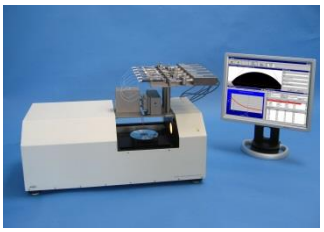
Application Report

Surface Characterization in Biomedical Engineering

Application report:	AR211e
Industry section:	Biotechnology, medical industry
Author:	UO
Date:	1999
Method:	SFE
Keywords:	medicine, biocompatibility, contact angle, surface free energy, surface activation

Drop Shape Analysis System DSA10



G2

Surface Characterization in Biomedical Engineering

A major subject of biomedical engineering is the development of artificial, technically produced components for the replacement of natural components in a human body.

These components can be bones or parts of it, joints, teeth, implants for teeth, skin, hair, sinews, vessels, complete organs or drug delivery systems.

High demands regarding mechanical stability and transfer of information by chemical and electrical processes are put on these artificial materials. Depending on the function of each component it has to be either biocompatible, bio-tolerant or bio-inert.

A simple, but illustrative example is a tooth implant. First of all the tooth has to be stable enough to transfer the forces during chewing from the surface to the bones. This is a mechanical problem. The surfaces should be non-wetting to avoid the settlement of Bacteria. This is a surface tension problem.

The middle part of a tooth should have a very good bonding to the gums (biophil to tissue) but also biophobe to Bacteria.

Surface modification of artificial material in contact with body fluids by corona-, plasma- or flame treatment can help to avoid deposition of proteins and enzymes on various materials. Albumine and Fibrinogen tend to adsorb on polyester filter material. Treating these filters by plasma deposition (plasma of Hydroxyethyl-methacrylate (HEMA)) reduces the adsorption drastically. This effect can be understood by the theory of van Oss, Good and Chaudhury: By increasing the basic character of the surface (σ^o) water with relatively high acid component ($\sigma^{\oplus}$ =25.5) can increasingly compete in adsorption with the proteins. The adsorption of proteins decreases.

Another example is to increase the surface tension of polymer surfaces (PTFE, PS) in ammonia plasma (result = 44-48 mN/m) to increase the deposition of endothel cells. These endothel cells are part of the natural surfaces of blood vessels. The result is a "haemo-compatible" surface, based on polymers.

In order to avoid bacteria adhesion, the surface tension of polymer surfaces has to be as high as possible. Water and bacteria (e.g. staphylococcus epidermi) compete in the adsorption process. The surface tension of water is significantly higher than the surface tension of the bacteria. An increase in the SFT value of the solid surface will decrease the ability of bacteria adsorption.

The above mentioned examples show the importance of interfaces for synthetic components in contact with biological material. Modification of the bulk material can optimize the interfacial tension only up to a certain extent. Surface coating offers the chance to optimize the surface behavior independent from mechanic demands. Plasma polymer coating is of special importance because of the low process temperature and the "dry" procedure. The examples of table 1 do show plasma coatings which are regarding their mechanical behavior more like steel than like polymers, but offer very low surface tension values. Introduction of hetero atoms like B, N, Si or F increase or decrease the surface tension values.

	micro-hardness (GPa)	E-module (GPa)	coefficient of friction (vs. steel)	Consumption (vs.Al_2O_3) ($10^{-15}m^3/Nm$)	temperature resistance (°C)	γ_s (mN/m)
PTFE	0,3	0,35	0,12	-	260	18,5
steel	5	210	0,7	222	-	>1000
DLC	20-30	250	0,20	1	350	42,4
F-DLC	2	40	-	-	-	19,9
Si-DLC 2	7	50	0,4	40	400	25,2
Si-DLC 1	11	90	0,12	16	400	31,2
BN-DLC	20	230	0,20	7	-	54,2

DLC = diamond like carbon

Table 1: Characteristic constants of plasma coatings compared to steel (100 Cr6) and PTFE (1)

In artificial hip joints DLC-based coatings with well-defined surface tension values do show increased behavior regarding wear compared to untreated polyethylene.

Chemical vapor deposition is another technique to increase the surface tension of polymer surfaces. This way chemical oxides can be deposited on the polymer surfaces (table 2).

sample:	γ_s	γ_s^d	γ_s^P	γ_s	γ_s^{LW}	γ_s^{AB}	γ_s^+	γ_s^-
PP-foil	(mN/m)							
untreated	29,1	25,5	3,6	30,9	28,6	2,3	0,14	95
flame treated only	36,9	26,0	10,9	37,2	32,6	4,6	0,48	11,4
flame, Si-oxide	51,3	23,2	28,1	49,3	33,3	16,0	2,2	29,7

Table 2: Free surface energies of flamed and untreated PP-films (2)
left column: according to the theory of Frederik Fowkes
right column: according to van Oss, Good and Chaudhury

Classical materials for micromechanics are made of modified boro silica glass and Si. Implantable instruments and applicators for medicine are made of these materials. In contact with a biological system the biocompatibility regarding:

- deposition on solid surfaces in contact with blood or its components
- degradation of surfaces in contact with liquid at static and dynamic stress has to be checked.

Specially the deposition of proteins and cells on ceramics can be detected easily by contact angle measurements. In order to check the biocompatibility of these materials the surface free energies have been measured:

material	surface free energy disperse part [mN/m]	surface free energy polar part [mN/m]	σ [mN/m]
silicon	24,9	23,2	48,1
TEMPAX®	21,1	33,0	54,1
BIOVERIT®	8,0	58,4	66,4
silicone rubber HV 50	11,2	3,6	14,8
polyurethane CV 35	19,4	12,0	31,4

Silicone (with Band P)
TEMPAX® = borosilicate glass
BIOVERIT® = glass ceramics
Table 3: Surface free energies of some biocompatible surfaces (3)

Bioverit is an accepted biocompatible surface used for implants and dialyze. The surface free energies of the boro silica glass (TEMPAX®) and the silicon are close enough to allow the assumption that both surfaces are also biocompatible. This result is in good agreement with biological tests.

Literature

[[1] M.Grischke, JOT 36 (1), (1996) IV-VI

[2] Claus-Peter Klages, Martin Grischke,Thomas Höing und Rudolf Thyen
Proceedings of FDS-Workshop "Anwendung moderner Oberflächentechnologien in der Medizintechnik", Dresden (May, 1996)

[3] Jürgen Uhlemann, Diethard Löper, Richard Freyer, Proceedings of FDS-Workshop "Anwendung moderner Oberflächentechnologien in der Medizintechnik", Dresden (May, 1996)