of polymer material used, carbon-containing moulded bodies can be produced whose base material has a structure ranging from amorphous to ordered crystalline graphite-like structures or mixtures of both materials.

The person skilled in the art will select a suitable temperature, suitable atmosphere and suitable pressure conditions depending on the specific temperature-dependent properties of the polymer materials used or the starting material mixtures.

The atmosphere in the carbonisation step in the method according to the invention is substantially free from oxygen, preferably with O₂ kept below 10 ppm, especially preferably below 1 ppm. It is preferable to use hydrogen or inert gas atmospheres, for example, of nitrogen, inert gases such as argon, neon and any other inert gases which do not react with carbon or gas compounds and mixtures thereof. Nitrogen is especially preferred.

The carbonisation step will preferably take place in a discontinuous method in suitable furnaces but can also be carried out in continuous furnace processes which can optionally also be preferable.

In this case, the semi-finished moulded parts are supplied to the furnace on one side and emerge again at the other end of the furnace. In preferred embodiments the semi-finished moulded part can be placed in the furnace on a perforated plate, a sieve or the like so that underpressure can be applied through the polymer film during the

pyrolysis or carbonisation. This makes it possible on the one hand to simply fix the implants in the furnace and on the other hand to achieve extraction and optimal flow of inert gas through the semi-finished moulded parts during the carbonisation.

The furnace can be divided into individual segments by corresponding inert-gas locks in which one or a plurality of carbonisation steps can be carried out successively, optionally under different carbonisation conditions such as, for example different temperature stages, different inert gases or vacuum. Furthermore, after-treatment, activation or intermediate treatment steps can optionally be carried out in corresponding segments of the furnace, such as for example partial oxidation, reduction or impregnation with metal salt solutions and the like.

Alternatively hereto, the carbonisation can be carried out in a closed furnace, which is particularly preferred if the carbonisation is to be carried out in vacuum. Depending on the carbonisable or organic polymer material used or fillers used, a reduction in the weight of the material from about 5% to 95%, preferably from about 40% to 90%, especially 50% to 70% takes place during the carbonisation step in the method according to the invention.

AFTER-TREATMENT

In preferred embodiments of the invention, the physical and chemical properties of the carbon-based moulded bodies or the pores produced are further modified after carbonisation by suitable after-treatment steps and adapted to the respectively desired intended usage.

Suitable after-treatments are, for example, reducing or oxidative after-treatment steps in which the porous moulded bodies are treated with suitable reducing agents and/or

oxidising agents such as hydrogen, carbon dioxide, nitrogen oxides such as N_2O , water vapour, oxygen, air, nitric acid and the like or optionally mixtures thereof.

Furthermore, the surfaces can have coatings which can be applied to one side or to both sides. Suitable coating materials can, for example, be the aforesaid organic polymer materials which are optionally subjected to a further carbonisation or pyrolysis step after application in order to produce asymmetric textures in the moulded body. Coating with inorganic substances, biocompatible polymers and materials is also possible according to the invention in order to give the surfaces of the moulded bodies the respectively desired properties.

The after-treatment steps can optionally be carried out at elevated temperature, but below the carbonisation temperature, for example, of $15^{\circ}C$ to $1000^{\circ}C$, preferably $70^{\circ}C$ to $900^{\circ}C$, particularly preferably $100^{\circ}C$ to $850^{\circ}C$, especially preferably $200^{\circ}C$ to $800^{\circ}C$ and especially at about $700^{\circ}C$. In particularly preferred embodiments the porous moulded bodies produced according to the invention are modified reductively or oxidatively, or using a combination of these after-treatment steps at room temperature.

The pore dimensions and their properties in the porous moulded bodies produced according to the invention can be specifically influenced or varied by oxidative or reductive treatment or by the incorporation of additives, fillers or functional materials. For example, the surface properties of the carbon-containing material can be hydrophilised or hydrophobised by incorporating inorganic nanoparticles or nanocomposites such as laminated silicates.

Furthermore, the porous moulded bodies can be sealed on one or both sides by subsequent coating, e.g. with polymer

solutions. This coating can optionally be carbonised again to improve the stability for example.

The porous moulded bodies produced according to the invention can also subsequently be provided with biocompatible outer and/or inner surfaces by incorporating suitable additives. Moulded bodies thus modified can be used, for example, as bioreactors, cell culture carrier systems or culture systems, implants or as pharmaceutical carriers or depots, especially as systems which can be implanted into the body. In the latter case, for example, medicaments or enzymes can be incorporated into the material where these can optionally be released in a controlled fashion by suitable retardation and/or selective permeation properties of applied coatings.

The porous moulded body can optionally also be subjected to a so-called CVD process (Chemical Vapour Deposition, chemical gas phase separation) or CVI process (Chemical Vapour Infiltration) in order to further modify the surface or pore structure and its properties, optionally to superficially or completely seal the pores. For this purpose, the carbonised coating is treated with suitable carbon-separating precursor gases at high temperatures. Other elements can also be separated in this way, for example, silicon, aluminium, titanium, especially to produce the corresponding carbides. Methods of this type are known in the prior art. By suitably pre-structuring the moulded bodies, for example using fibre materials of different length and/or thickness, graded materials can thus be obtained which have concentrations of certain interstitial or reaction compounds, for example, of metal or non-metal carbides, nitrides or borides distributed asymmetrically over the volume of the moulded body. Graded materials can thus be obtained which are provided with symmetrical or asymmetrical, isotropic or anisotropic,

closed-pore, porous or fibre-like guide structures or any combinations thereof.

Almost all known saturated and unsaturated hydrocarbons with sufficient volatility under CVD conditions can be considered as carbon-separating precursors. Examples of these are methane, ethane, ethylene, acetylene, linear and branched alkanes, alkene and alkynes with carbon numbers C_1 - C_{20} , aromatic hydrocarbons such as benzene, naphthalene etc. as well as singly and multiply alkyl-, alkenyl- and alkynyl-substituted aromatic compounds such as toluol, xylol, cresol, styrene etc.

As ceramic precursors it is possible to use BCl_3 , NH_3 , silanes such as SiH_4 , tetraethoxysilane (TEOS), dichlorodimethylsilane (DDS), methyltrichlorosilane (MTS), trichlorosilyldichloroborane (TDADB), hexadichloromethylsilyloxide (HDMSO), $AlCl_3$, $TiCl_3$ or mixtures thereof.

These precursors are used in the CVD method mainly in low concentrations of about 0.5 to 15 vol.% mixed with an inert gas, such as for example, nitrogen, argon or the like. It is also possible to add hydrogen to corresponding separating gas mixtures. At temperatures between 500 and 2000°C, preferably 500 to 1500°C and especially preferably 700 to 1300°C, said compounds separate hydrocarbon fragments or carbon or ceramic preceding stages which are deposited substantially uniformly distributed in the pore system of the porous moulded body, modify the pore structure there and thus result in a substantially homogeneous pore size and pore distribution.

Pores in the carbon-containing porous moulded body can be specifically reduced in size by means of CVD methods as far as complete closure/sealing of the pores. The sorptive

properties and also the mechanical properties of the moulded body can hereby be adjusted in a tailored manner.

The carbon-containing porous moulded body can be modified by carbide or oxycarbide formation, for example in an oxidation-resistant fashion, by CVD of silanes or siloxanes mixed with hydrocarbons.

In preferred embodiments the porous moulded bodies according to the invention can be additionally coated or modified by means of sputtering. For this purpose carbon, silicon or metals or metal compounds of suitable sputter targets can be applied using methods known per se. Examples for this are Ti, Zr, Ta, W, Mo, Cr, Cu which can be dusted into the porous moulded bodies, with the corresponding carbides usually being formed.

Furthermore, the surface properties of the porous moulded body can be modified by means of ion implantation. Thus, nitride, carbonitride or oxynitride phases with incorporated transition metals can be formed by implantation of nitrogen, which significantly increases the chemical resistance and mechanical resistivity of the carbon-containing porous moulded body.

Coating with, for example, liquid-crystal tar pitch can result in asymmetric material properties depending on the alignment of the lattice structures during the subsequent cross-linking, carbonisation or graphitisation. These are among others the thermal expansion, the mechanical properties, the electrical conductivity, among others.

In certain embodiments it can be advantageous to at least partially coat the porous moulded bodies with a coating of biologically degradable or resorbable polymers such as collagen, albumin, gelatin, hyaluronic acid, starch, celluloses such as methyl cellulose, hydroxypropyl

cellulose, hydroxypropylmethyl cellulose, carboxymethyl cellulose phthalate; casein, dextrans, polysaccharide, fibrinogen, poly(D,L-lactide), poly(D,L-lactide-co-glycolide), poly(glycolide), poly(hydroxybutylate), poly(alkylcarbonate), poly(orthoester), polyester, poly(hydroxyvaleric acid), polydioxanone, poly(ethylene terephthalate), poly(malic acid), poly(tartaric acid), polyanhydride, polyphosphazene, poly(amino acids) and their co-polymers or non-biologically degradable or resorbable polymers. Preferred are in particular anionic, cationic or amphoteric coatings, such as for example, alginate, carrageenan, carboxymethyl cellulose; chitosan, poly-L-lysine; and/or phosphorylcholine.

If necessary, in especially preferred embodiments after carbonisation and/or after optionally implemented after-treatment steps the porous moulded body can be subjected to further chemical or physical surface modifications. Cleaning steps can also be provided here to remove any residue and impurities. The acids already mentioned, in particular oxidising acids or solvents can be used for this purpose, boiling out in acids or solvents being particularly preferred.

The pH and the buffer capacity in an aqueous environment of the moulded bodies according to the invention can be specifically adjusted over wide ranges by a suitable choice of initial substances and additives. The pH of the moulded bodies produced according to the invention in water can lie in the range of pH 0 to pH 14, preferably in the range of pH 6-8 and particularly preferably at pH values of 6.5 to 7.5. The buffer range of the moulded bodies produced according to the invention preferably lies in the neutral to acidic range, especially preferably in the weakly acidic range, the buffer capacity can be up to 50 mol/litre, preferably up to 10 mol/litre and in preferred applications is usually 0.5 to 5 mol/litre.

MOULDED BODIES

The moulded bodies produced by the method according to the invention can be produced in any two- or three-dimensional shapes. For this purpose, the semi-finished moulded parts are processed from the organic polymer materials, optionally mixed with polymeric or non-polymeric fillers, by means of suitable shaping methods to produce corresponding blanks, which optionally correspond to the final shapes of the porous carbon-based moulded bodies bearing in mind the dimensional shrinkage which occurs during carbonisation. The porous moulded bodies according to the invention can be produced in the form of tubes, round rods, plates, blocks, rectangular parallelepipeds, cubes, solid or hollow spheres, flanges, seals, housings and the like or they can also be elongated, such as circular-column-shaped, polygonal-column-shaped and possibly triangular-column-shaped or bar-shaped; or plate-shaped; or also polygonal-shaped such as tetrahedral-shaped; pyramidal-shaped, octahedral-shaped, dodecahedral-shaped, icosahedral-shaped, rhomboid, prismatic; or spherical, and possibly ball-shaped, spherical or cylindrical lens-shaped or annular, honeycomb-shaped with straight or curved channels, wound, folded with different channel diameters and flow directions (parallel, cross-wise or with arbitrary angles between the channels).

According to a particular embodiment of the present invention, a tube of porous carbon-based material is produced using one of the methods according to the invention. In this case, a hose of natural or synthetic rubber or suitable plastics is preferably carbonised as mentioned above as carbon-containing moulded bodies which can be carbonised to give carbon, which is optionally reinforced with fibre or fabric inserts. It is especially preferable to use a textile fabric impregnated with synthetic resins in the form of a hose which is used as a

semi-finished moulded part to produce a tube of porous carbon-based material according to one of the methods of the present invention.

The hose used to produce a porous tube can have a multilayer structure, for example, comprising an inner layer of foamed plastic and an outer layer of non-foamed plastic or conversely. The application of further layers is also possible according to the invention.

It is particularly preferable if the multilayer hose is produced as a semi-finished moulded part by co-extrusion blow moulding and is then carbonised to form a tube.

In a further embodiment of the present invention, a tube of carbon-based material can be produced by winding a paper material impregnated or coated with polymer materials, to form a tube for example on a lathe, which is then carbonised under carbonisation conditions to form a porous carbon-containing tube.

According to this method of production, a flat fibre fabric, channel structures or felt structures as well as all combinations thereof, is preferably impregnated and/or coated with organic polymer materials and wound by means of a suitable mandrel. Carbonisation is then carried out with or without mandrel and the mandrel is then optionally removed. In this way, simple and precise porous tubes can be produced and these can then be after-treated, post-compacted or sealed.

Porous tubes thus produced can be completely or partially sealed by suitable after-treatment by means of CVD or coating, e.g. using organic polymers.

It is also possible according to the invention to use semi-finished moulded parts to produce tubes such as polymer

hoses, especially endless hoses in continuous methods for producing carbon tubes. The use of fibre-reinforced hoses is especially preferred here, where the fibres can be selected from textile or fabric fibres, glass fibres, carbon fibres, rock wool, polymer fibres, for example, of polyacrylnitrile, nonwoven materials, fibre nonwovens, felts, cellulose, PET fibres and any mixtures of these materials.

Asymmetric structures of carbon-containing moulded bodies produced according to the invention can be achieved by using multilayer semi-finished moulded parts. For example, foamed polymer materials such as polyurethane foam, polyacrylnitrile foam and the like can be moulded with a further layer of dense polymer material which are then carbonised to form moulded bodies having regionally different porosity distribution.

In the case of hollow bodies, flanges can be laminated on in the semi-finished moulded part and these are then substantially through-carbonised with closed pores. When using polymer fibres and fabrics, solid-carbon module units with exceptional adhesion between fibre and matrix are thus produced.

The carbon-based moulded bodies produced by a method according to the invention, especially carbon tubes, can be used as tube membrane, in tube membrane reactors, in tube bundle reactors and heat exchangers and also in bioreactors.

The moulded bodies according to the invention can also be used as porous catalyst supports, especially in the automobile field or flue-gas purification in technical installations, Advantageous here is their heat resistance, their chemical resistance and dimensional stability. Furthermore, the moulded bodies and materials according to

the invention are almost free from stress and extremely stable under thermal shock, i.e., severe jumps in temperature are tolerated without any problem. By applying metals, especially precious metals, and other catalytically active materials, long-term stable and highly effective catalyst supports can be produced according to the invention.

Plates made of flat channel structures as well as tube structures wound herefrom are extremely suitable as insulating materials, e.g. for high-temperature applications or for shielding microwaves (microwave absorber). The electrical properties can be adjusted in this case so that, for example, high-frequency heaters can couple their energy into the furnace area through these insulating materials almost free from losses. However, highly oriented materials can also be adjusted so that they are directly excited by high frequency and thus directly heated. This is also a simple method for technical production (carbonisation) or for graphitisation.

Moulded bodies produced by the method according to the invention can also be used as medical implants, for example, orthopaedic, surgical and/or non-orthopaedic implants such as bone or joint prostheses, orthopaedic plates, screws, nails, and the like.

As a result of their biocompatibility and the flexible surface properties such as adsorption capacity, absorptive capacity, adhesion of biological material, porosity which can be specifically adjusted over wide ranges, pore sizes and volumes as far as closed-pore moulded bodies etc., it is especially preferable to use the moulded bodies produced according to the invention as substrate or carriers for colonisation with micro-organisms and cell cultures.

It is especially preferable to use the carbon-based, carbon-containing moulded bodies produced according to the invention as well as ceramic materials and composites as carrier and/or culture systems (TAS) for the cultivation of primary cell cultures such as eukaryotic tissue, e.g. bone, cartilage, liver, kidneys, as well as for the cultivation or immobilisation of xenogenic, allogenic, syngenic or autologous cells and cell types and optionally also of genetically modified cell lines.

In addition to the moulded bodies produced according to the invention, in principle all porous or non-porous carbon-containing materials are suitable for use as carrier and culture systems (TAS) for the cultivation of primary cell cultures. In addition to the moulded bodies produced according to the invention, it is also preferable to use materials such as are described in WO 02/32558 ("Flexible, porous membranes and adsorbents ...") whose disclosure is completely included herewith, especially the carbon and ceramic materials, membranes and carriers described on pages 24, line 11 to page 43. Symmetrical or asymmetrical, textured carbon- or ceramic-based materials and combinations thereof are also suitable for use as carrier and culture systems.

Said materials and moulded bodies can especially be used as carrier and culture systems for nerve tissue. It is particularly advantageous that carbon-containing materials are especially adaptable and suitable here for the cultivation of nerve tissue in particular by the simple adjustment of the conductivity of the moulded body and the application of pulsed currents.

Said materials and moulded bodies are further used in the usage as carrier and culture systems according to the invention as in vitro or in vivo guide structures, so-called, scaffolds for two- and three-dimensional tissue

growth; as a result of their specific shaping it is possible to cultivate organ parts or entire organs from cell cultures. In this case, the carrier and culture systems support or modulate cell, tissue or organ growth in the physical respect as guide structures by suitable adjustment of the porosity, by the flow-channel design and the two- or three-dimensional shaping, but especially also by adjustable provision, distribution and replenishment of nutrient solution or medium at the usage site, and by supporting or promoting cell and tissue proliferation and differentiation.

For use as carrier and culture systems the materials and moulded bodies can be two- and three-dimensionally shaped. Suitable macrostructures are, for example, tubes, especially for the production or cultivation of natural vessels, cubic forms etc. as mentioned above in the case of moulded bodies.

In particular, the moulded bodies according to the invention and other carbon-based materials can be after-perceived for use as carrier and culture systems for natural organ forms, e.g. cartilaginous joint surfaces of knee, hip, shoulder, finger joints etc. which can then be used to used to culture suitably shaped cartilage, periosteum and the like. These can then either be implanted with the grown tissue or the cultured tissue is separated in suitably grown form by methods of the prior art, such as for example mechanical or chemical enzymatic detachment and then implanted.

Since carbon-based materials and moulded bodies also have good mechanical properties which make it possible to use them as implants, e.g. as artificial joints and the like, according to the invention these can be used in a tissue culture as substrates or carriers and following the growth of a sufficient layer of cartilage, they can be used as

highly compatible biomimetic implants in the body of patients. Thus, it is possible according to the invention to use individual patient implants which are coated with the body's own tissue grown directly on the implant from the patient's own cell samples. This can reduce or completely avoid rejection phenomena and immune defence reactions.

According to the invention, the moulded bodies and materials can be used as carrier and culture systems for cultivation in existing bioreactor systems, e.g. passive systems without continuous control technology, e.g. tissue plates, tissue bottles, roller bottles; but also active systems with gas supply and automatic adjustment of parameters (acidity, temperature) that is reactor systems with measurement and control technology in the broadest sense.

Furthermore, by providing suitable devices such as, for example, connections for perfusion with nutrient solutions and gas exchange, the carrier and culture systems according to the invention can be operated as reactor systems, especially in modular fashion in corresponding series reactor systems and tissue cultures.

Carrier and culture systems according to the invention can also be used as ex vivo reactor systems, e.g. extracorporeal assistance systems or as organ reactors e.g. so-called liver assist systems or liver replacement systems; or also in vivo or in vitro for encapsulated islet cells, e.g. as artificial pancreas, encapsulated urothelial cells, e.g. as artificial kidney and the like which are preferably implantable.

In addition, the carrier and culture systems according to the invention can be suitably modified to promote organogenesis, for example, with proteoglycans, collagens,

tissue-type salts, e.g. hydroxylapatite etc., especially also with the aforesaid biologically degradable or resorbable polymers.

The carrier and culture systems according to the invention are preferably further modified by impregnation and/or adsorption of growth factors, cytokines, interferons, and/or adhesion factors. Examples of suitable growth factors are PDGF, EGF, TGF- α , FGF, NGF, erythropoietin, TGF- β , IGF-I and IGF-II. Suitable cytokines comprise, for example IL-1- α and - β , IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13. Suitable interferons comprise, for example, INF- α and - β , INF- γ . Examples of suitable adhesion factors are fibronectin, laminin, vitronectin, fetuin, poly-D-lysine and the like.

The moulded bodies according to the invention can also be applied, especially when used as carrier and culture systems, as microarray systems for drug discovery, tissue screening, tissue engineering etc.

EXAMPLES

The following examples are used to illustrate the principles according to the invention and are not intended to be restrictive.

Example 1:

To produce a tube by the winding method having a DN25 core, 500 mm long, 300 mm wall thickness, a glass fibre fabric of E-CR-glass (chemical-resistant modified E glass), 30 mm wide, coated/impregnated with phenol-resin-based GFK resin, was laid crosswise on a suitable steel mandrel and the mandrel removed. The weight was 3.6 g/cm before pyrolysis. Pyrolysis was carried out in nitrogen at 800°C for 48 hours. The weight after pyrolysis was 3.0 g/cm. The

membrane properties were measured using the bubble-point test (ASTM E1294) where a pore size of 500 Angstrom was determined.

Example 2:

Tube production by the winding method as specified under Example 1 using a glass fibre nonwoven of C-glass (chemical-resistant C glass, nonwoven), 30 mm wide and vinyl-ester-resin-based GFK resin, cross-wise laying on steel mandrel. Weight 3.5 g/cm before pyrolysis. Pyrolysis in nitrogen at 800°C for 48 hours. Weight after pyrolysis 0.9 g/cm. The membrane properties were measured using the bubble-point test (ASTM E1294) and a pore size of 0.8 micron was determined.

Example 3:

Tube production by the winding method as specified under Example 1 using a polyacrylnitrile (PAN) nonwoven (Freudenberg), 30 mm wide and phenol-resin-based GFK resin, cross-wise laying on steel mandrel. Weight 3.5 g/cm before pyrolysis. Pyrolysis in nitrogen at 800°C for 48 hours. Weight after pyrolysis 1.94 g/cm. The membrane properties were measured using the bubble-point test (ASTM E1294). No pore size (gas breakthrough) could be determined in the measurement range. Subsequent partial oxidation in an air flow at 400°C for 15 minutes yielded an average pore size of 1.2 μm according to the bubble-point test.

Example 4:

Tube production by the winding method as specified under Example 1 using a glass-fibre nonwoven of E-CR glass (chemical-resistant modified E glass), 30 mm wide and polyacrylnitrile (PAN) nonwoven (Freudenberg), 30 mm wide (ratio 1:1) and phenol-resin-based GFK resin, cross-wise

laying on steel mandrel. Weight 3.6 g/cm before pyrolysis. Pyrolysis in nitrogen at 800°C for 48 hours. Weight after pyrolysis 2.0 g/cm.

Example 5:

Tube production by the winding method as specified under Example 1 using a glass-fibre nonwoven of E-CR glass (chemical-resistant modified E glass), 30 mm wide and polyacrylnitrile (PAN) nonwoven (Freudenberg), 30 mm wide (ratio 1:1) and phenol-resin-based GFK resin with 20% Aerosil R972, cross-wise laying on steel mandrel. Weight 3.6 g/cm before pyrolysis. Pyrolysis in nitrogen at 800°C for 48 hours. Weight after pyrolysis 3.0 g/cm.

The Aerosil was then washed out using 30% NaOH alkali solution. The membrane properties were measured using the bubble-point test (ASTM E1294) and a pore size of 0.6 μm was determined.

Example 6:

Carbon-based plates of natural-fibre-reinforced composite polymer with inorganic fillers and having a weight per unit area of 100 g/m² and a thickness of 110 micron were produced. This flat composite material was provided with a channel structure by a commercially available embossing machine which yielded a channel diameter of 3 mm after placing two sheets one on top of the other. These sheets were glued to form honeycomb-shaped blocks and were carbonised in protective gas (nitrogen) at 800°C for 48 hours. The pressure loss in the channel direction was only 0.1 bar/m and a weight loss of 66 wt.% was obtained during carbonisation.

A tube wound from this material, 10 cm long and 40 mm in diameter with a wall thickness of 6 mm was adjusted in a coupling-in test in a 8 kHz high-frequency heating device.

The current showed almost no variation compared with the quiescent current and after 5 minutes no significant heating of the material occurs. The materials thus produced can be sawn, drilled, milled etc. precisely and without any problem.

Example 7:

For the provided application as a carrier material for cell culture systems, a natural-fibre-containing polymer composite having a weight per unit area of 100 g/m^2 and a thickness of $110 \text{ }\mu\text{m}$, was carbonised in a nitrogen atmosphere at 800°C for 48 hours, where air was added towards the end to modify the pores. A weight loss of 50 wt.% occurred. The resulting material has a pH of 7.4 in water and a buffer range in weak acids. Pieces of this carbon material measuring $20 \times 40 \text{ mm}$, each $60 \text{ }\mu\text{m}$ thick, were fed with 4 ml of nutrient solution and 1.5 ml of cell suspension each on conventional six-well tissue plates. The cell suspension contains hybridoma FLT₂ cell lines producing MAB against shigatoxin, known for non-adherent, non-adhesive suspension-resistant growth.

As a comparison, six-well tissue plates without carbon material were used under otherwise the same conditions and loading.

The samples using carriers according to the invention revealed a spontaneous quantitative immobilisation of the cells and no clouding of the suspension could be detected. Within an incubation time of 7 days, the cell density was increased sevenfold to 1.8×10^7 cells per ml. The MAB production increased from initially $50 \text{ }\mu\text{g/ml}$ to $350 \text{ }\mu\text{l/ml}$ of the average culture lifetime without any signs of proteolytic degradation. Twelve of 12 samples were still living after 25 days, after which incubation was interrupted. This shows that the carriers according to the

invention result in an interruption of the contact inhibition despite the higher cell density. Even after cryoconservation and thawing, MAB production is spontaneously restored after adding fresh nutrient medium.

In the comparative experiment only one of 6 cultures survived until the 11th day.

CLAIMS

1. Method for the production of porous carbon-based moulded bodies,

characterised by the following steps:

- mixing organic polymer materials which can be carbonised to carbon with non-polymeric fillers;
 - producing a semi-finished moulded part from the mixture;
 - carbonising the semi-finished moulded part in a non-oxidising atmosphere at elevated temperature, wherein a carbon-based moulded body is obtained;
 - dissolving the fillers out from the carbonised moulded body using suitable solvents.
2. The method according to claim 1, characterised in that the fillers are selected from inorganic metal salts, especially salts of alkali and/or alkaline earth carbonates, sulphates, sulphites, nitrates, nitrites, phosphates, phosphites, halides, sulphides, oxides and mixtures thereof.
 3. The method according to claim 1 or claim 2, characterised in that the fillers are selected from organic metal salts, preferably those of alkali, alkaline-earth and/or transition metals, especially their formates, acetates, propionates, malates, maleates, oxalates, tartrates, citrates, benzoates, salicylates, phthalates, stearates, phenolates, sulphonates, amine salts, and mixtures thereof.

4. The method according to any one of the preceding claims, characterised in that water or diluted or concentrated inorganic or organic acids are used for dissolving out the fillers.
5. The method according to any one of claims 1 to 3, characterised in that organic solvents are used for dissolving out the fillers.
6. The method according to any one of the preceding claims, characterised in that the fillers used consist of substances which are converted into a soluble form during the carbonisation step.
7. A method for the production of porous carbon-based moulded bodies,

characterised by the following steps:
 - mixing organic polymer materials which can be carbonised to carbon with non-polymeric fillers;
 - producing a semi-finished moulded part from the mixture;
 - carbonising the semi-finished moulded part in a non-oxidising atmosphere at elevated temperature, wherein the polymeric fillers are substantially completely decomposed.
8. The method according to claim 7,

characterised in that the polymeric fillers are selected from saturated, branched or unbranched aliphatic hydrocarbon homo- or copolymers, preferably polyolefins such as polyethylene, polypropylene, polybutene, polyisobutene, polypentene and mixtures thereof.

9. The method according to any one of claims 7 or 8, characterised in that after carbonisation the moulded body is treated with oxidising or reducing agents.
10. Method for the production of porous carbon-based moulded bodies,

characterised by the following steps:

- producing a semi-finished moulded part from carbonisable organic polymer materials;
 - carbonising the semi-finished moulded part in a non-oxidising atmosphere at elevated temperature, wherein a carbon-based moulded body is obtained;
 - partial oxidation of the carbonised moulded body to produce pores.
11. The method according to claim 10, characterised in that the partial oxidation takes place by means of heat treatment in an oxidising gas atmosphere.
 12. The method according to claim 11, characterised in that the partial oxidation is carried out by means of air, oxygen, carbon monoxide, carbon

dioxide, nitrogen oxides at temperatures in the range of 50°C to 800°C.

13. The method according to claim 10, characterised in that the partial oxidation is carried out using oxidising acids.
14. The method according to any one of the preceding claims, characterised in that the carbonisable organic polymer material comprises unsaturated, branched aliphatic hydrocarbons, branched or unbranched, cross-linked or non-cross-linked aromatic or partially aromatic hydrocarbons, and substituted derivatives thereof.
15. The method according to any one of the preceding claims, characterised in that the carbonisable organic polymer material is selected from polybutadiene; polyvinyls such as polyvinylchloride or polyvinyl alcohol, poly(meth)acrylic acid, polyacryl cyanoacrylate; polyacrylnitrile, polyamide, polyester, polyurethane, polystyrene, polytetrafluoroethylene; polymers such as collagen, albumin, gelatin, hyaluronic acid, starch, celluloses such as methylcellulose, hydroxypropylmethyl cellulose, carboxymethyl cellulose phthalate; casein, dextran, polysaccharide fibrinogen, poly(D,L-lactide), poly(D,L-lactide-co-glycolide), polyglycolide, polyhydroxybutylate, polyalkylcarbonate, polyorthoester, polyester, polyhydroxyvaleric acid, polydioxanone, polyethylene terephthalate, polymalic acid, polytartaric acid, polyanhydride, polyphosphazene, polyamino acids; polyethylenevinyl acetate, silicone; poly(ester urethane), poly(ether urethane), poly(ester urea),

polyethers such as polyethylene oxide, polypropylene oxide, pluronics, polytetramethylene glycol; polyvinyl pyrrolidone, poly(vinyl acetate phthalate), alkyd resin, chlororubber, epoxy resin, acrylate resin, phenol resin, amine resin, melamine resin, alkylphenol resins, epoxided aromatic resins, tar, tar-like materials, tar pitch, liquid-crystal tar pitches, bitumen, starch, cellulose, shellac, fibres of polyacrylnitrile, cellulose or novolak, organic materials of renewable raw materials as well as their copolymers, mixtures and combinations of these homo- or copolymers.

16. The method according to any one of the preceding claims, characterised in that the polymer material contains usual additives such as fillers, softeners, lubricants, flame retardants, glass, glass fibres, carbon fibres, cotton, fabric, metal powder, metal compounds, metal oxides, silicon, silicon oxide, zeolites, TiO_2 , aluminium oxide, aluminosilicate, zirconium oxide, talc, graphite, soot, clay materials, phyllosilicates.
17. The method according to any one of the preceding claims, characterised in that the semi-finished moulded parts are produced by means of casting, extrusion, pressing, injection moulding or other usual shaping methods.
18. The method according to any one of the preceding claims, characterised in that the carbonisation is carried out under protective gas, preferably nitrogen or argon, optionally at underpressure or in vacuum, optionally with the addition of reactive gases such as hydrogen, at temperatures in the range of 200°C to 4000°C.

19. The method according to any one of the preceding claims, further comprising the step of separating carbon, nitrogen, silicon and/or metals by means of chemical or physical vapour deposition (CVD or PVD), sputtering, ion implantation or chemical vapour infiltration (CVI) on the surface of the moulded body and/or in its pores.
20. The method according to claim 19, characterised in that the pores of the moulded body are completely or partially sealed.
21. A porous moulded body which can be produced by the method according to one of the preceding claims.
22. The moulded body according to claim 21, in the form of tubes, round rods, plates, blocks, rectangular parallelepipeds, cubes, injection moulds, honeycomb structures, imprinted, folded, wound, rolled two- or three-dimensional structures, with channel structures, solid or hollow spheres, flanges, seals, housings and the like.
23. A tube which can be manufactured using the method according to any one of claims 1 to 20, comprising a hose of natural or synthetic rubber, cellulose, epoxy resin compound or plastics, optionally reinforced with fibre or fabric inserts.
24. The tube according to claim 23, characterised in that a textile fabric impregnated with synthetic resins is used as hose.

25. The tube according to claim 23, characterised in that a multilayer hose is carbonised.
26. The tube according to claim 25, characterised in the multilayer hose contains an inner layer of foamed plastic and an outer layer of non-foamed plastic.
27. The tube according to any one of claims 25 or 26, characterised in that the multilayer hose was obtained by co-extrusion blow moulding.
28. A catalyst support which can be manufactured according to any one of claims 1 to 22.
29. An insulating material which can be manufactured according to any one of claims 1 to 22.
30. Use of the tube according to any one of claims 23 to 27, as a tube membrane, in tube bundle reactors, in heat exchangers, for distillation, pervaporation, recovery and/or recycling of reaction products and/or extraction in devices suitable for this purpose.
31. Use of the moulded body according to claim 21 or 22 as a carrier and/or culture system for the cultivation of primary cell cultures.
32. Use according to claim 31, wherein the cell cultures are selected from eukaryotic tissue such as bone, cartilage, liver, kidneys, pancreas, nerves and the like as well as

xenogenic, allogenic, syngenic or autologous cells and cell types and from genetically modified cell lines.

33. Use according to claim 31 or 32, wherein the moulded body is used as a guide structure for two- or three-dimensional tissue growth, especially for culture of organs or organ parts.
34. The use according to any one of claims 31 to 33, characterised in that the carrier and/or culture system is used ex vivo as a reactor system.
35. The use according to any one of claims 31 to 33, characterised in that the carrier and/or culture system is used in vivo as an implant.
36. The use according to any one of claims 31 to 35, characterised in that the carrier and/or culture system is modified with proteoglycans, collagens, tissue-type salts or biologically degradable or resorbable polymers.