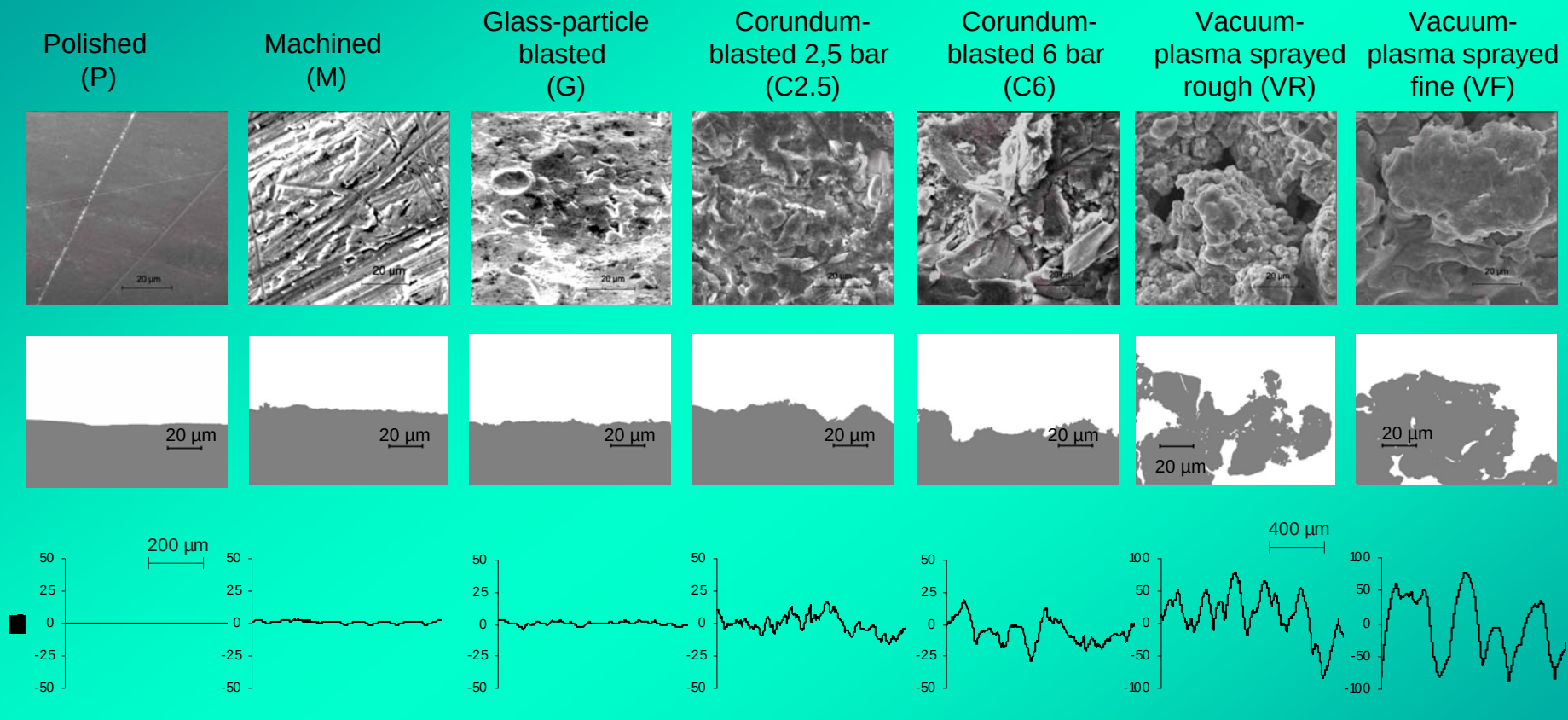
Methods for the physical and chemical characterisation of surfaces of titanium implants

Surface modifications of titanium implants



Commercial distributed implants do not have an uniform surface:

--> every part of the implant needs an optimized surface

Complete and exact

description of titanium surfaces with different roughness

Searching for relevant parameters for a correlation

physico-chemical characteristics --> cell behaviour

--> biocompatibility

(1) Estimation of the "true" surface area

quality control, input parameter for further working steps
in modifying the implant surface:
-electrochemical deposition of hydroxyapatite
-embedding of antibiotic substances

3 electrochemical methods:
-Electrochemical Impedance Spectroscopy (EIS)
-Linear Sweep Voltammetry (LSV)
-Chronoamperometry (CA)

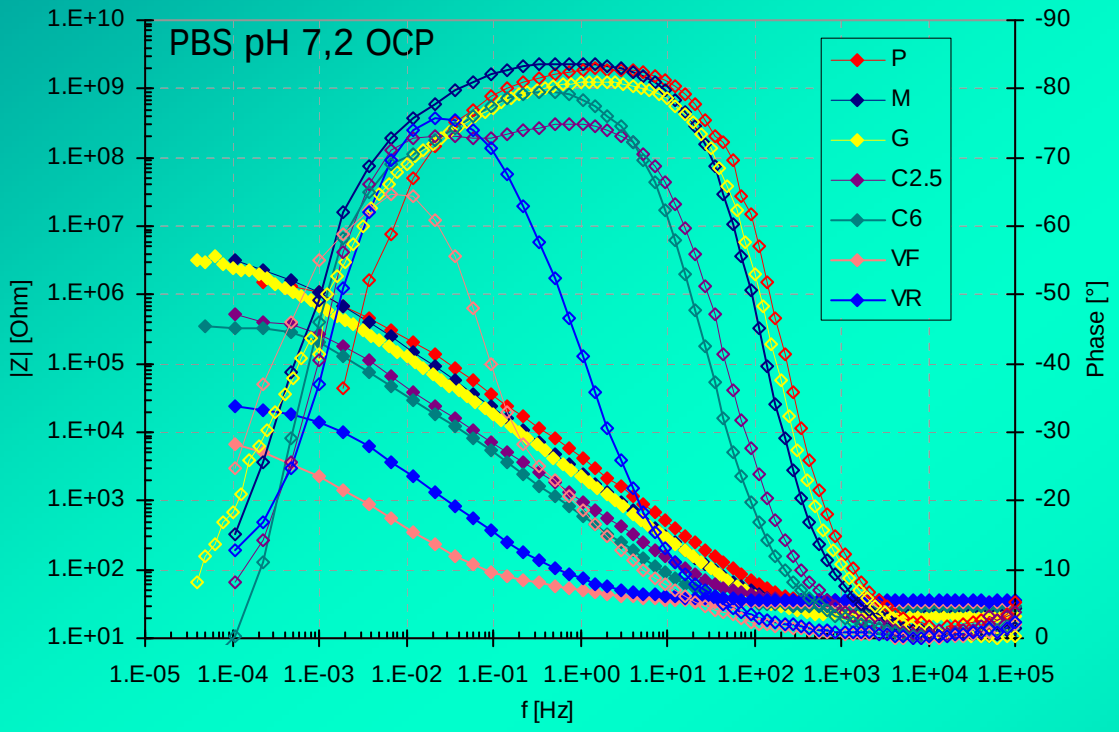
(2) Characterisation of the surface roughness with the parameter fractal dimension D_F

-2 electrochemical methods: EIS and LSV
comparison with results of Digital Image Processing (DIP)

(3) Cell biological tests

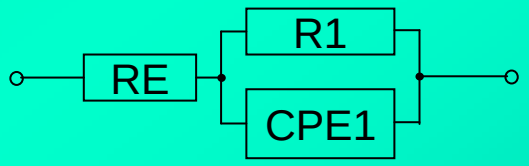
Electrochemical Impedance Spectroscopy (EIS)

Bode plot for all investigated titanium surfaces

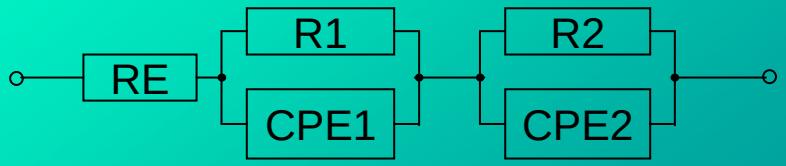


modification	Capacity C of the CPE [µF]
P	38.34
M	67.37
G	78.51
C2.5	170.34
C6	264.06
VF	6334.16
VR	4807.91

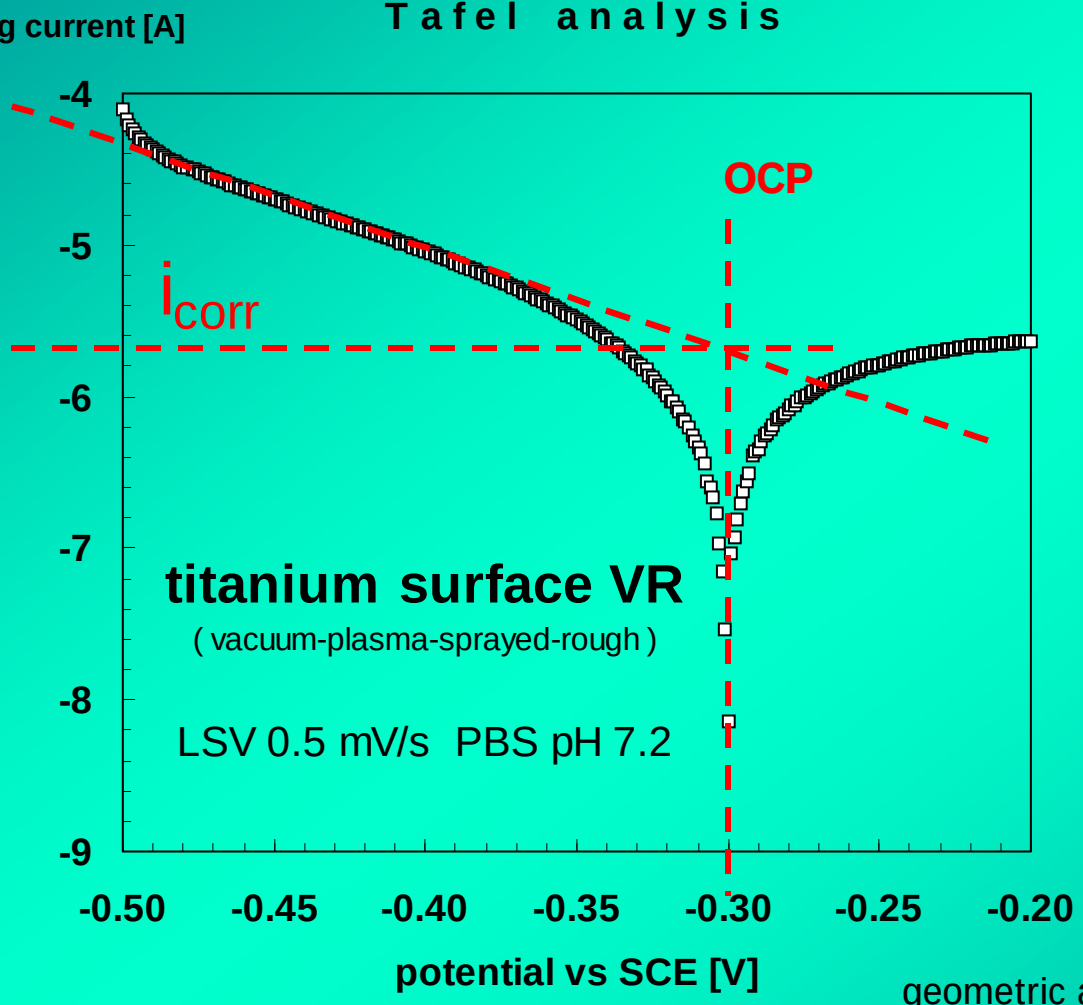
P, M, G, C2.5, C6



VF, VR



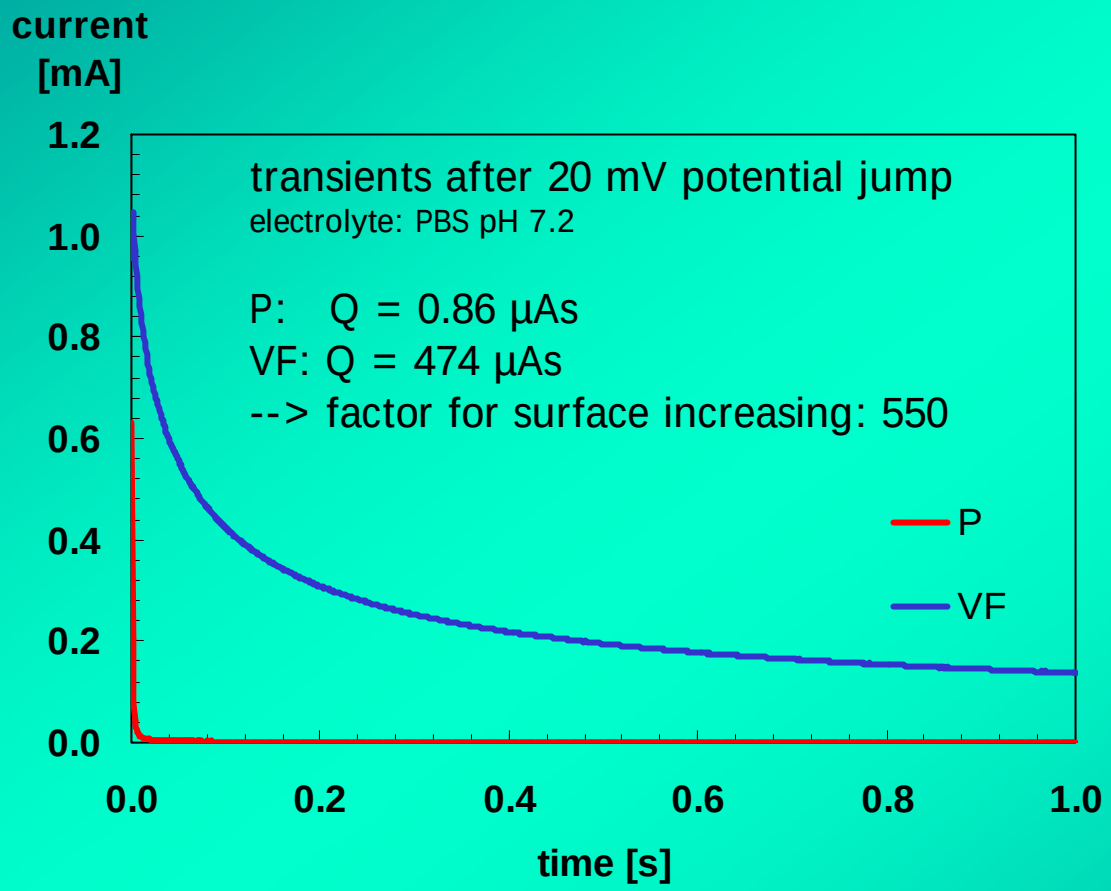
Linear Sweep Voltammetry (LSV)



modification	I_{corr} [nA]
P	13
M	16
G	37
C2.5	51
C6	341
VF	7294
VR	1740

geometric area : 2.27 cm^2

Chronoamperometry (CA)

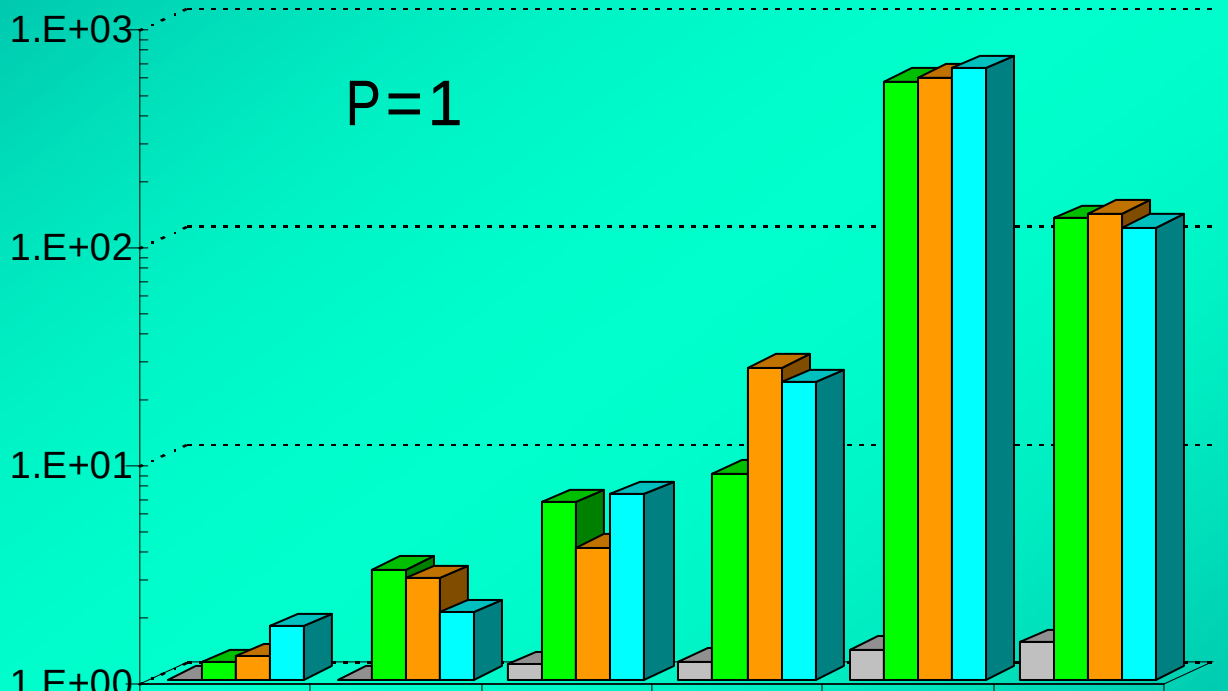


geometric area : 2.27 cm^2

modification	Q [µC]
P	0.86
M	1.03
G	2.75
C2.5	5.59
C6	7.57
VF	474.00
VR	112.00

Increasing of the electroactive area

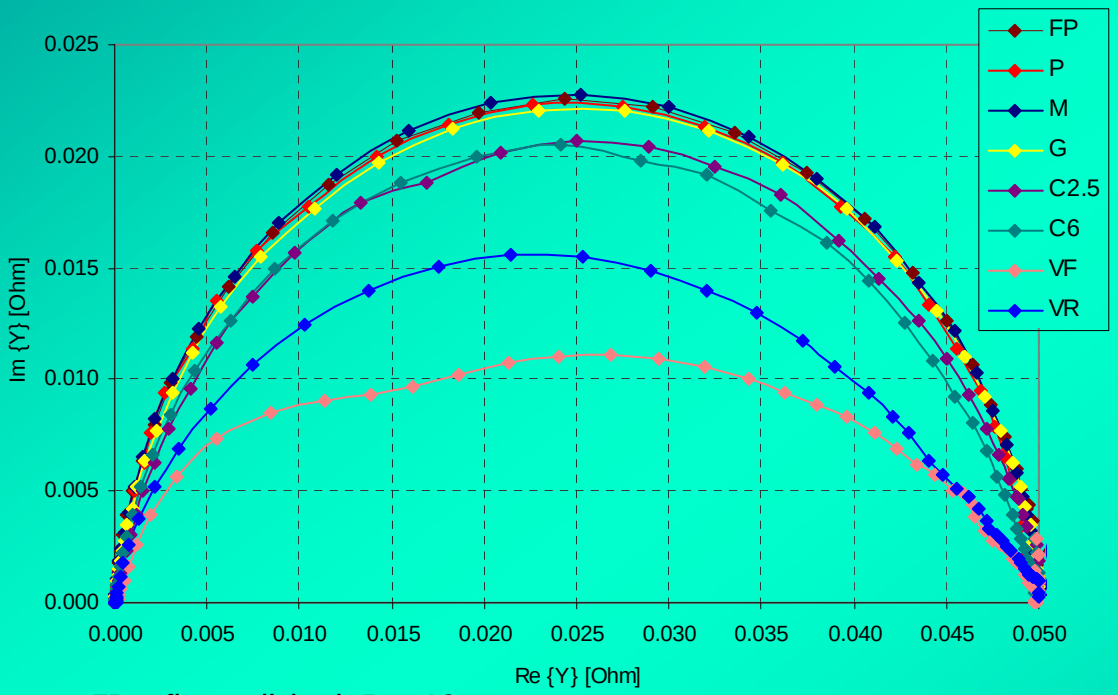
obtained by three electrochemical methods (EIS, LSV, CA) in comparison to that obtained by surface profiling



	M	G	C2.5	C6	VF	VR
SP	1.01	1.01	1.18	1.22	1.37	1.48
CA	1.20	3.20	6.50	8.80	551.00	130.00
LSV	1.27	2.90	4.03	26.94	575.98	137.39
EIS	1.75	2.05	7.07	22.92	630.79	118.69

Determination of the fractal dimension D_F by EIS

Admittance plot for all modifications



FP – fine polished, Ra=10 nm
Mr. Velten, University of Saarland, Germany

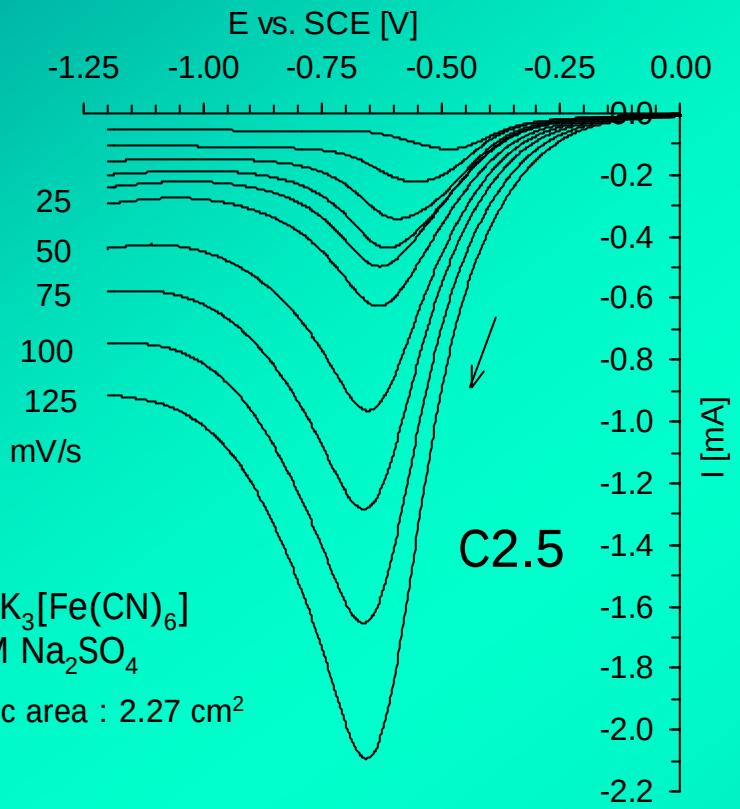
modification	Exponent n of the CPE
FP	0.947
P	0.927
M	0.921
G	0.890
C2.5	0.854
C6	0.874
VF	0.611
VR	0.572

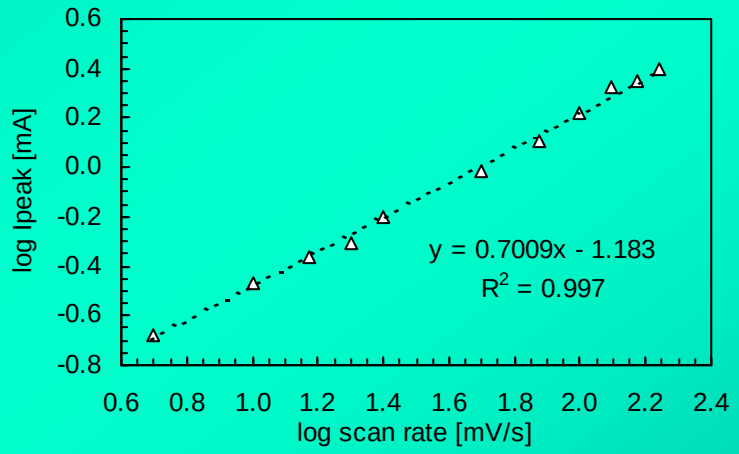
$$n = \frac{1}{D_F - 1} \qquad [1]$$

[1] T. PAJKOSSY, L. NYIKOS
"Impedance of fractal blocking electrodes"
J. Electrochem. Soc. 133 (10) (1986) 2061

Determination of the fractal dimension D_F by LSV measurement

(reduction of ferricyanide)





10 mM $K_3[Fe(CN)_6]$
in 0,5 M Na_2SO_4

geometric area : 2.27 cm^2

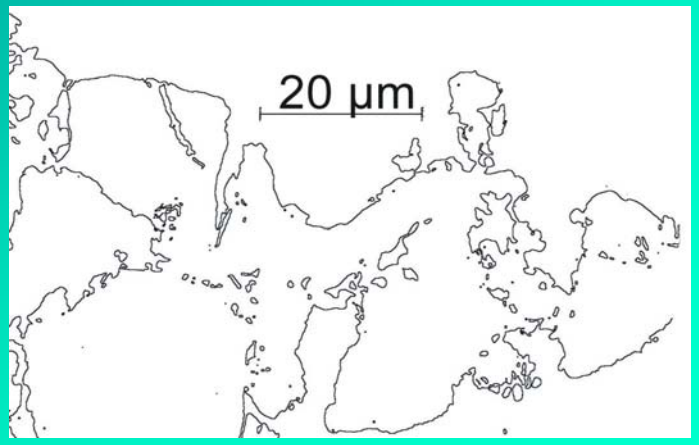
modification	slope a
FP	0.598
P	0.642
M	0.745
G	0.574
C2.5	0.701
C6	0.669
VF	0.889
VR	0. 769

$$a = \frac{D_F - 1}{2} \qquad [2]$$

[2] T. PAJKOSSY, L. NYIKOS
"Diffusion to fractal surfaces -
III. Linear sweep and cyclic voltammograms"
Electrochim. Acta 34 (2) (1989) 181-186

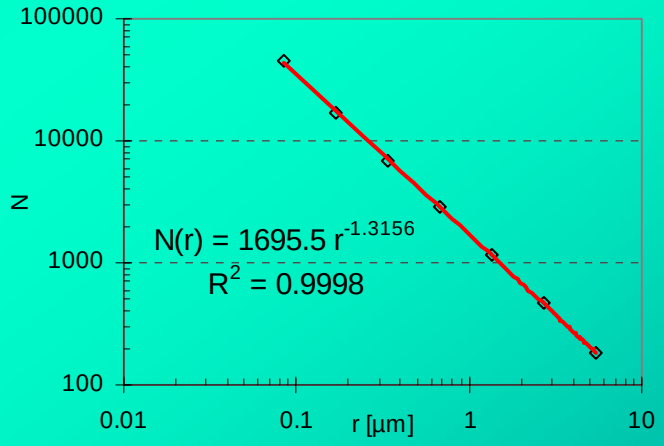
Determination of the fractal dimension D_F by Digital Image Processing (DIP)

Border line obtained from the SEM-picture of the cross section of a VF-sample



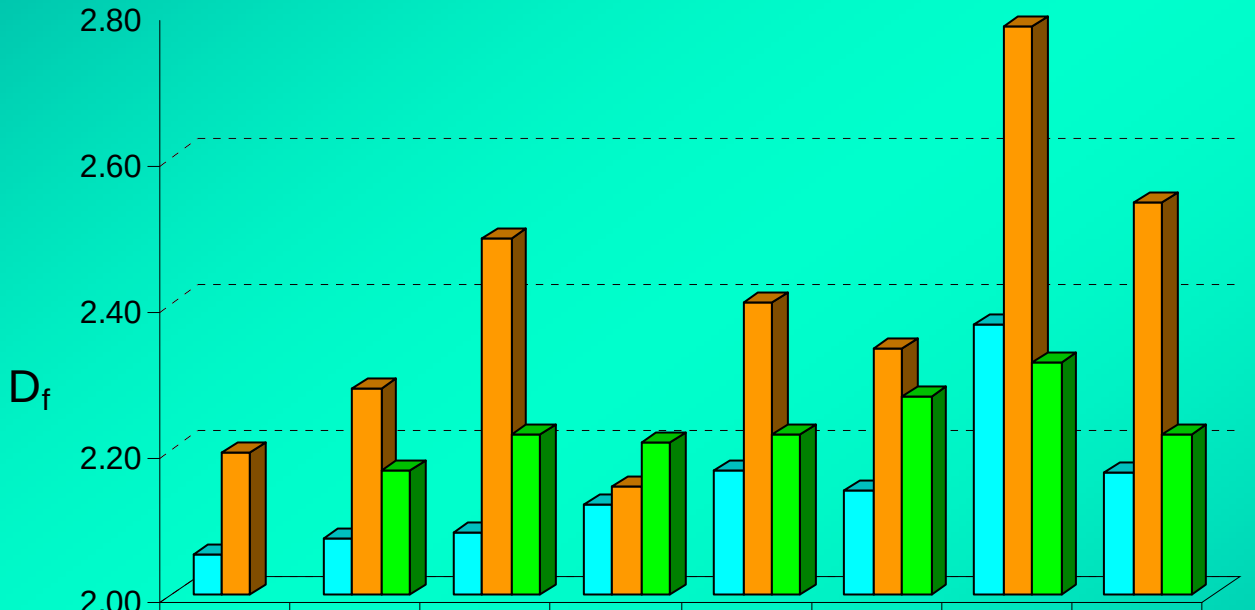
box counting algorithm
(Corel, UTHSCSA Image tool)
N - Number of boxes
r - box size
plot log (N)=f(log(r))
→ slope of the regression line is the fractal dimension $D_{F,B}$:

Results of the box counting procedure for VF



$$N(r) = const. \cdot r^{-D_{F,B}}$$

Comparison of the fractal dimension D_F obtained by three different methods



	FP	P	M	G	C2.5	C6	VF	VR
EIS	2.06	2.08	2.09	2.12	2.17	2.14	2.37	2.17
LSV	2.20	2.28	2.49	2.15	2.40	2.34	2.78	2.54
DIP		2.17	2.22	2.21	2.22	2.27	2.32	2.22

Cell biological examinations

Expression of fibronectin in MG-63 osteoblastic cells
on differently structured titanium surfaces (Western Blot)

M G VR C6 P

R_a [µm]	0.53	1.22	20.99	6.07	0.07
D_F (LSV)	2.49	2.15	2.54	2.34	2.28