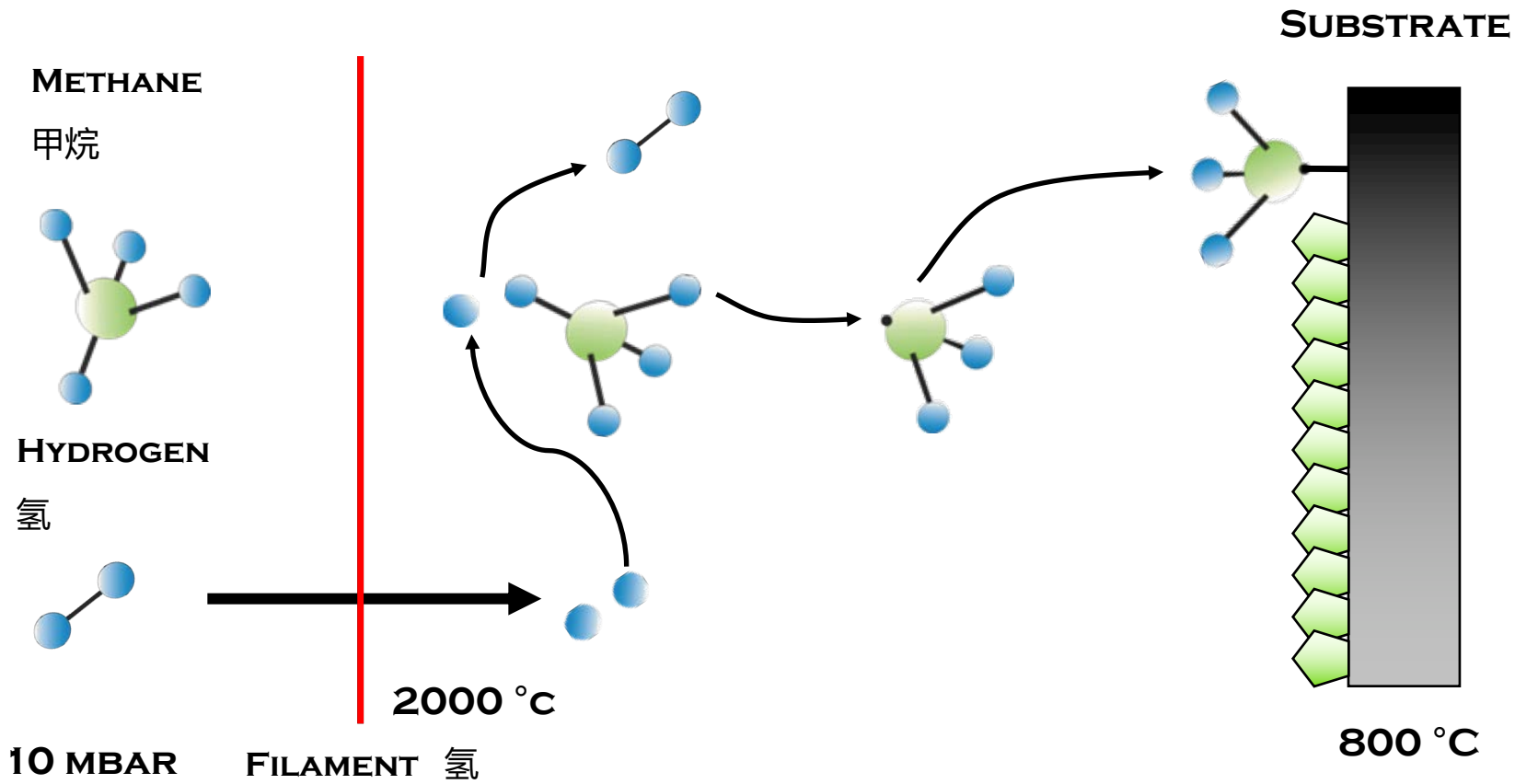
Diamond electrodes
金刚石电极

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



Generation of radicals

自由基的生成

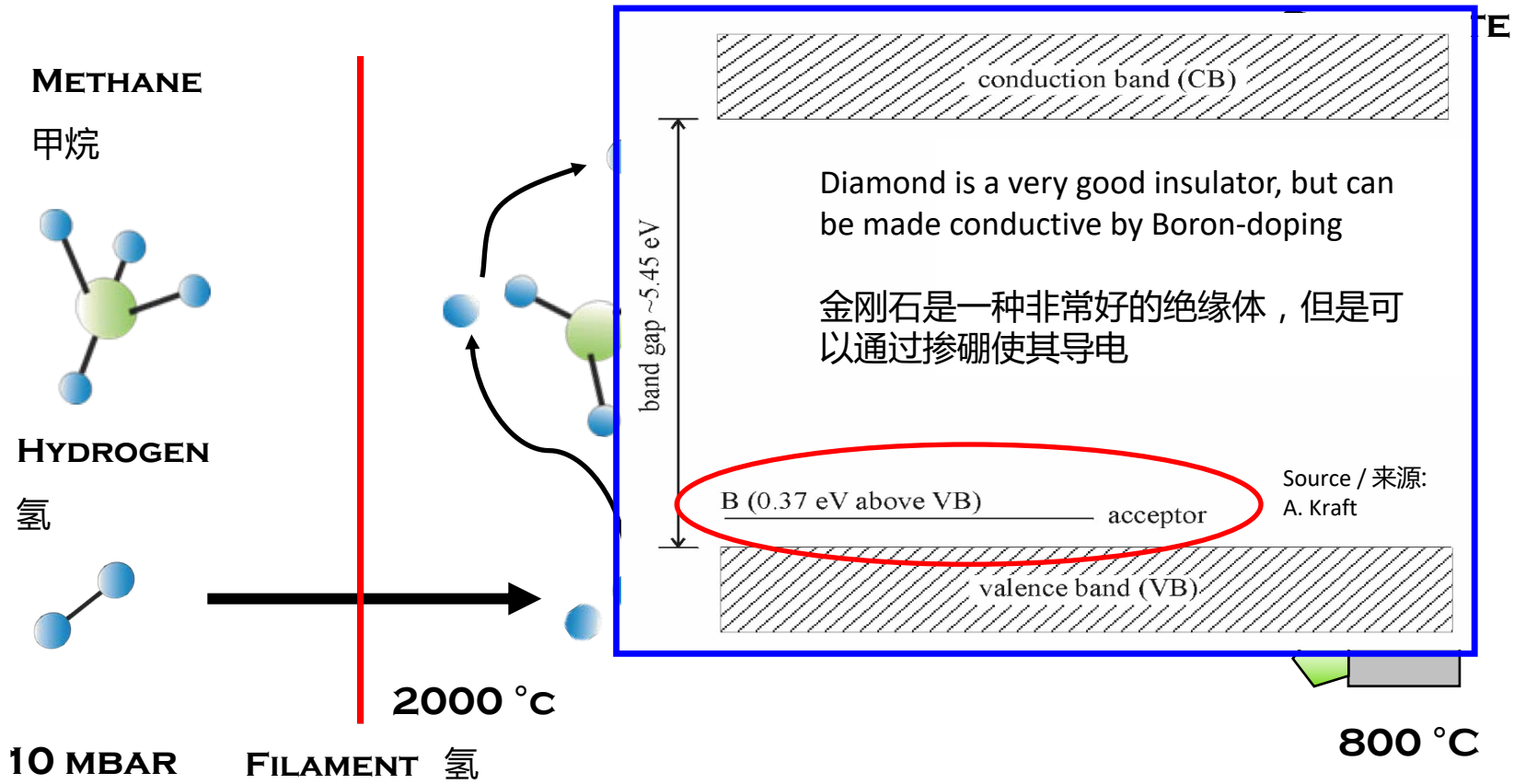
Basic setup

自由基的生成

Deposition of diamond

金刚石的沉积

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



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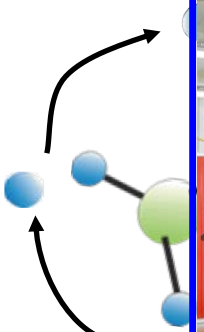
Fabrication - How to make diamond 制造 - 如何制造金刚石

METHANE

甲烷

HYDROGEN

氢

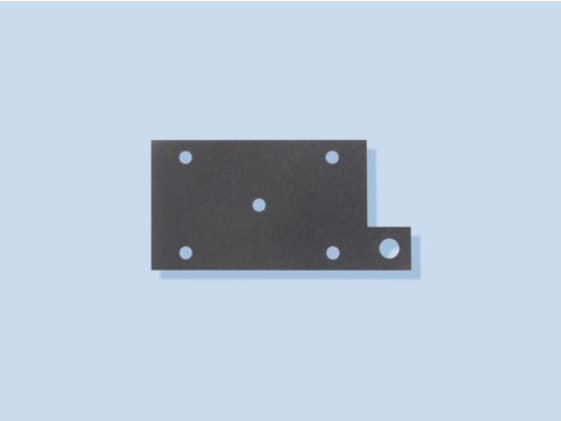


800 °C

DEPOSITION OF DIAMOND

金刚石的沉积

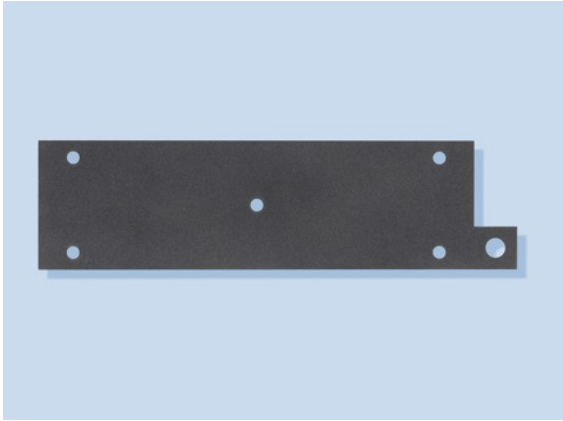
Fabrication -Electrode types 制造 -电极类型



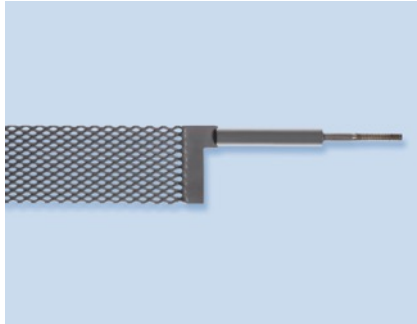
Type Baerbel 型
250mmx150mm

Main types
Standardised electrodes

主要类型
标准化电极

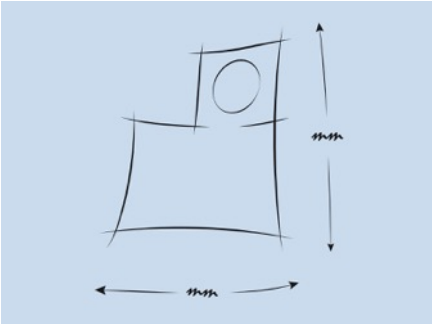


Type Barbara型
500mmx150mm



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

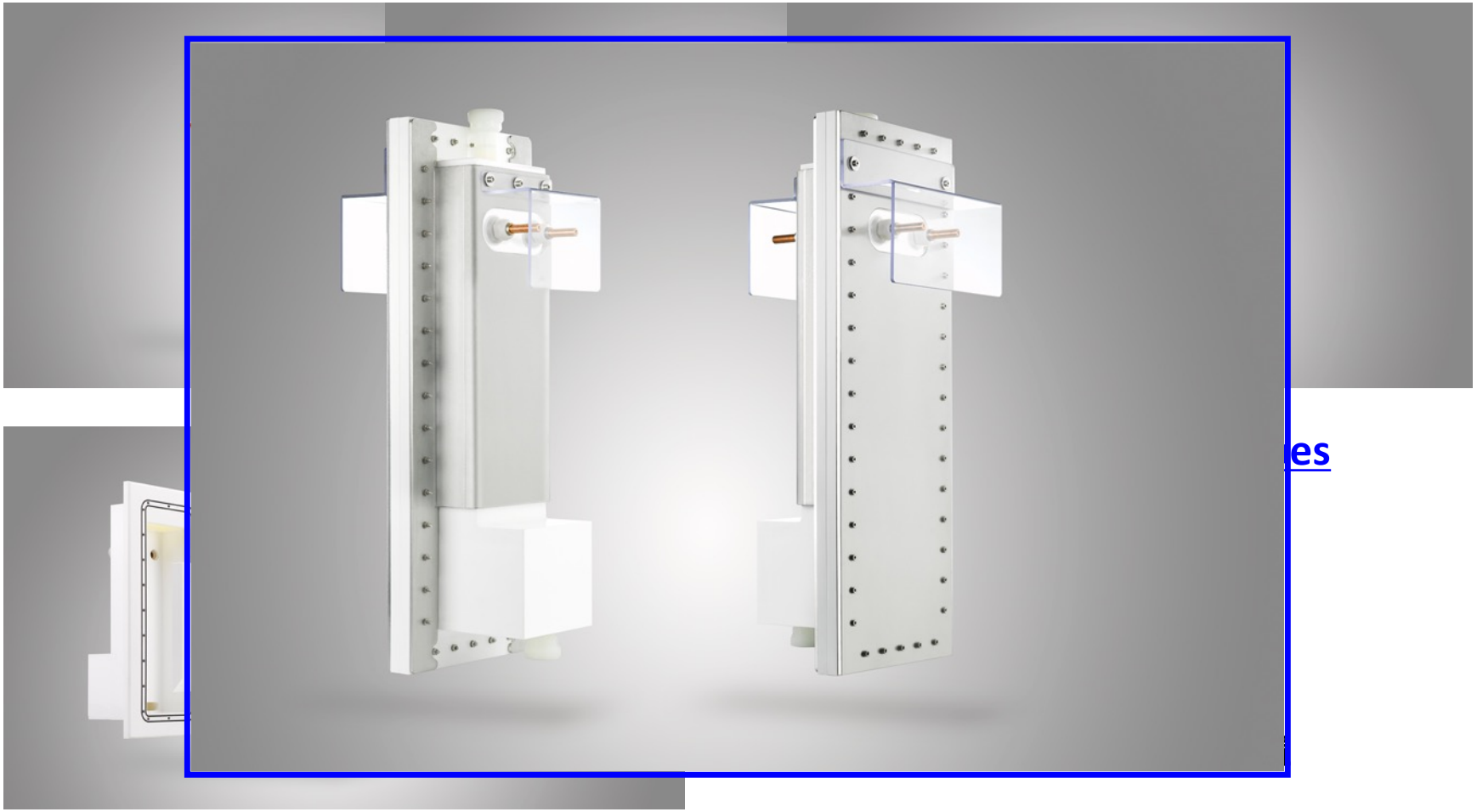
Electrolysers for standard types
标准型电解装置

-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



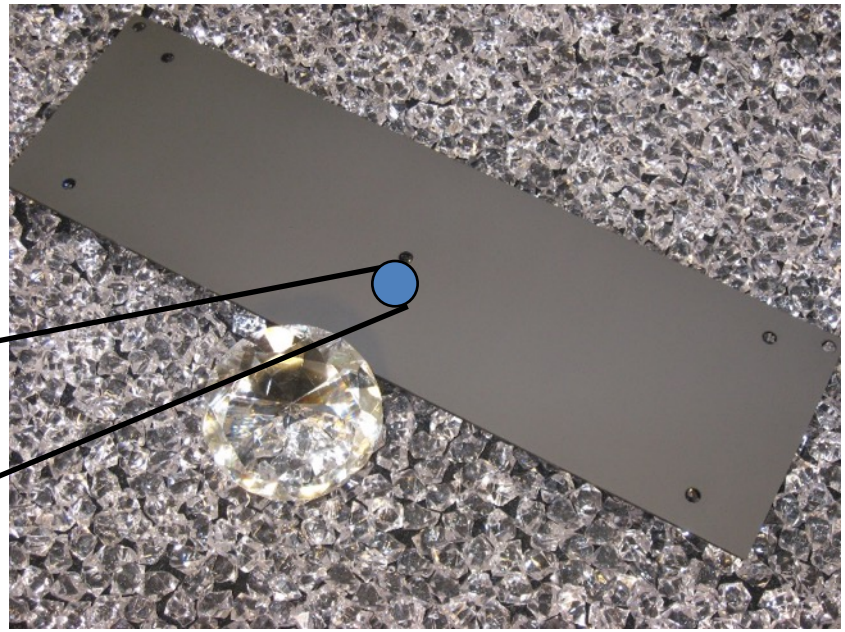
es

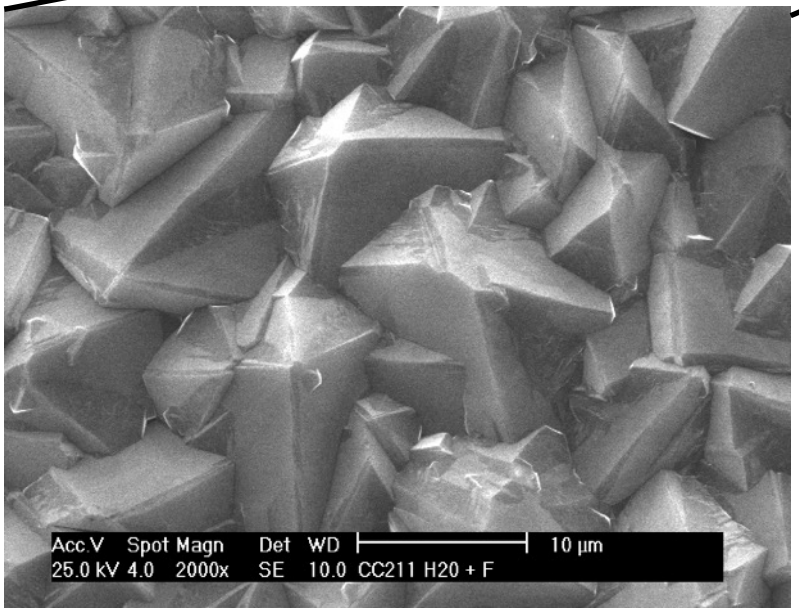
-ready made equipment
-现成设备

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

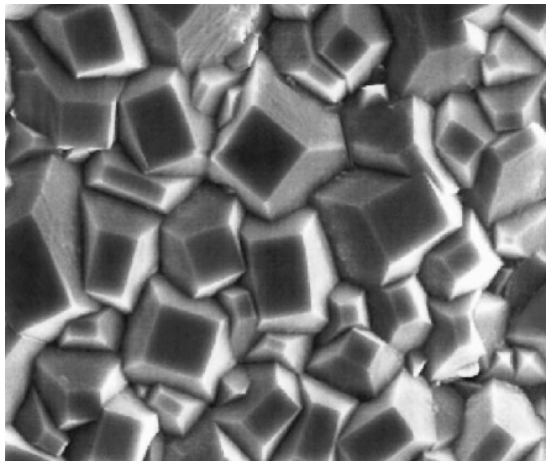
Morphology can be influenced by:

-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





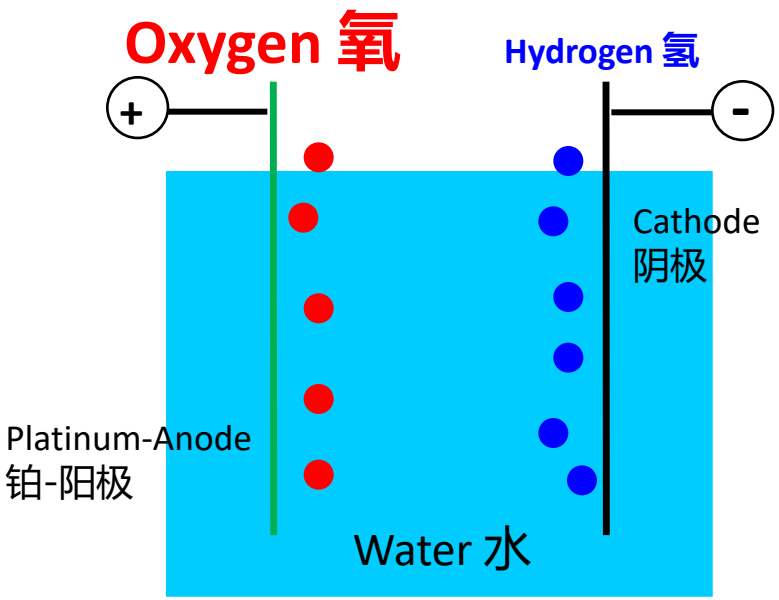
Various Morphologies
各种形态



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

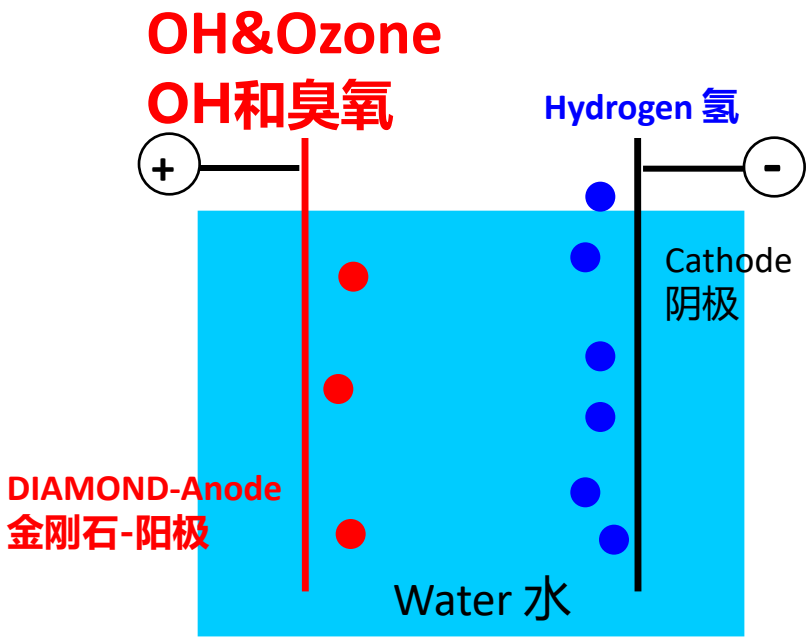
Elektrochemistry in aqueous media leads to unwanted water splitting, but…
水介质中的电化学会导致不必要的水分解，但…

…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 <u>only</u> !
  几乎<u>只有</u>水分解！
- waste of energy!
  浪费能源！

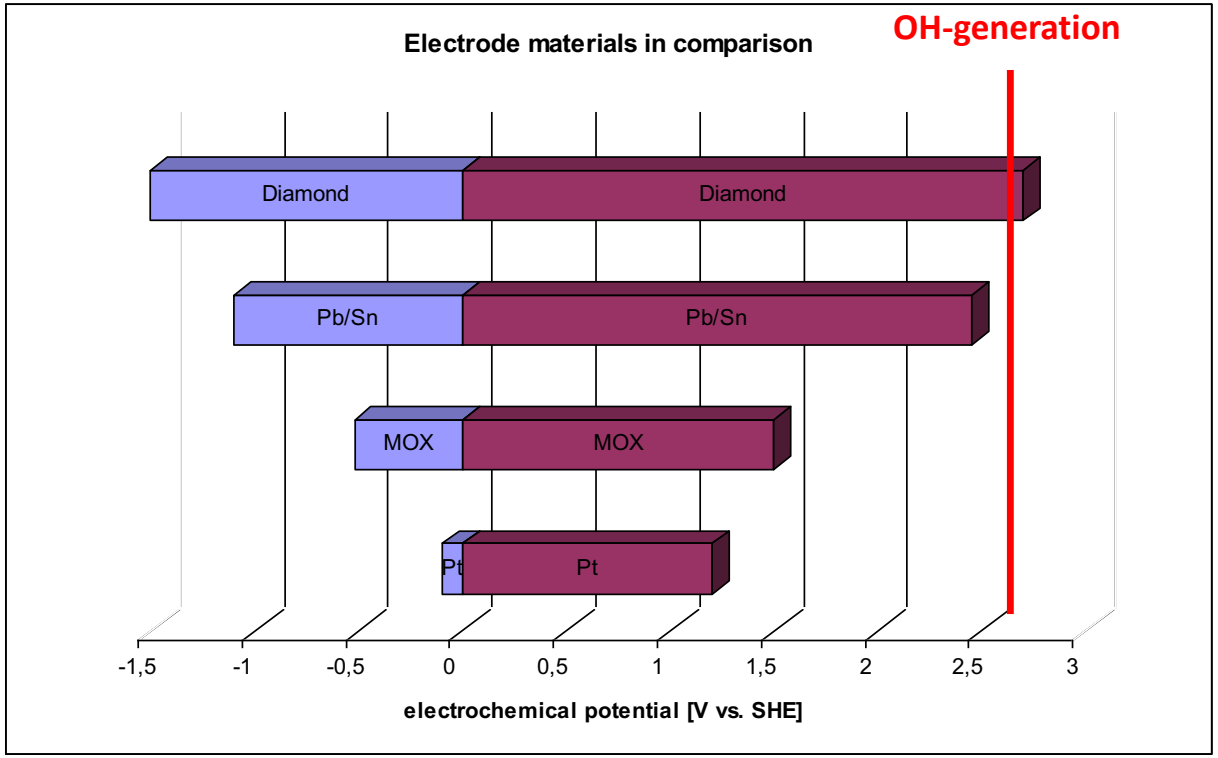
…with DIAMOND ELECTRODES
…金刚石电极情况下



- ~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

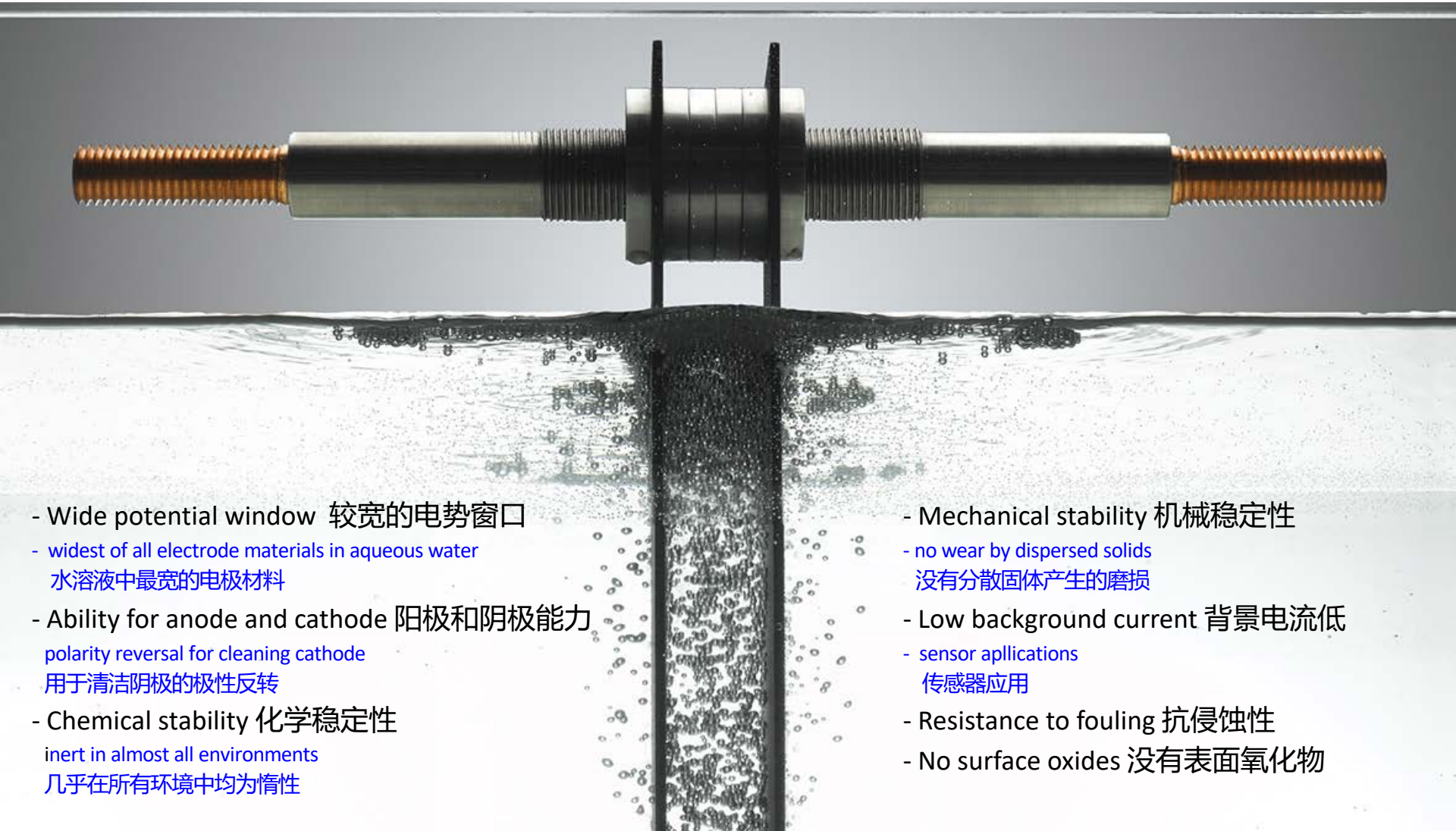
-Diamond has ultra wide potential window for water decomposition, anodic as well as cathodic!
金刚石具有超宽的水分解、阳极和阴极的电势窗口！
-Production of extremely strong oxidants like OH° & Ozone
产生极强氧化剂，如OH和臭氧



Substance 物质	formation potential [V] 生成电势[V]
Hydroxyl radical 羟基自由基 ($H_2O/OH^{\cdot}$)	2,80
Ozone 臭氧 (O_3)	2,07
Peroxodisulfate ($SO_4^{2-}/S_2O_8^{2-}$)	2,01
Hydrogen Peroxide 过氧化氢 (H_2O/H_2O_2)	1,77

Source √ 来源: Tröster

Properties - diamond electrodes at a glance 性能 - 金刚石电极一瞥

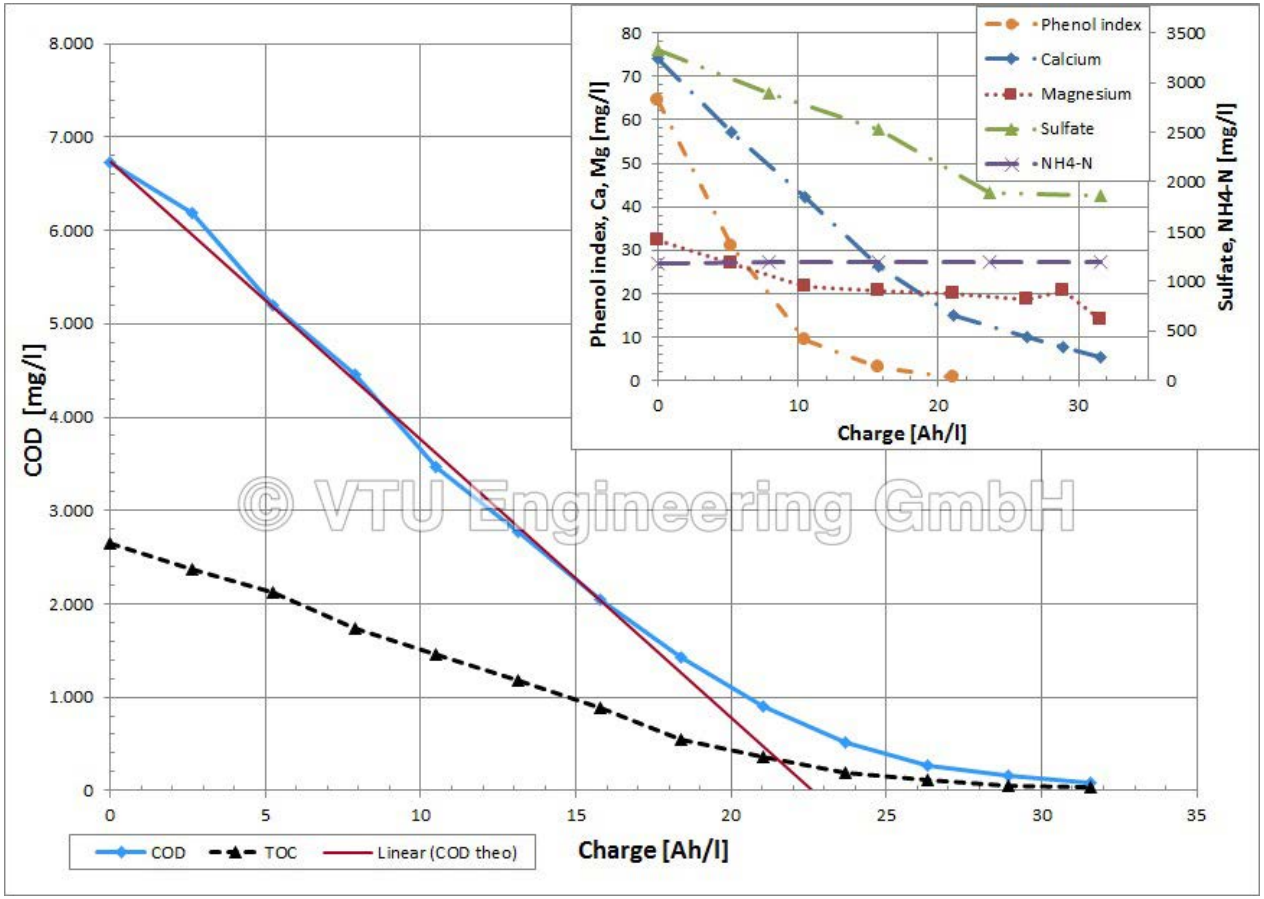


- Wide potential window 较宽的电势窗口
  - widest of all electrode materials in aqueous water
    水溶液中最宽的电极材料
- Ability for anode and cathode 阳极和阴极能力
  polarity reversal for cleaning cathode
  用于清洁阴极的极性反转
- Chemical stability 化学稳定性
  inert in almost all environments
  几乎在所有环境中均为惰性
- Mechanical stability 机械稳定性
  - 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 apllications
    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 **C**hemical **O**xygen **D**emand
  化学需氧量(COD)的减少
  (equivalent for contained waste)
  (相当于所含废物)

- **A**dvanced **O**xidation **P**rocess
  高级氧化法(AOP)

- No additional chemical required
  无需额外的化学品

Source 来源:

VTU engineering

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

Removal of:
清除：

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

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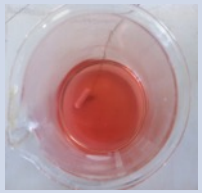
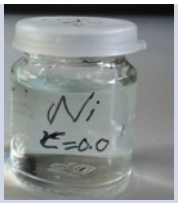
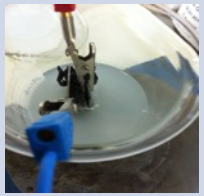
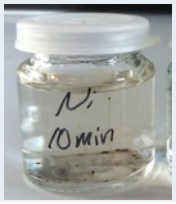
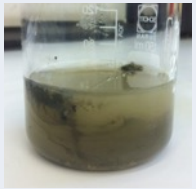
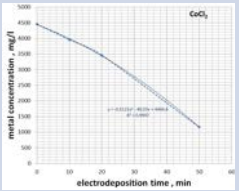
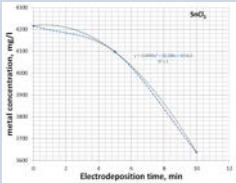
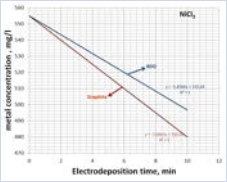
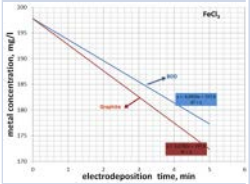
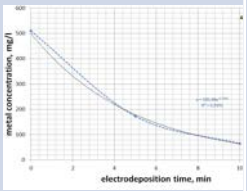
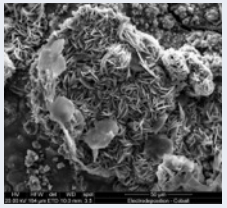
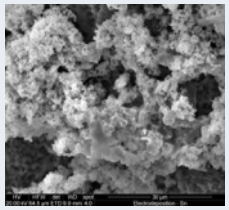
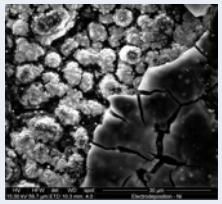
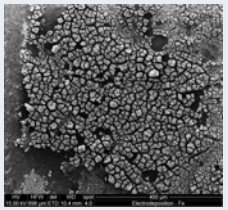
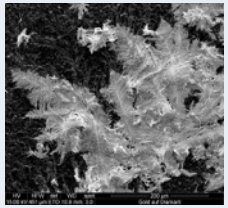
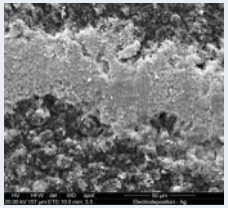
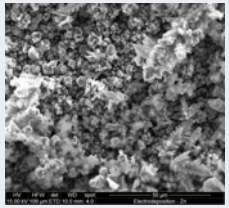
Application – cathodic metal recovery 应用 – 阴极金属回收

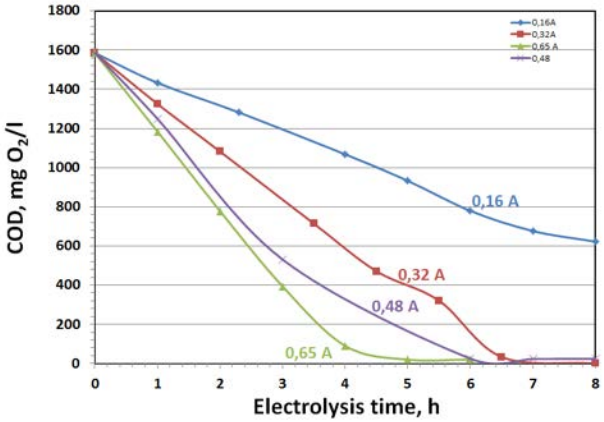
- Diamond electrodes have a high overpotential for hydrogen evolution -> efficient metal deoxidation
  金刚石电极具有很高的析氢过电位 -> 有效的金属脱氧
- efficient precipitation off dissoluted metals in the aqueous solution or on the BDD cathode
  有效沉淀水溶液中或BDD阴极上的溶解金属

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

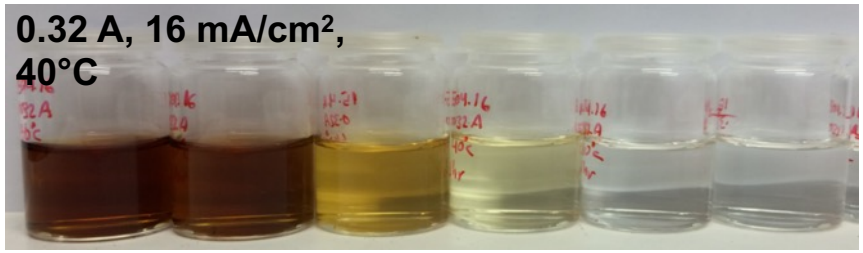
Application – landfill leachate 应用 – 垃圾渗滤液

- 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



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

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

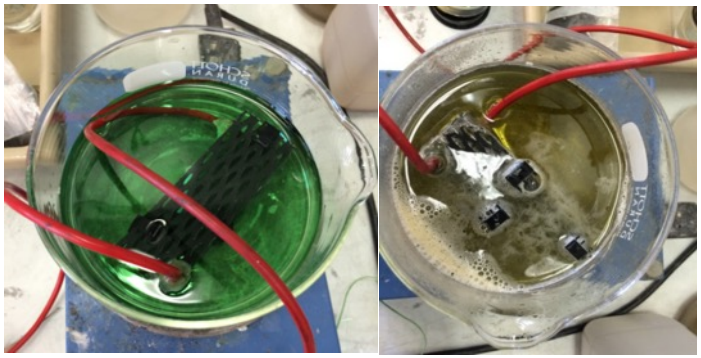
Application – electroless nickel waste water 应用 – 化学镀镍废水

- 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

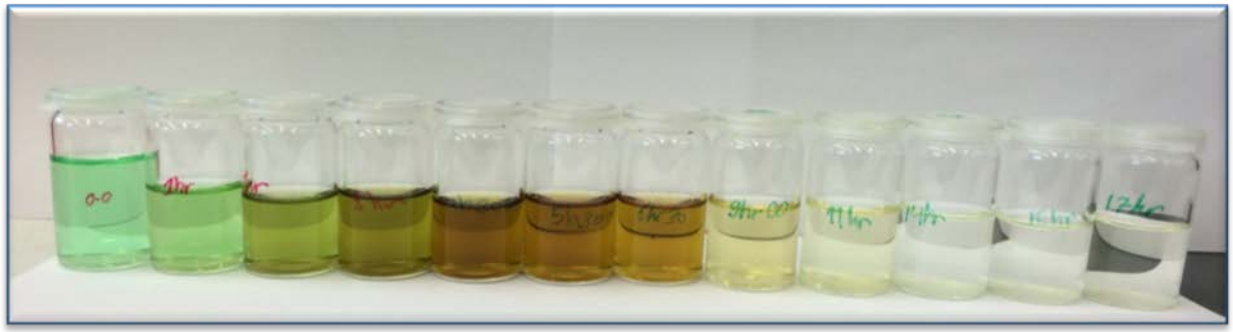
- nickel-ion is embedded into a lactic acid complex -> high COD!
  镍离子嵌入乳酸复合物中 -> 高COD！

- nickel is not available for recovery!
  镍无法回收！
- waste water is toxic -> not biodregradable!
  废水有毒 -> 不可生物降解！

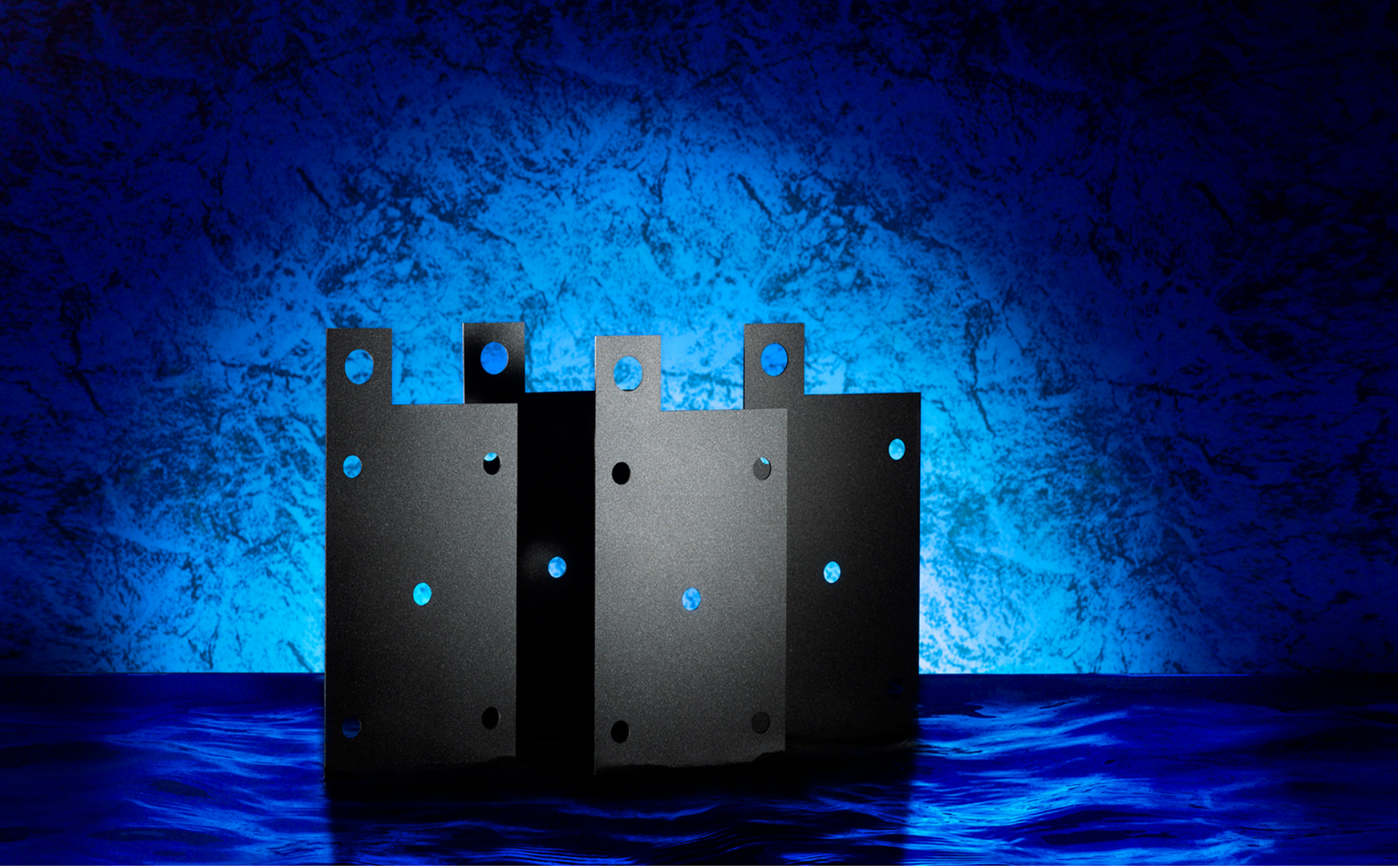
Solution 解决方案:
- anodic destruction of lactic acid complex
  乳酸复合物的阳极破坏
  释放嵌入的镍
- cathodic nickel-recovery
  阴极镍回收



laboratory trial
实验室试验



toxic green becomes clear! 有毒的绿色变得清澈！



Thank you!　　谢谢！