

Diamond electrodes

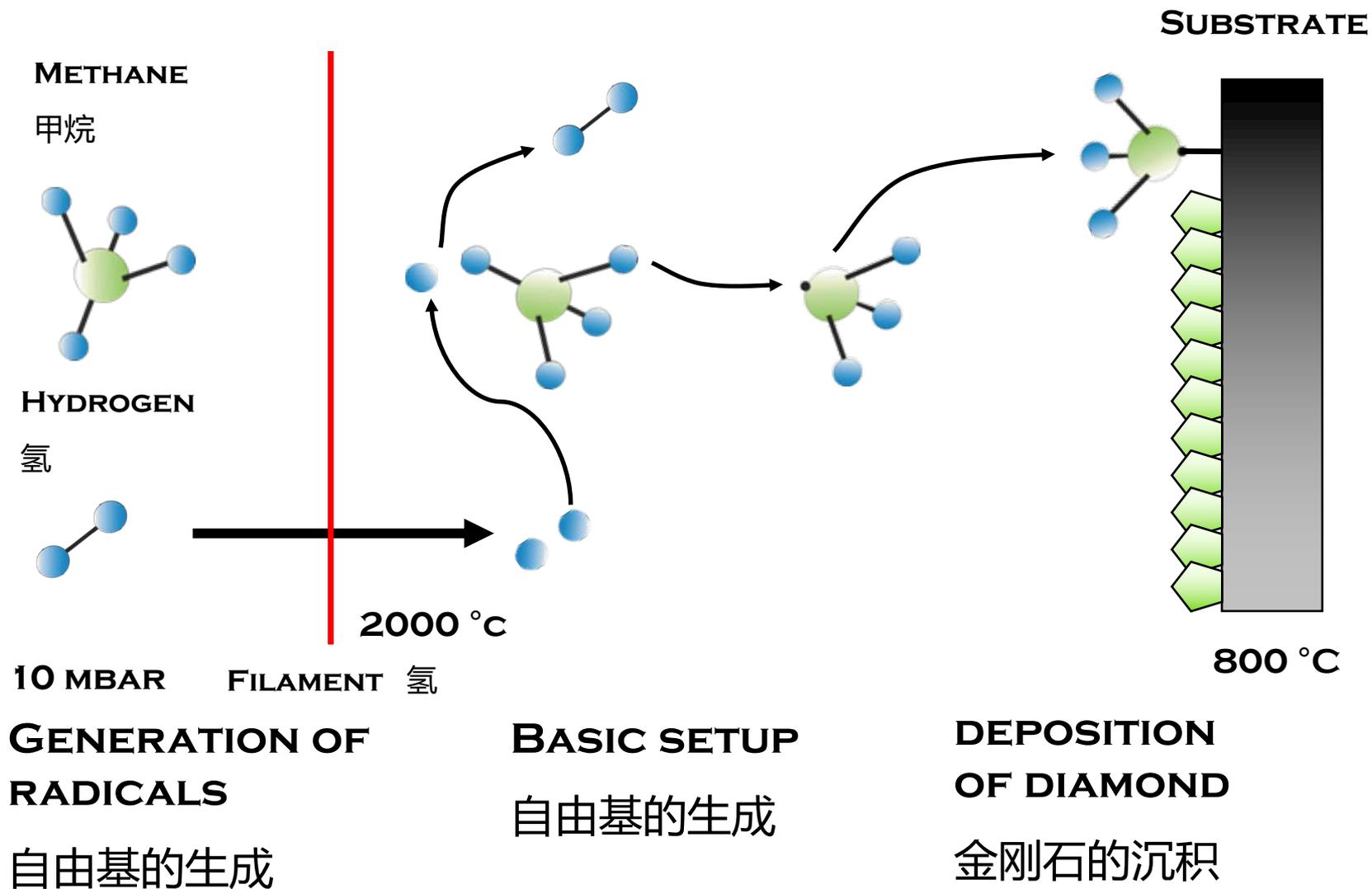
金刚石电极

properties, fabrication,
applications

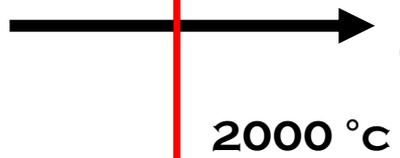
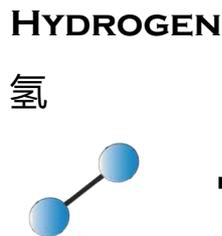
性能、制造、应用

DiaCCon GmbH
Dipl.-Ing. Martin Rüffer

Fabrication - How to make diamond 制造 - 如何制造金刚石

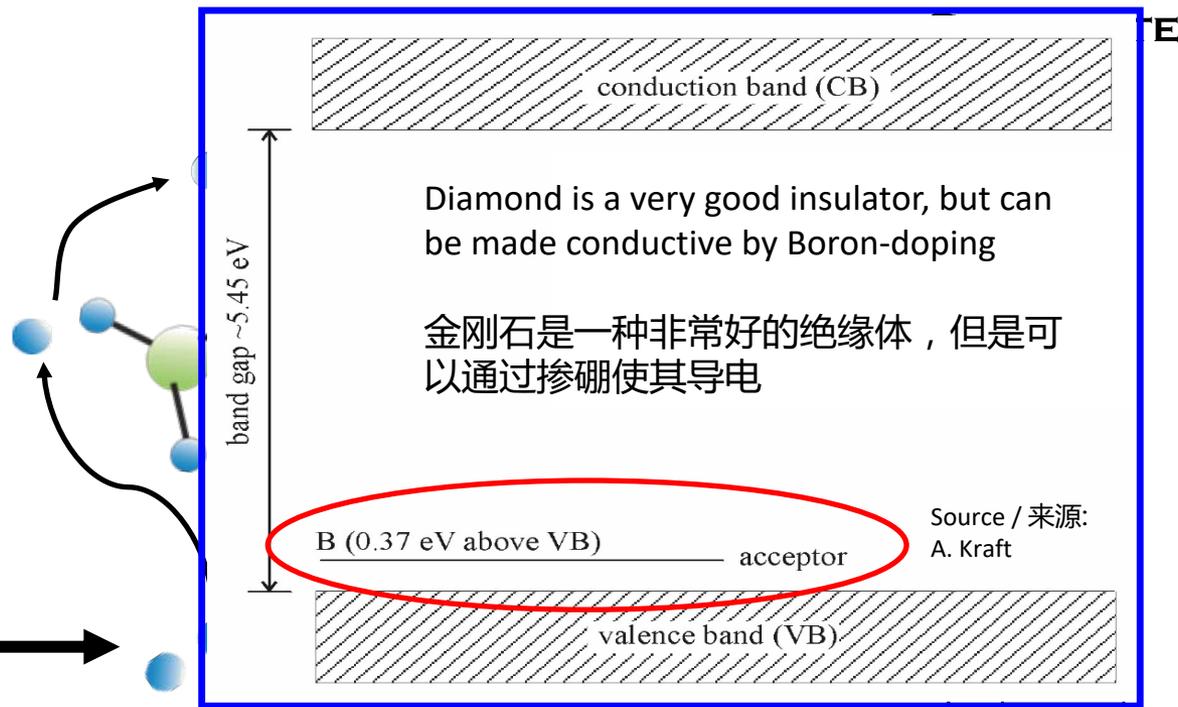


Fabrication - How to make diamond 制造 - 如何制造金刚石



10 MBAR FILAMENT 氢

GENERATION OF RADICALS
自由基的生成



Diamond is a very good insulator, but can be made conductive by Boron-doping

金刚石是一种非常好的绝缘体，但是可以通过掺硼使其导电

Source / 来源:
A. Kraft

BASIC SETUP
自由基的生成

DEPOSITION OF DIAMOND
金刚石的沉积

800 °C

Fabrication - How to make diamond

制造 - 如何制造金刚石

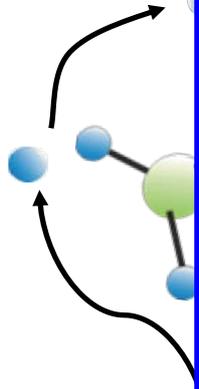
METHANE

甲烷



HYDROGEN

氢



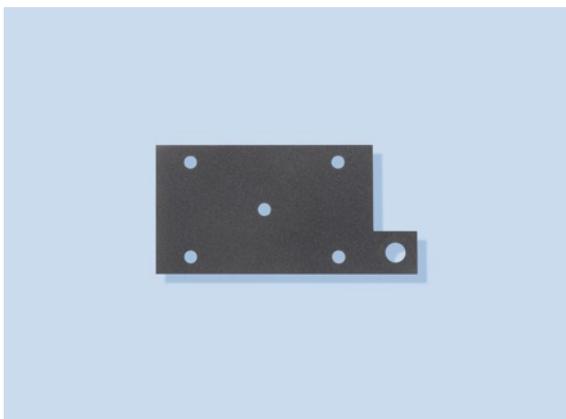
800 °C



**DEPOSITION
OF DIAMOND**

金刚石的沉积

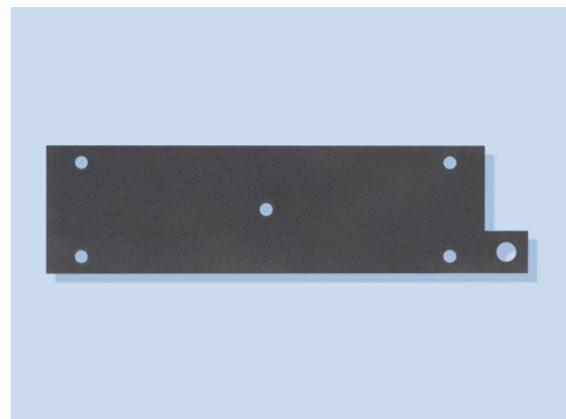
Fabrication - Electrode types **制造 - 电极类型**



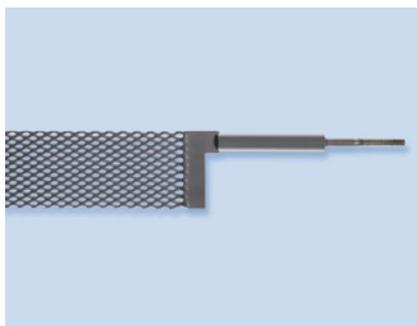
Type Baerbel 型
250mmx150mm

Main types
Standardised electrodes

主要类型
标准化电极



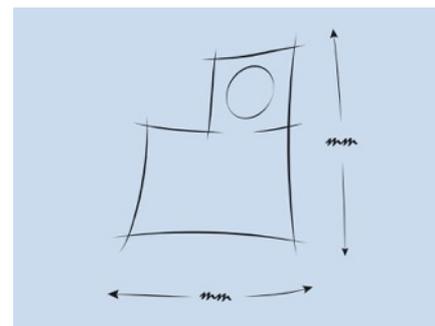
Type Barbara型
500mmx150mm



Mesh electrodes 网格电极
welded connectors 已焊接连接器



Welded electrodes 已焊接电极
large / complex geometries
大型/复杂几何形状



Custom-made 定制
water jet cut 水射流切割

Fabrication – Electrolysers 现成设备



Electrolysers for standard types 标准型电解装置

-Baerbel & Barbara Diamond electrodes

-Baerbel和Barbara金刚石电极

-0,075sqm - 0.95sqm anode/electrolyser

-0.075sqm - 0.95sqm 阳极/电解装置

-ready made equipment

-现成设备

Fabrication – Electrolysers 现成设备



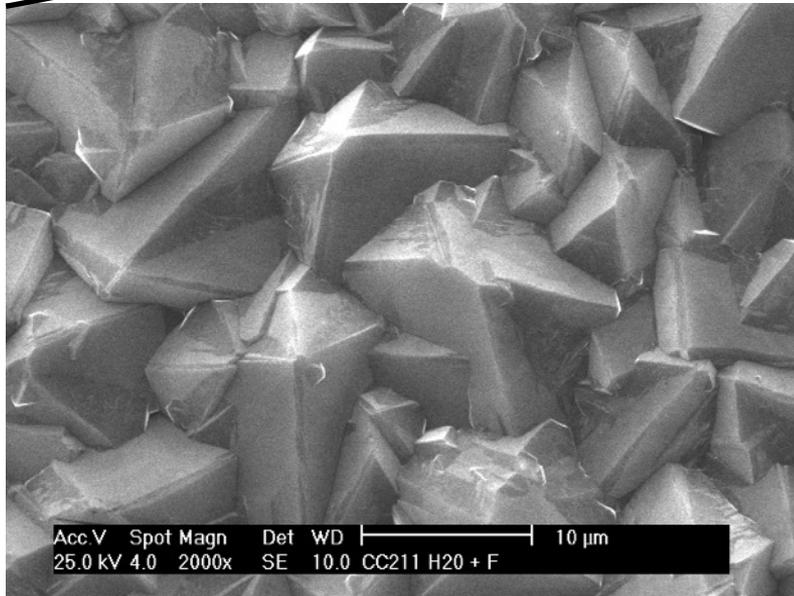
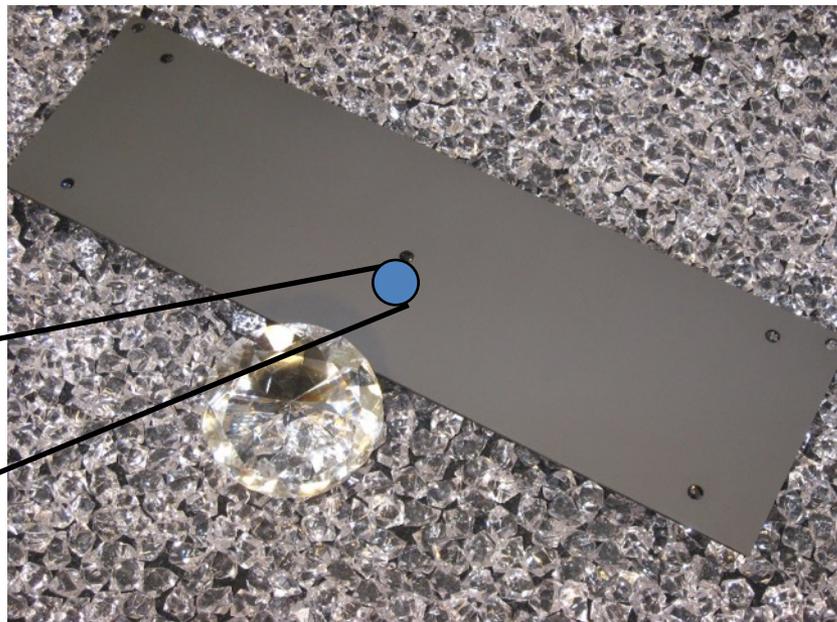
es

-ready made equipment
-现成设备

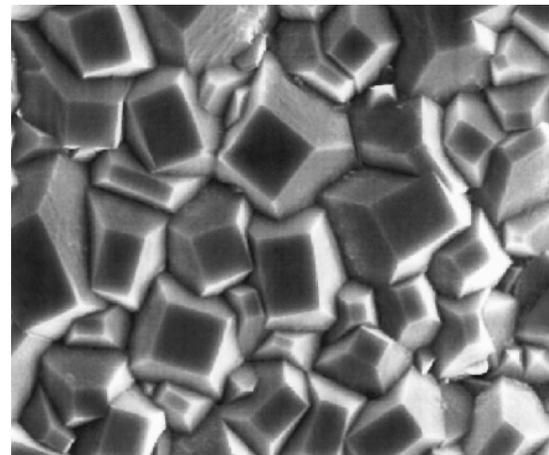
Properties - The Diamonds... 性能 - 这些金刚石...

Morphology can be influenced by:

- gas composition / 气体成分
- gas flow / 气体流量
- gas pressure / 气体压力
- substrate temperature / 基板温度
- filament temperature / 灯丝温度
- etc. / 其他



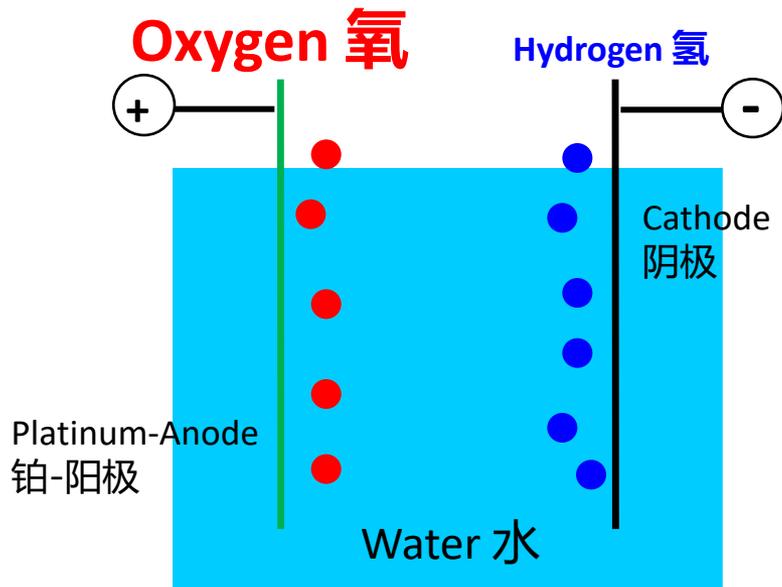
Various
Morphologies
各种
形态



Properties - Electrochemistry with diamond electrodes 性能 - 金刚石电极的电化学

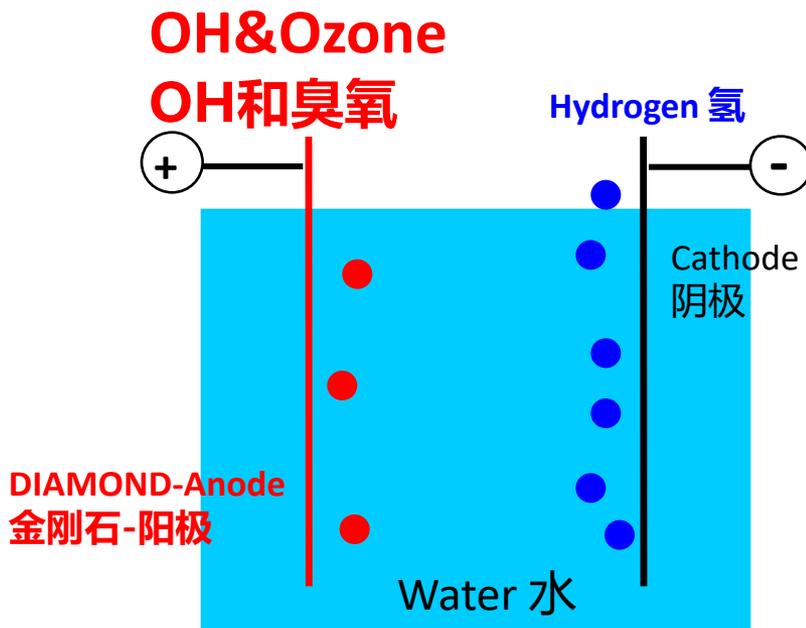
Elektrochemistry in aqueous media leads to unwanted water splitting, but...
水介质中的电化学会导致不必要的水分解，但...

...with standard electrodes
...标准电极情况下



- only 1,5V is required for water splitting
只有3.5V才能实现水分解
- > almost water splitting only !
几乎只有水分解！
- waste of energy!
浪费能源！

...with DIAMOND ELECTRODES
...金刚石电极情况下

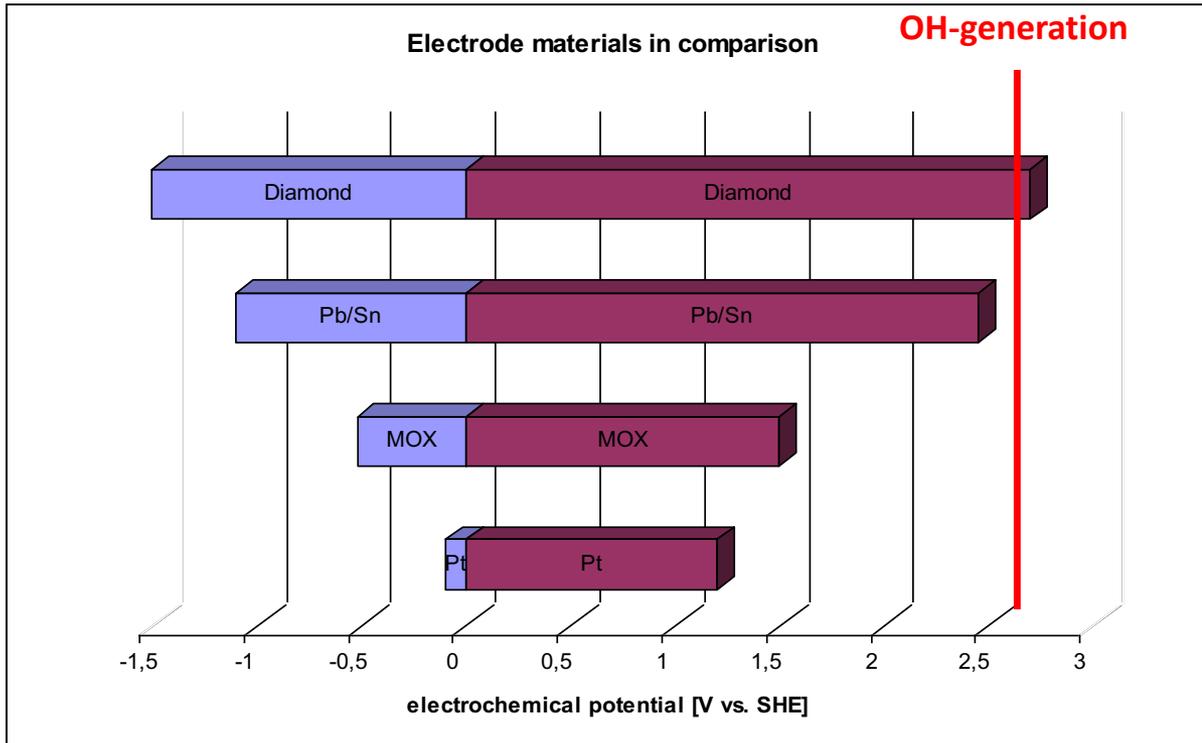


- ~3,5V are required for water splitting
需要~3.5V实现水分解
- > almost no water splitting
几乎没有水分解
- new electrochemical reactions are possible
新的电化学反应是可能的

Properties - Different electrode materials in comparison

性能 - 不同电极材料的比较

- Diamond has ultra wide potential window for water decomposition, anodic as well as cathodic!
金刚石具有超宽的水分解、阳极和阴极的电势窗口！
- Production of extremely strong oxidants like OH° & Ozone
产生极强氧化剂，如OH和臭氧

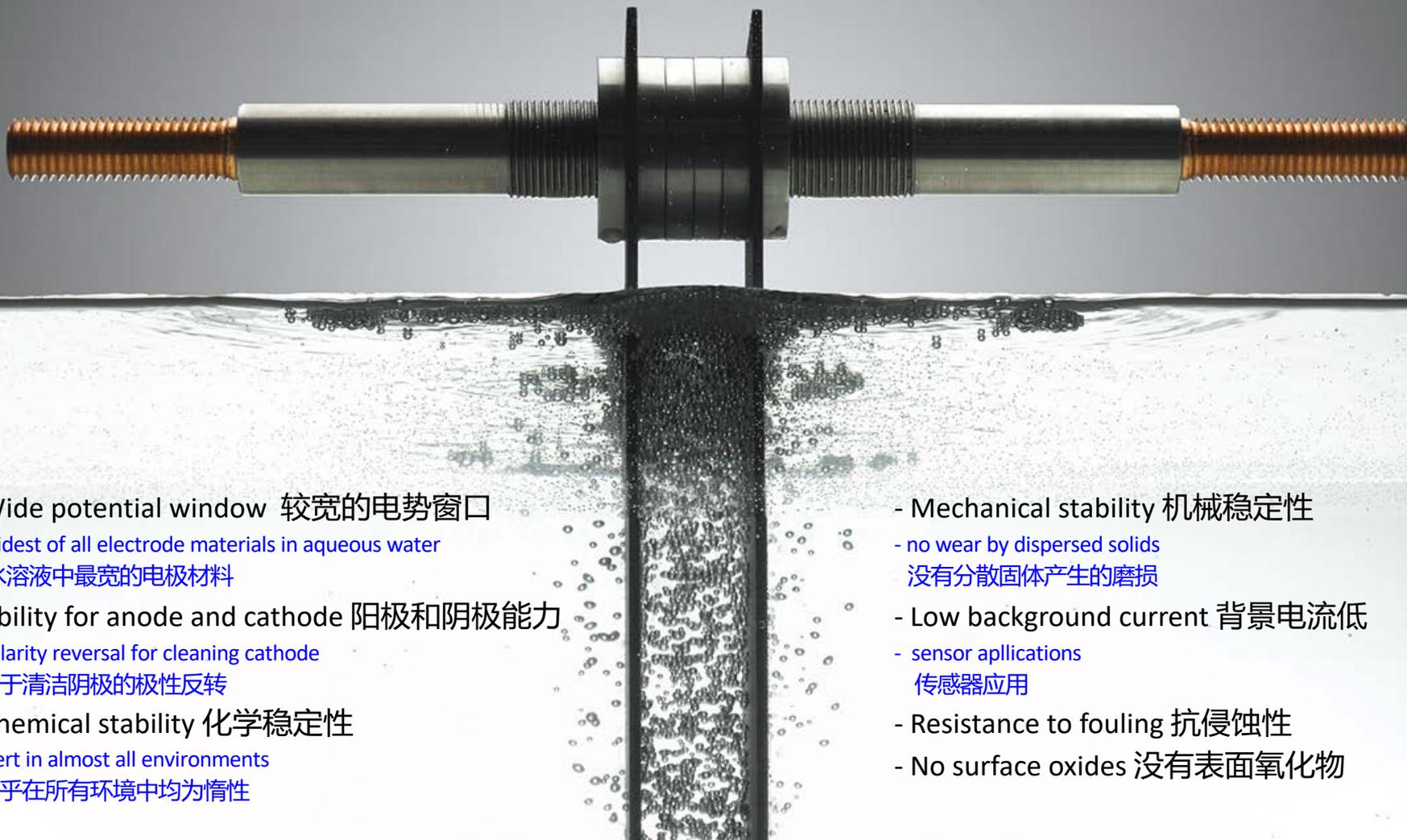


Substance 物质	formation potential [V] 生成电势[V]
Hydroxyl radical 羟基自由基 ($\text{H}_2\text{O}/\text{OH}^\cdot$)	2,80
Ozone 臭氧 (O_3)	2,07
Peroxodisulfate ($\text{SO}_4^{2-}/\text{S}_2\text{O}_8^{2-}$)	2,01
Hydrogen Peroxide 过氧化氢 ($\text{H}_2\text{O}/\text{H}_2\text{O}_2$)	1,77



Properties - diamond electrodes at a glance

性能 - 金刚石电极一瞥

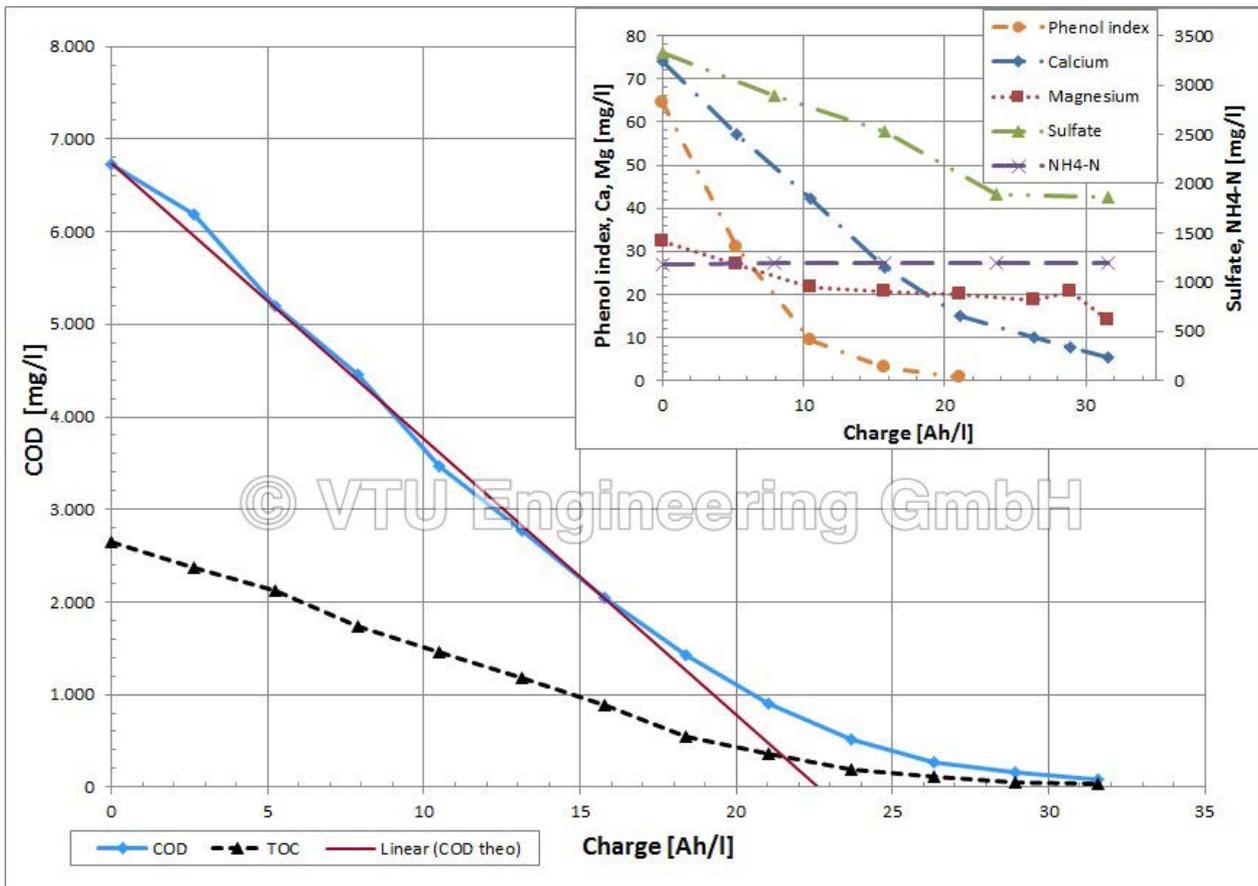


- Wide potential window 较宽的电势窗口
- widest of all electrode materials in aqueous water
水溶液中最宽的电极材料
- Ability for anode and cathode 阳极和阴极能力
polarity reversal for cleaning cathode
用于清洁阴极的极性反转
- Chemical stability 化学稳定性
inert in almost all environments
几乎在所有环境中均为惰性

- Mechanical stability 机械稳定性
- no wear by dispersed solids
没有分散固体产生的磨损
- Low background current 背景电流低
- sensor applications
传感器应用
- Resistance to fouling 抗侵蚀性
- No surface oxides 没有表面氧化物

Application – COD-reduction in waste water 应用 – 减少废水中的COD

OH-radical is an extremely strong oxidant -> Oxidation of the waste
 OH-自由基是一种极强的氧化剂 -> 废物的氧化



- Reduction of the **Chemical Oxygen Demand** 化学需氧量(COD)的减少 (equivalent for contained waste) (相当于所含废物)
- **Advanced Oxidation Process** 高级氧化法(AOP)
- No additional chemical required 无需额外的化学品

Source 来源:

Application- COD-reduction in waste water

应用 - 减少废水中的COD



Plastic industry
塑料行业



Food industry
食品行业



Metal industry
金属行业



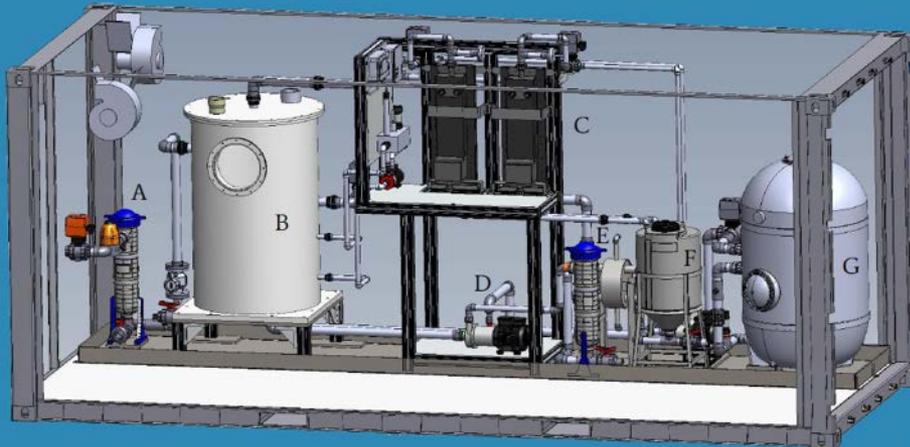
Pharma industry
制药行业



Textile industry
纺织行业

Powerful plants for treating waste waters of all kinds of industries
强大工厂，处理各种工业废水

Main components of DAREIOS®



A Bag filter
B Wastewater container
C Diamond electrodes cells
D Circulation pump
E Bag filter
F Self-cleaning system
G Filtration/adsorption unit

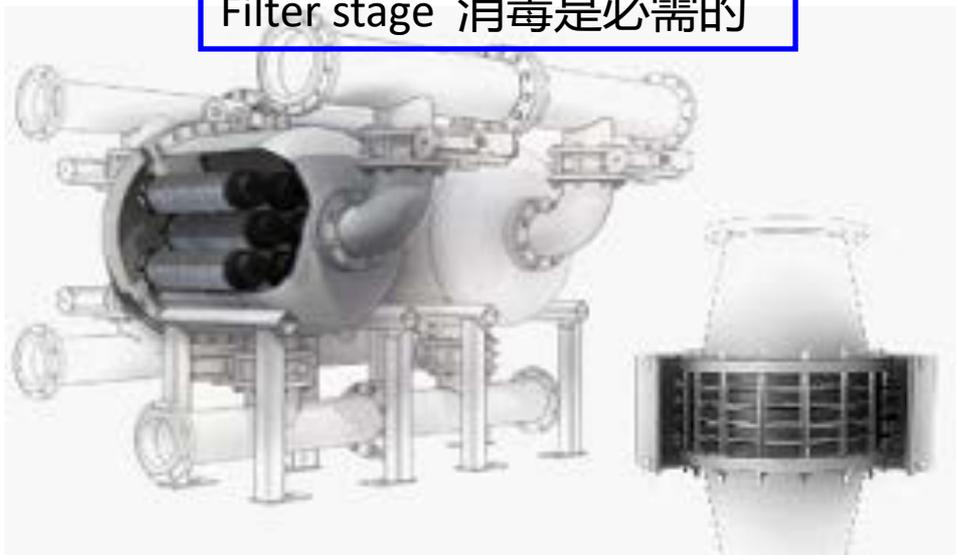
Removal of: 清除：

- Phenols
酚类物质
- Alcohols
醇类物质
- Dyes
染料
- Fungicides
杀真菌剂
- Pesticides
杀虫剂
- Drugs
药剂
- etc.
其他

Application – Disinfection of Ballast water 应用 – 压载水消毒



Filter stage 消毒是必需的



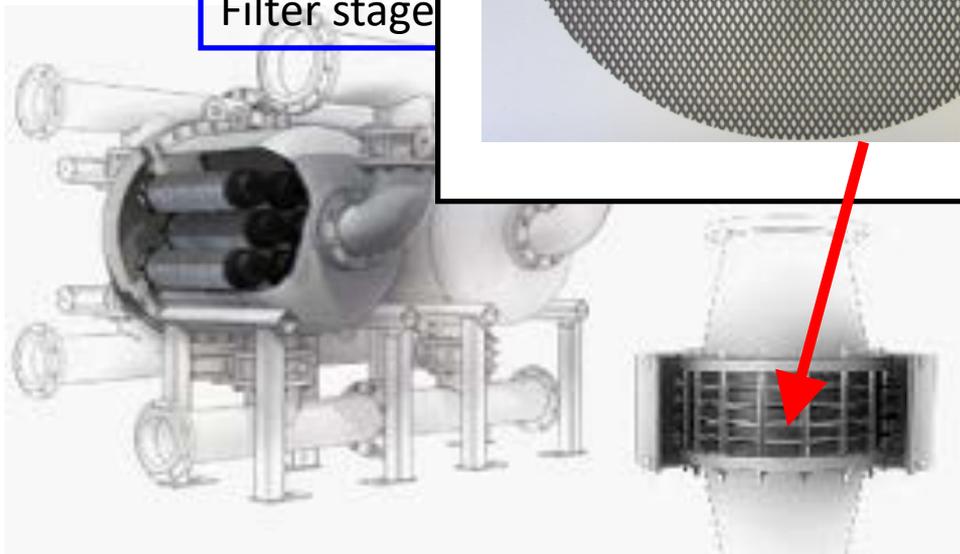
Disinfection stage with diamond electrodes
采用金刚石电极的消毒阶段

- Ballast water is required to stabilize ships in the sea
需要压载水来稳定海上船只
- transferred species can become a non control able invasion
迁移的物种可能成为一种不受控制的入侵物种
- disinfection is required
消毒是必需的

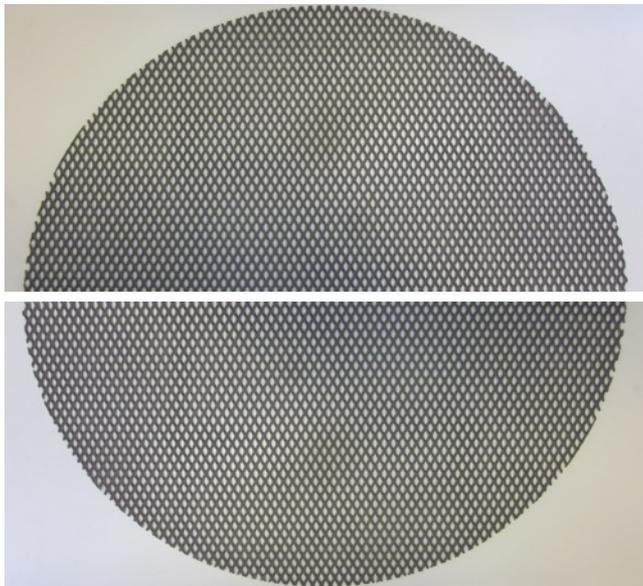
Application – Disinfection



Filter stage



Disinfection stage with diamond electrodes
采用金刚石电极的消毒阶段



Electrode-type
电极类型:

- disc of two halves
两半圆盘
- mesh type
网格类型

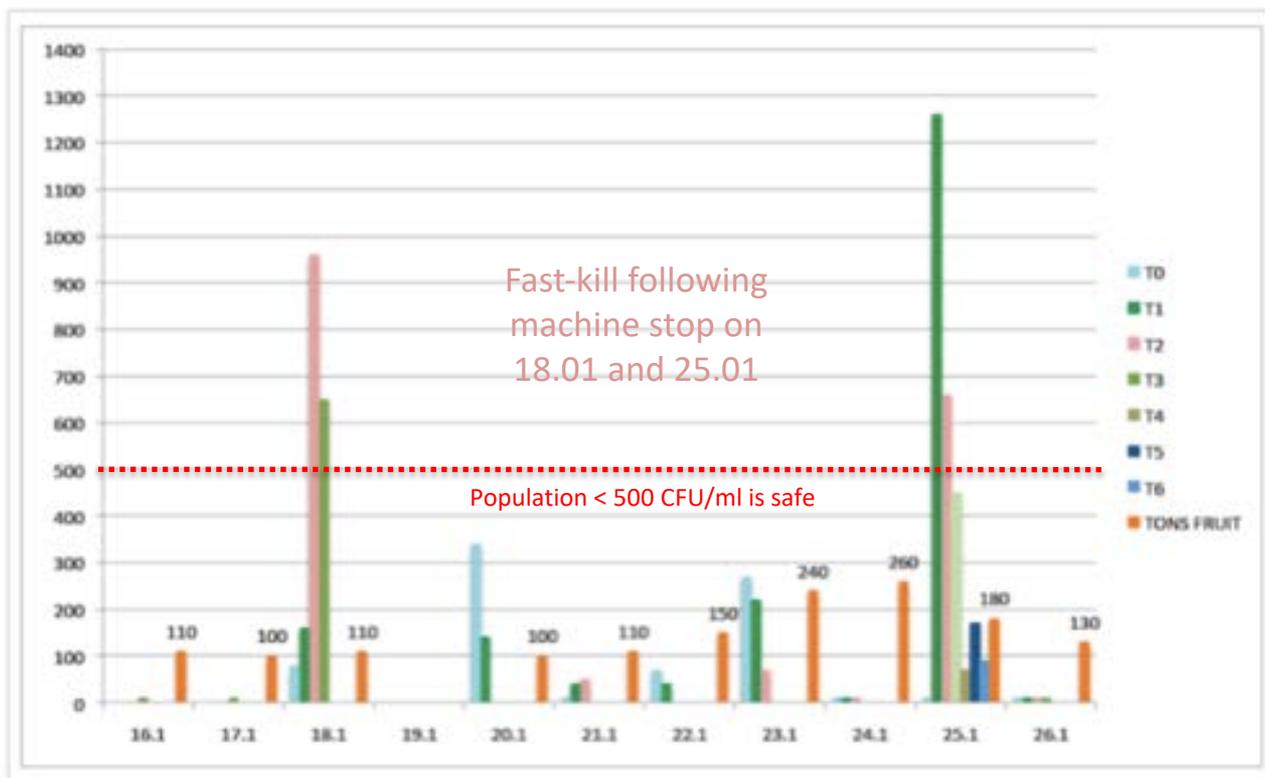
- transferred species can become a non control able invasion
迁移的物种可能成为一种不受控制的入侵物种
- disinfection is required
消毒是必需的

Application - disinfection in food processing 应用 - 食品加工消毒

Conventional: Fruits are washed and treated with fungicides, high water consumption

常规：水果用杀菌剂清洗和处理，耗水量高

采用金刚石电极：洗涤水时刻保持消毒，无需杀菌剂



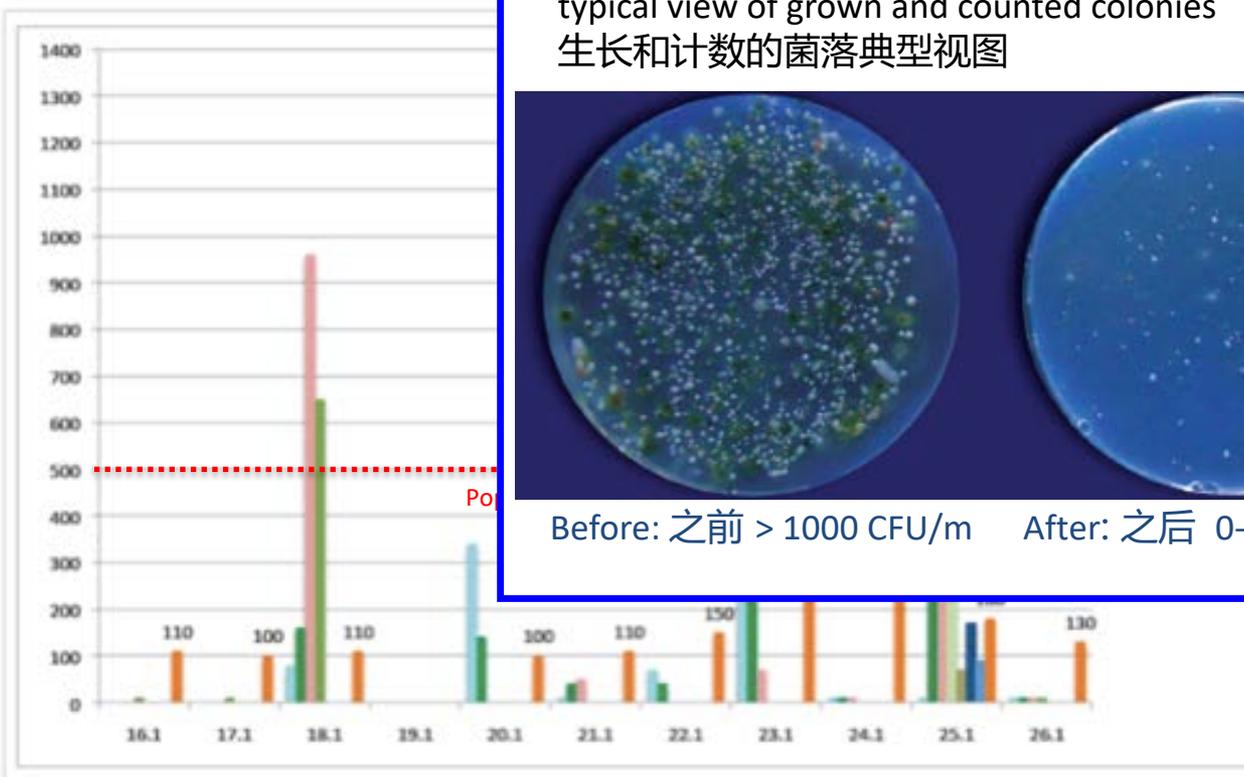
Population of Penicillium spp. (CFU – Colony Forming Units/ml) in citrus dip tank
柑橘浸渍槽中青霉菌种群数量(CFU-菌落形成单位/ml)

Application - disinfection in food processing 应用 - 食品加工消毒

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采用金刚石电极：洗涤水时刻保持消毒，无需杀菌剂



typical view of grown and counted colonies
生长和计数的菌落典型视图

Before: 之前 > 1000 CFU/m After: 之后 0-50 CFU/ml



Population of *Penicillium* spp. (CFU – Colony Forming Units/ml) in citrus dip tank
柑橘浸渍槽中青霉菌种群数量(CFU-菌落形成单位/ml)

Application – cathodic metal recovery 应用 – 阴极金属回收

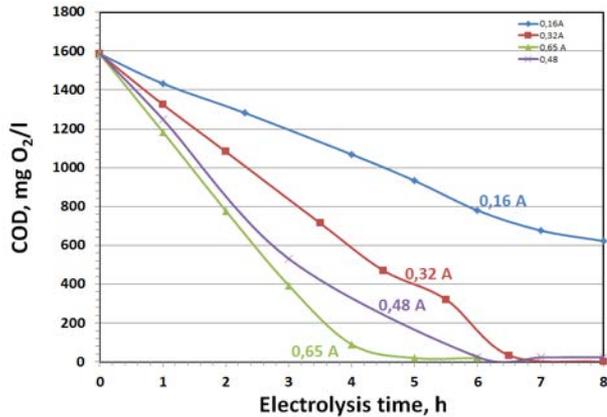
- Diamond electrodes have a high overpotential for hydrogen evolution -> efficient metal deoxidation
金刚石电极具有很高的析氢过电位 -> 有效的金属脱氧
- efficient precipitation off dissolved metals in the aqueous solution or on the BDD cathode
有效沉淀水溶液中或BDD阴极上的溶解金属

Co^{+2}	Sn^{+2}	Ni^{+2}	Fe^{+3}	Au	Ag^{+1}	Zn^{+2}

Application – landfill leachate 应用 – 垃圾渗滤液

- combination of anodic COD destruction and cathodic metal removal
 阳极COD破坏和阴极金属去除的组合

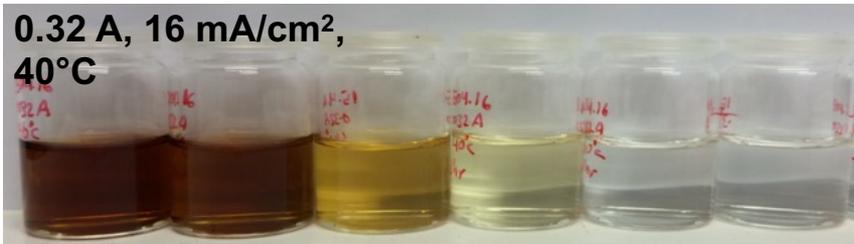
Anode: COD destruction 阳极：COD破坏



Cathode: metal recovery 阴极：金属回收



0.32 A, 16 mA/cm²,
 40°C



a toxic soup becomes clear!
有毒的溶液变得清澈！

Metals 金属	removal efficiency % 去除效率%	
	BDD/BDD	Pt/Ti
Mg	40	35
Al	78	76
Ca	25	5
Cr	19	54
Mn	70	46
Fe	70	64
Ni	55	27
Cu	41	40
As	60	---
Sr	21	7
COD	91	33

Application – electroless nickel waste water

应用 – 化学镀镍废水

- again combination of anodic COD destruction and cathodic metal removal
阳极COD破坏和阴极金属去除的再次组合
- nickel-ion is embedded into a lactic acid complex -> high COD!
镍离子嵌入乳酸复合物中 -> 高COD！
- nickel is not available for recovery!
镍无法回收！
- waste water is toxic -> not biodegradable!
废水有毒 -> 不可生物降解！

Solution 解决方案:

- anodic destruction of lactic acid complex
乳酸复合物的阳极破坏
释放嵌入的镍
- cathodic nickel-recovery
阴极镍回收



laboratory trial
实验室试验

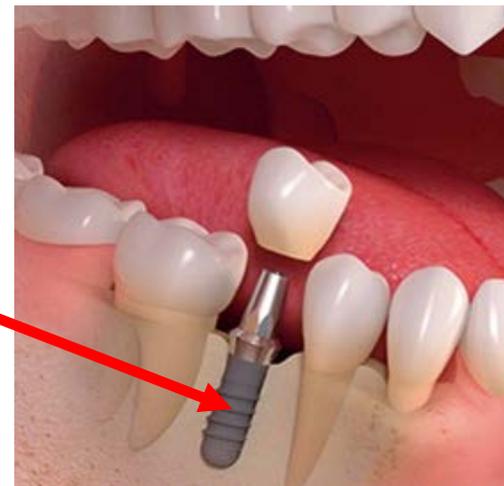


toxic green becomes clear! 有毒的绿色变得清澈！

R&D – in situ disinfection of implants 研发 – 种植体的原位消毒

Inflammation of implants can lead to lost of implant and further surgery!
种植体的炎症可导致种植体丢失和再次手术！

Idea: disinfection of implant in human body by use of diamond coated implants/tools as electrode
想法：采用金刚石涂层种植体/工具作为电极对人体中的种植体进行消毒



diamond coated
tooth implant
金刚石涂层
牙种植体

root canal treatment 根管治疗



diamond coated tool
金刚石涂层工具

dental implant
牙种植体

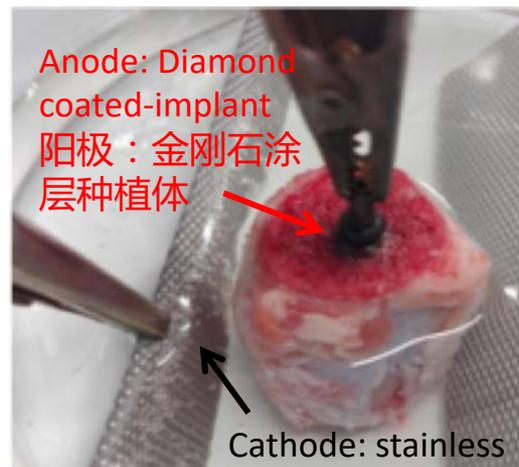
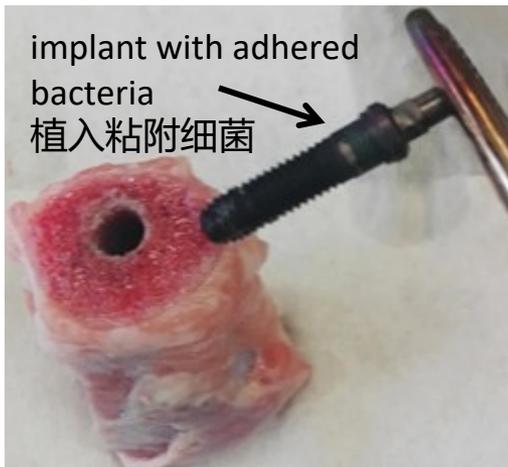
S. Rosiwal (Sp)¹; H. Ghanem¹; M. Stiesch²;
A. Burkovski¹; M. Schuman¹; A. Labitzke¹

¹ Friedrich-Alexander-
Universität Erlangen-
Nürnberg (FAU) (Germany)

² Hannover Medical School
(MHH) (Germany)

R&D – in situ disinfection of implants 研发 – 种植体的原位消毒

lab-tests show complete disinfection of implants!
实验室测试显示种植体完全消毒！



Bacteria colonies growing from the implant surface
细菌菌落从种植体表面生长



no bacteria colonies due to electrochemical disinfection
由于电化学消毒，没有细菌菌落

R&D – applications for third world/isolated rural areas 研发 – 第三世界/孤立的农村地区的应用

- no technical infrastructure (electricity, fresh water supply, waste water disposal)

没有技术基础设施(电力、淡水供应、废水处理)

- danger of spread of diseases - need for disinfection!

疾病传播的危险 - 需要消毒!

- no skilled personal

没有技术熟练的人员

- low budget

预算低



- cascade of diamond electrodes for disinfection!

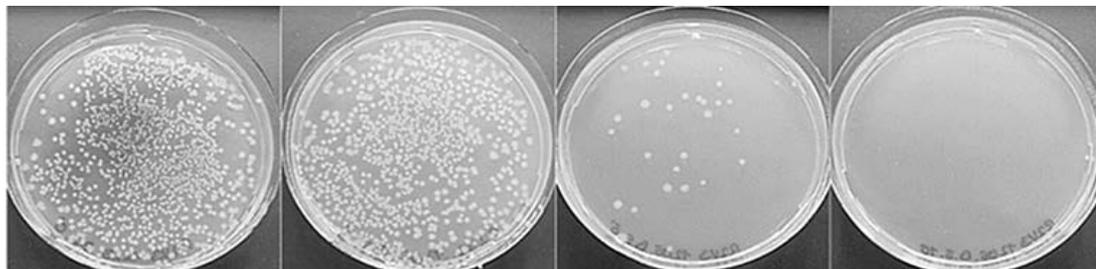
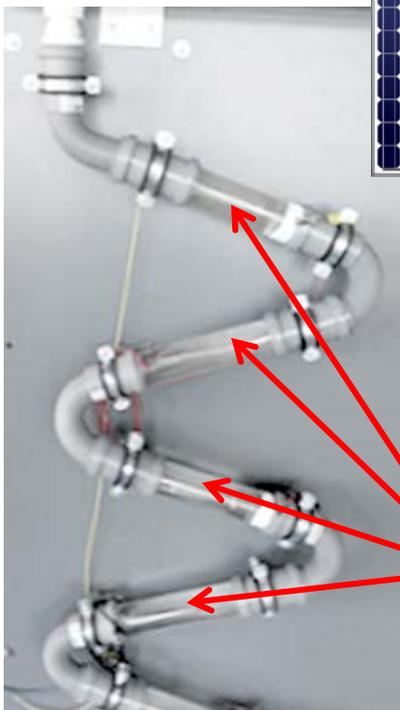
用于消毒的金刚石电极级联!

- water flow is top-down

水流自上而下

- solar power possible and gravity only, no moving parts!

太阳能可能, 只有重力, 没有活动部件!



bacteria kills/treatment time 细菌杀灭/处理时间

diamond electrodes in standard plastic piping 标准塑料管道中的金刚石电极

Bastian Schorr, Hanadi Ghanem, Stefan Rosiwal, Walter Geißdörfer, Andreas Burkovski
Elimination of bacterial contaminations by treatment of water with boron-doped diamond electrodes
(通过掺硼金刚石电极处理水消除细菌污染)

World Journal of Microbiology and Biotechnology 世界微生物学和生物技术杂志 (2019)

Most fascinating application 最迷人的操作

Seabox™ - Subsea water treatment 海底水处理

Using diamond electrodes
in the process
使用钻石焊条

Water injection to offer
increased oil recovery
通过注射水提升油的探索

16-MAY-2019.



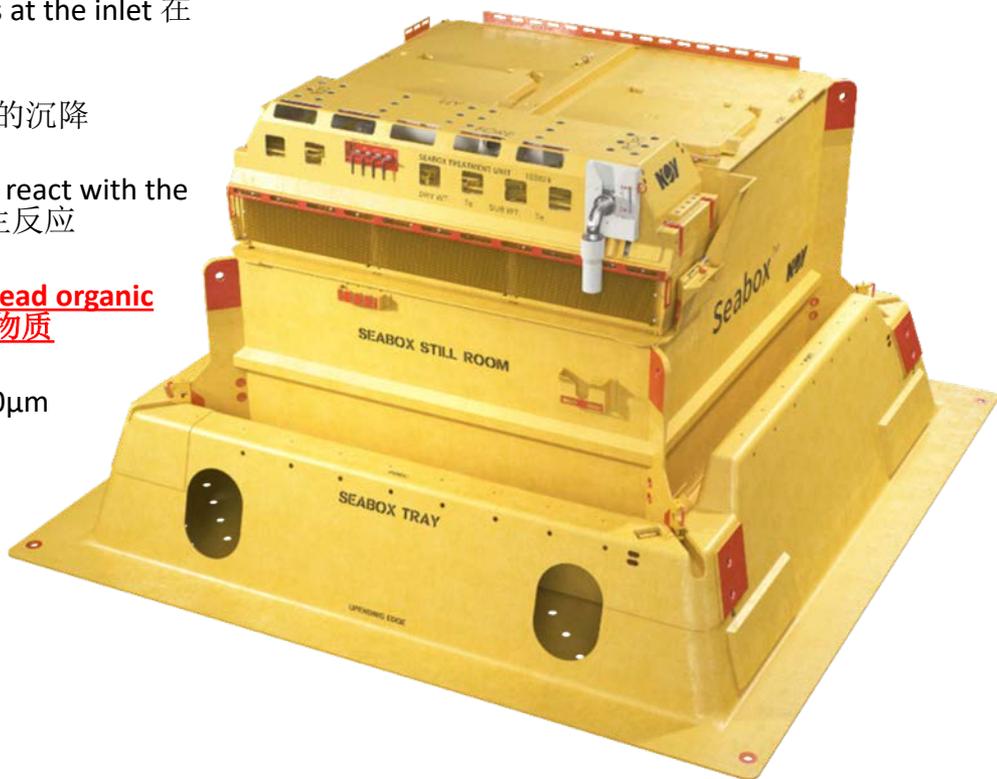
Most fascinating application– subsea water treatment 深海水如理

In the oil industry, water is injected into the oil field, to increase pressure and thereby to increase oil recovery from an existing reservoir. (Wikipedia)

在油的工业领域，水被注射进油的区域，来提升压力以增加在已存在的容器中的油的探索率

- ① In situ generation of sodium hypochlorite via electrolysis at the inlet 在入口处通过电解原位生成次氯酸钠
- ② Settlement of solids inside the still room 静止室内固体的沉降
- ③ Laminar flow inside the still room enable the chlorine to react with the seawater 静止室内的层流使氯气与83/5000的海水发生反应
- ④ In situ generation of hydroxyl radicals to de-compose dead organic matter at the outlet 原位产生羟基在出口处分解有机物质

Result: **Disinfected seawater**; Particle removal, down to 8-10 μ m
 结果: **消毒过的深海水**, 颗粒去除, 小至8-10 μ m



Most fascinating application– subsea water treatment 深海水处理

HRG

Hydroxyl-Radical-Generator

羟基发生器

Diamond electrodes in a support frame

钻石焊条支持体系



Look at the dimensions, imagine the parameters!





Thank you! 谢谢!

