# DEVELOPMENT OF CARBON MATERIALS FOR ENDOPROSTHETICS

H. Brückmann, K. J. Hüttinger, U. Rosenblatt
Schunk & Ebe GmbH, D-6300 Giessen, W.-Germany

## 1. INTRODUCTION

In recent years, new materials for application in bioengineering are in development. For endoprosthetic application, especially $Al_2O_3$-ceramic has been developed to a high standard and hip joints are now under clinical testing (1). Carbon seems to be extremely promising according to its well known biocompatibility, friction and wear behaviour (2, 3). Mechanical properties of commercially available carbon materials are insufficient for endoprosthetic purposes. It is the aim of our development program to supply carbon materials with sufficient strength for joint replacements. Those materials must posses excellent gliding properties, wear resistance and perfect biocompatibility, the latter property being especially important for worn off particles.

When starting this project, we were convinced, that all these demands cannot be fullfilled by a single carbon material. Therefore the program includes the development of three different types of materials, namely

(1) high strength isotropic carbon
(2) carbon fibre reinforced carbon
(3) silicon impregnated carbon.

## 2. MATERIALS

### 2.1 High strength isotropic carbon

The development of such material was concentrated primarily on high strength combined with maximum hardness.

These demands are satisfied by a carbon grade based on a special raw coke, which is treated with coal tar pitch for several times with intermediate heat treatments. Thereby, the raw coke is reduced to a state comparable to mesophase (4). The mix is milled and formed to blocks. These are baked in an industrial ring furnace up to 1200°C. Final heat treatment includes gas-phase purification. The mechanical properties of the material are listed in table 1.

Table 1 - Properties of high strength isotropic carbon

| | | |
|---|---|---|
| Bulk density, | $g/cm^3$ | 1,8 - 1,9 |
| Flexural strength, | $N/mm^2$ | 120 - 140 |
| Compressive strength, | $N/mm^2$ | 300 - 400 |

### 2.2 Carbon fibre reinforced carbon

For the manufacture of carbon fibre reinforced composites we developed a new process. Carbon fibres, usually of the HT-type, are wound on a kernel, impregnated with coal tar pitch, and thermally pretreated before pressing and baking. The treatment of the matrix is similar to that used for the high strength isotropic carbon. After baking up to 1200°C, the composites exhibit densities in the range of 1,6 to 1,7 $g/cm^3$ without any impregnation. We aim to produce C-C-composites of low Young's modulus and sufficient flexural strength.

Some properties of our unidirectionally reinforced composites are given in table 2.

Table 2 - Properties of unidirectionally reinforced carbon-carbon composites

| | | |
|---|---|---|
| Bulk density, | $g/cm^3$ | 1,6 - 1,7 |
| Young's modulus, | $KN/mm^2$ | 120 - 150 |
| Flexural strength, parallel to fibre axis | $N/mm^2$ | 600 - 800 |
| Flexural strength, perpendicular to fibre axis | $N/mm^2$ | 30 - 35 |
| Interlaminar shear strength, | $N/mm^2$ | 30 - 40 |

### 2.3 Silicon impregnated carbon

This material was developed based on our experience as manufacturer of metal impregnated carbons for a wide range of mechanical applications. Silicon has been chosen due to its ability of forming a chemically resistant carbide, the composite being a material with superiour gliding properties. Furthermore, test results with "silicon alloyed carbon" indicate the biocompatibility of a silicon-carbon composite (2). Carbon materials, especially suitable for impregnation with liquid silicon in a vacuum-pressure-process had to be developed. As expected and eludicated in our experiments, porosity and reactivity of the base carbon material strongly influence the properties of the Si-C-composite. Therefore the further development includes not only Optimizations of the impregnation process but also of the carbon material.

During the impregnation process silicon is completely transformed to SiC by consumption of carbon.

Properties of the materials developed are shown in table 3.

| Table 3 - Properties of silicon impregnated carbon | | |
|---|---|---|
| Bulk density, | $g/cm^3$ | 2,6 - 2,7 |
| Flexural strength, | $N/mm^2$ | 150 - 200 |
| Brinell hardness | | 280 HB 2,5/30 |
| Porosity, | % | 0,1 - 0,5 |

## 3. APPLICATIONS

The material development program is accompanied by a clinical testing program. Test specimen of joint prosthesis for hips and knees were designed by taking into account the special properties of the materials. Their qualifications are being tested in vitro under standard conditions before animal tests will be started. Isotropic carbon and silicon impregnated carbon are of interest for gliding parts, whereas carbon fibre reinforced carbon shall be used for load-bearing parts.

## 4. REFERENCES


(1) D. Geduldig, E. Dörre, M. Happel, R. Lade, P. Prüssner, H.-G. Willert, L. Zichner, Med. Orthop. Techn., 6, 138, (1975)

(2) J. C. Bokros, L. D. Lagrange, F. J. Schoen, Chem. and Phys. of Carbon, 9, 103, (1973)

(3) J. K. Lancaster, Proceed. 4th London Intern. Conf. on Carbon and Graphite, Soc. of the Chem. Industry, London 1974, p.663

(4) K. J. Hüttinger, Chem. Ing. Techn, 21, 1145, (1971)



Acknowledgement

This research program is supported by the Federal Minister for Research and Technology under Grant MT 267.