» EDM@AMP «

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Fraunhofer IPK
INSTITUT
PRODUKTIONSANLAGEN UND
KONSTRUKTIONSTECHNIK

Agenda

- Dry-EDM Machining of Ceramic Materials
- Process Optimization for Dry-EDM by means of gases
- Our next goals with the Dry-EDM process

Dry-EDM Machining of Ceramic Materials

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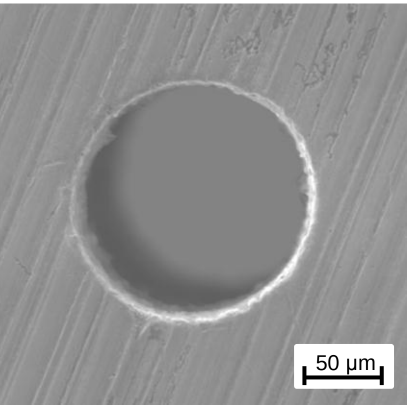
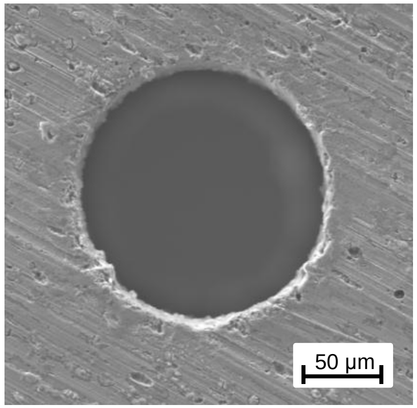
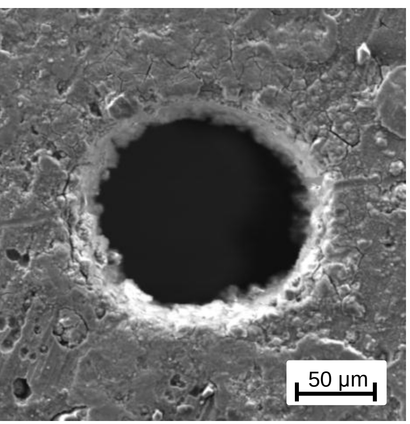
Dry-EDM Machining of Ceramic Materials



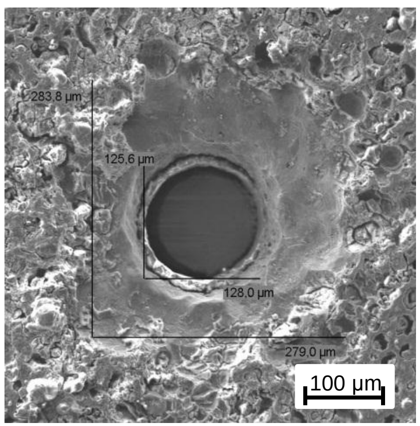
Conductivity of deionized water **≤ 1,5 µS/cm**



Conductivity of deionized water **≤ 3 µS/cm**



Conductivity of deionized water **≤ 7 µS/cm**



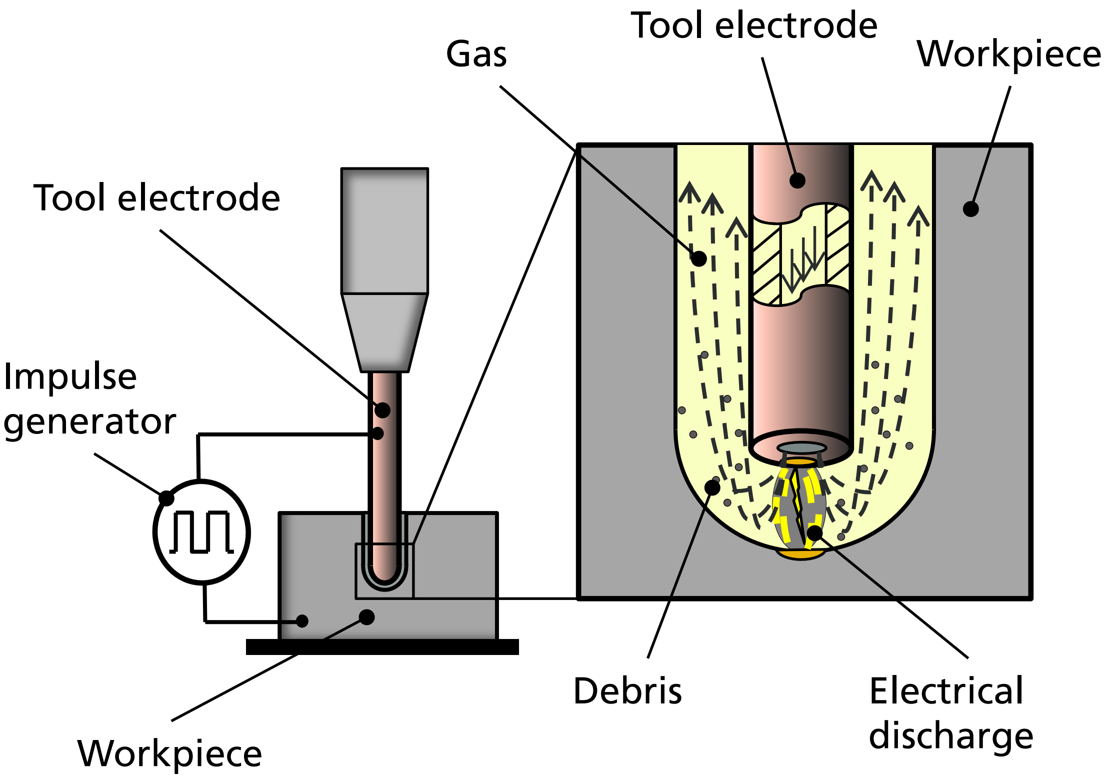
Conductivity of deionized water **≥ 15 µS/cm**

- **Motivation and Challenge:**
- Consequences of contaminated dielectric with debris
  - Fault discharges and short-circuits
  - Reduction of the Material Removal Rate
  - Increase of Tool Electrode Wear
  - Form deviation of the boreholes

→ good EDM-machining process is dependent on:

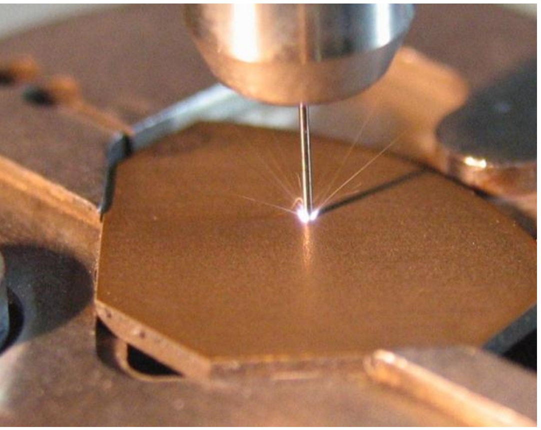
  - **the dominant flushing conditions in the working gap and**
  - **the quality of the dielectric fluid**

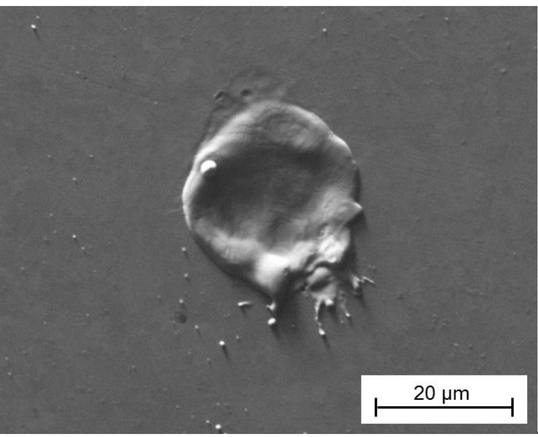
Dry-EDM Machining of Ceramic Materials



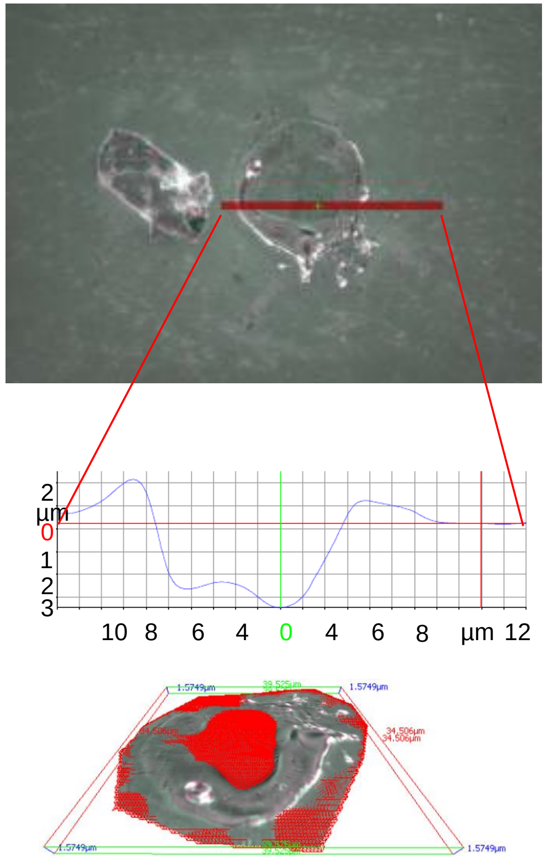
- **Objectives and Approach of the presented project**
  - Replacement of liquid dielectric by gas with the following objectives:
    - Increase the material removal rate compared to the conventional fine drilling
    - Increase of the machining accuracy
    - Reduction of tool electrode wear

Dry-EDM Machining of Ceramic Materials





Generation of single relaxation discharge



Metrological evaluation

- **Solution Approach:**
  - Targeted single relaxation discharges on workpiece surfaces of the materials TiN, TiB_2
  - Metrological evaluation of the resulting discharge crater
  - Development of technologies
- **Findings:**
  - Process behavior of individual parameter settings
    → derivation of technologies
  - Material removal mechanisms of the materials

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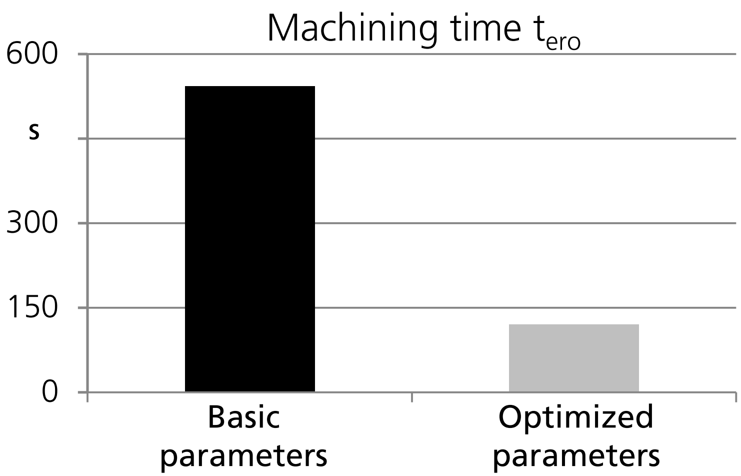
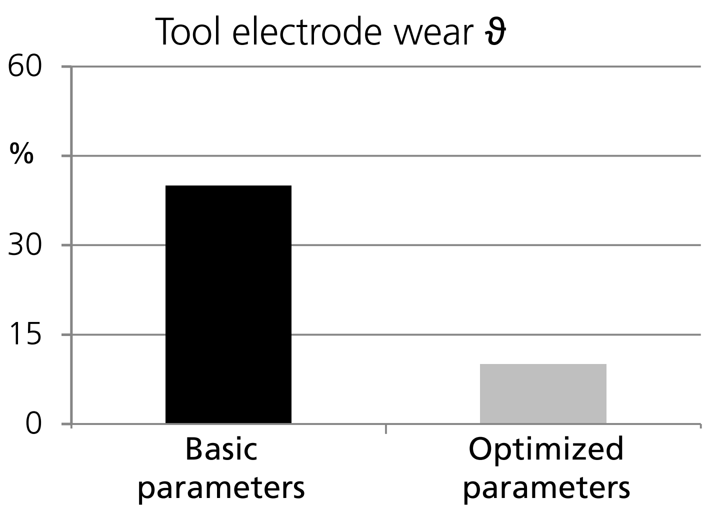
Dry-EDM Machining of Ceramic Materials





- **Challenges:**
  - Machining of boreholes in TiN (depth: 1 mm)
  - Electrode diameter d_{el} = 300 µm
  - Compressed air as dielectric fluid
  - Adjustment of the parameters at the generator through statistical design of experiments
- **Result after Process Optimization**
  - Reduction of the machining time from t_{ero} = 543 s down to t_{ero} = 120 s and of the relative tool wear from ϑ = 40 % down to 10 %
  - Identification of main and interactive effects

Dry-EDM Machining of Ceramic Materials

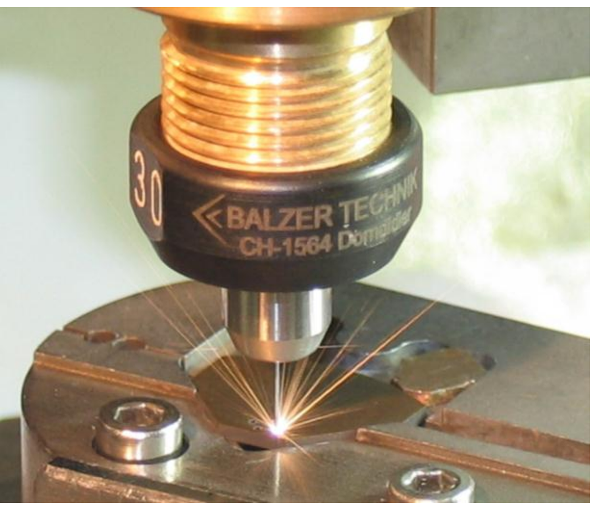
Workpiece materials: ■ TiN
□ TiB_2

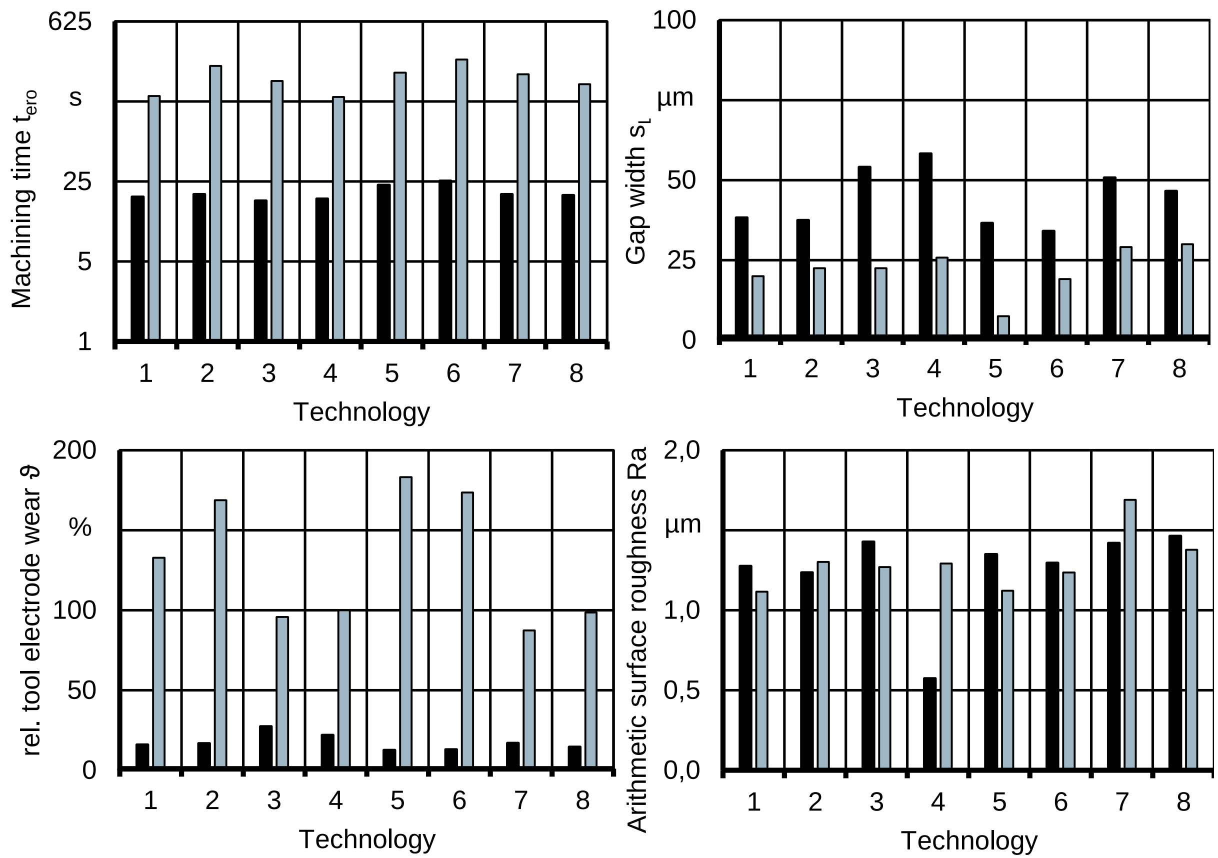
Tool electrode: cemented carbide d_{el} = 300 µm

Through hole: 1 mm

Dielectric fluid: compressed air

Impulse typ: Relaxation discharge





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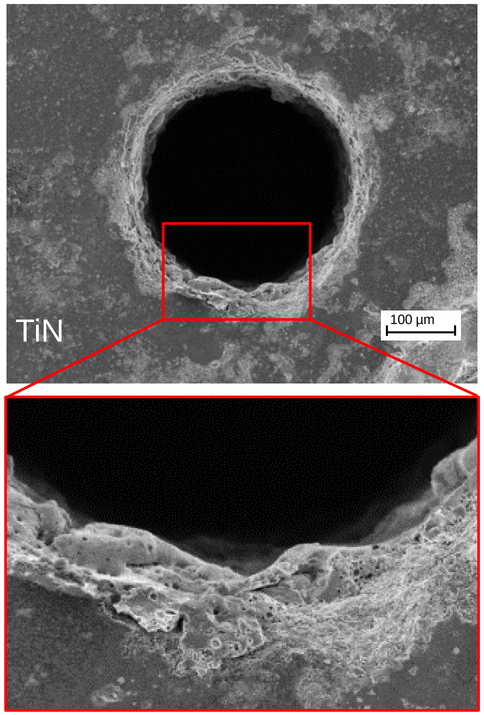
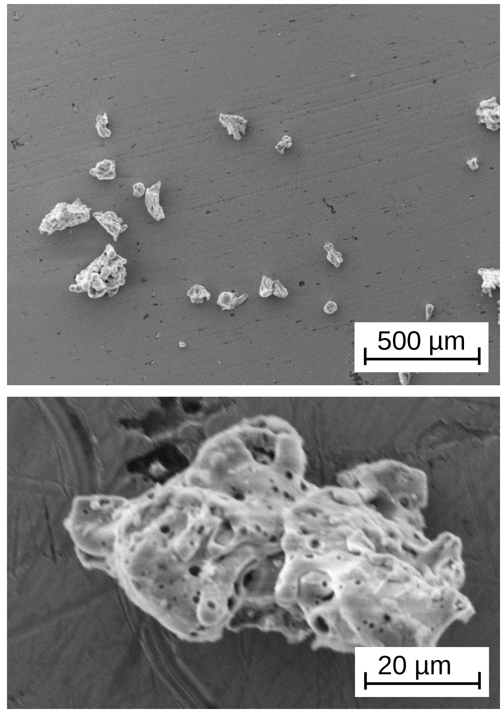
Dry-EDM Machining of Ceramic Materials



Microhole in TiN

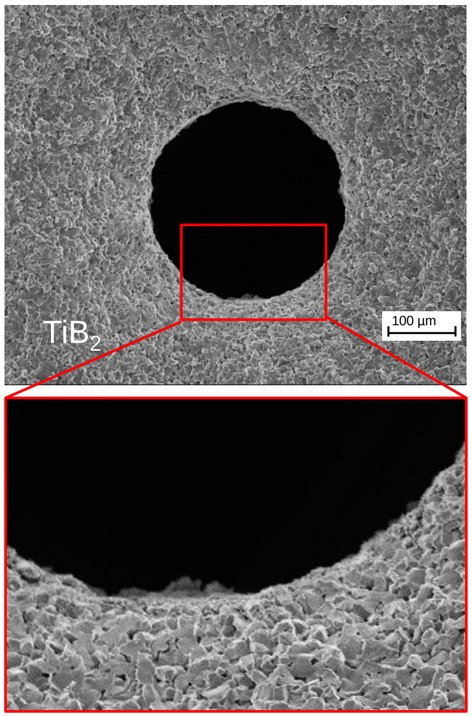


TiN debris of the dry-EDM process

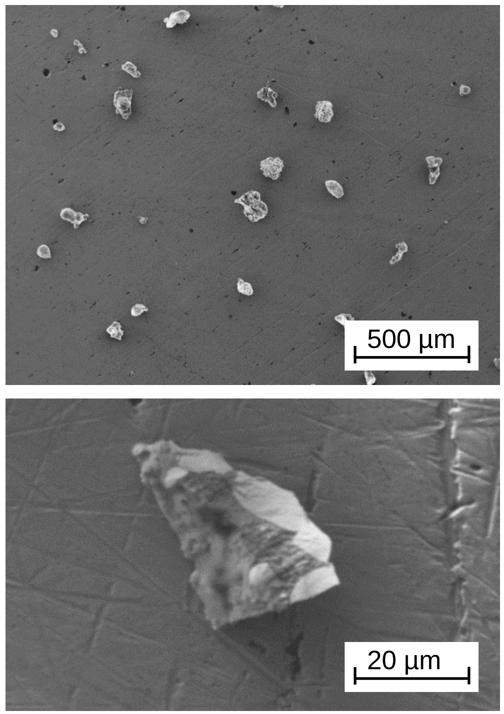
Results:

- Material removal of TiN is based on the **Melting Effect**
- Less recognition of the Spalling Effect
- Result after process optimization
  - Machining time for 1 mm drilling depth t_{ero} = 16 s
  - Relative tool wear ϑ = 9 %
  - Gap width s_L = 34 µm

Dry-EDM Machining of Ceramic Materials



Microhole in TiB_2

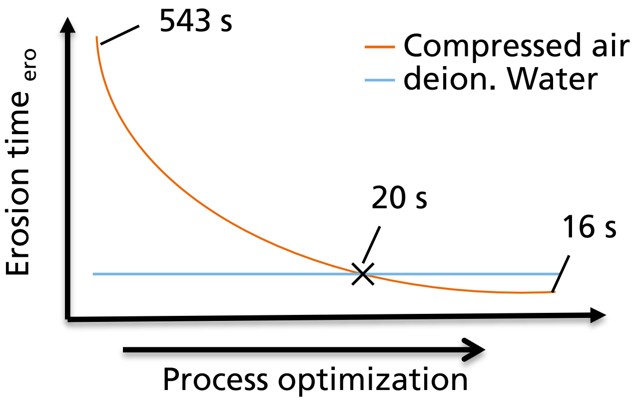


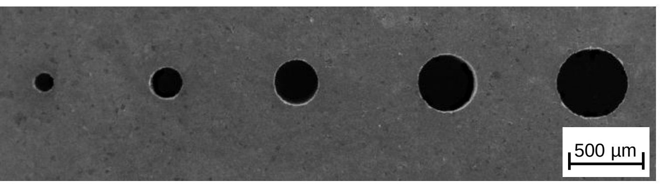
TiB_2 debris of the dry-EDM process

- Material removal of TiB_2 based on the **Spalling Effect**
- No recognition of the Melting Effect
- Result after process optimization
  - Machining time for 1 mm drilling depth t_{ero} = 120 s
  - Relative tool wear ϑ = 183 %
  - Gap width s_L = 7 µm

Dry-EDM Machining of Ceramic Materials

Example: 1 mm depth through borehole in TiN





Dry EDM-machined through boreholes in TiN

- **Overall Results:**
  - Development, analysis and application of the dry EDM fine drilling process
  - Provision of production technologies for the EDM machining of TiN and TiB_2 with electrode diameters in the range 80 µm ≤ del ≤ 300 µm
- **Innovations:**
  - No dangerous gases, pollutants or disposal of used oil-based dielectric fluid
  - Dielectric tank is no longer required, resulting in a work space without restrictions

Process Optimization for Dry-EDM by means of gases

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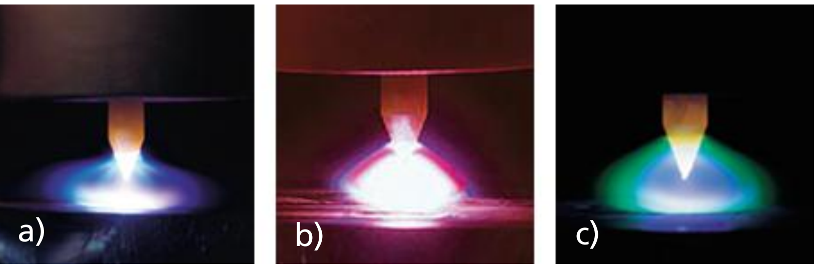
Process Optimization for Dry-EDM by means of gases



a) Argon-, b) VARIGON-, und c) Helium-light arc in TIG-welding

Breidenbach Service + Vertriebs GmbH

„With the TIG method (TIG = Tungsten Inert Gas) the electric arc burns between the non melting tungsten electrode and the workpiece.“ (Linde AG)

Goals and approach

- Fine-tuning of the process parameters, to the process gases with the aim of:
  - Increasing the material removal rate

    → Roughing parameter
  - Increase of the exactness and the hole quality by decreasing the electrode wear

    → Finishing parameter

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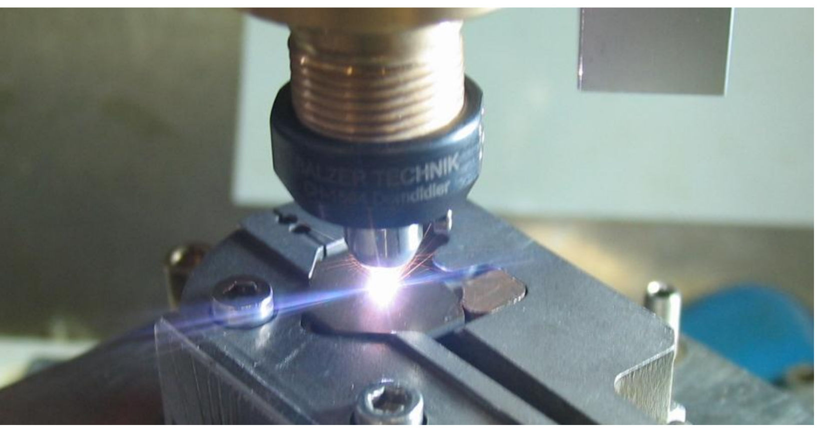
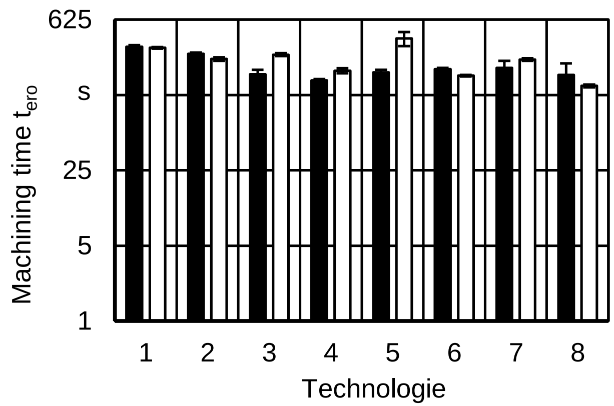
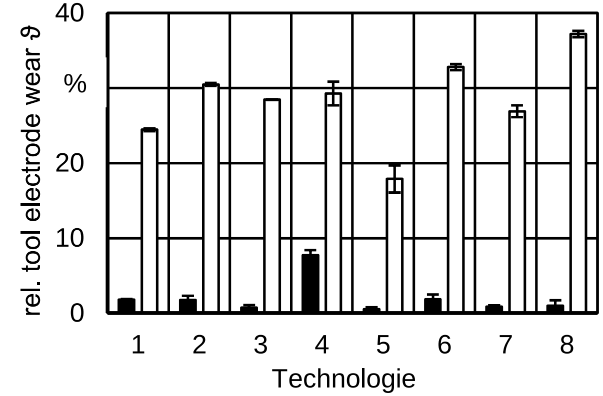
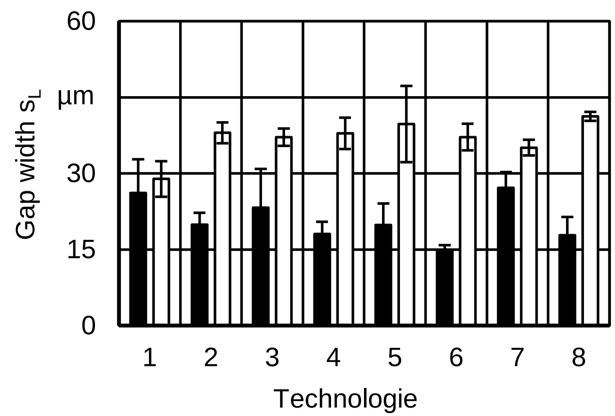
Process Optimization for Dry-EDM by means of gases

Workpiece material:	■ TiN □ TiB_2
Electrode material:	cemented carbide d_{el} = 300 µm
Through hole:	1 mm
Dielectric fluid:	argon
Impuls type:	relaxation generator



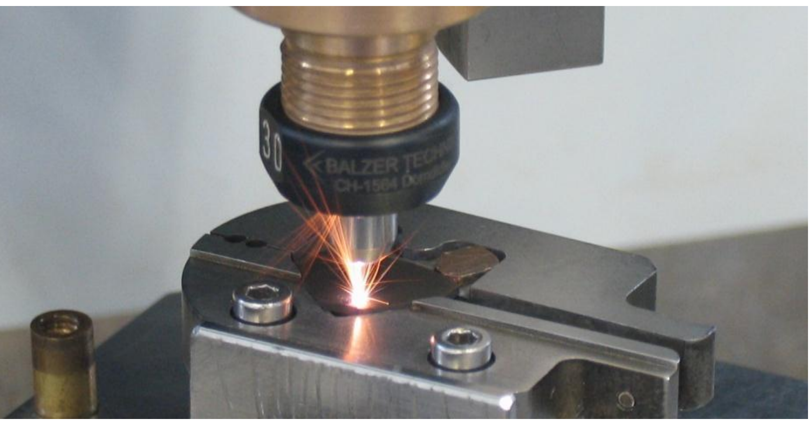


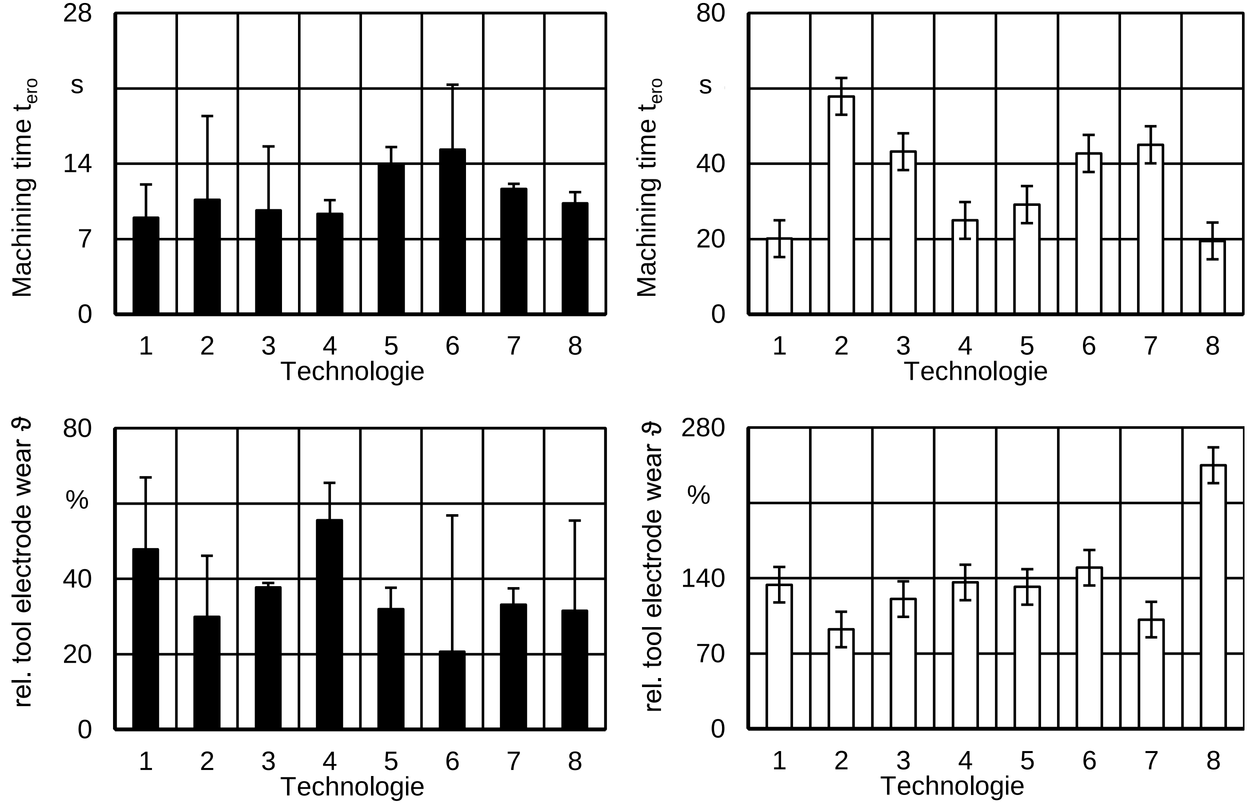




Process Optimization for Dry-EDM by means of gases

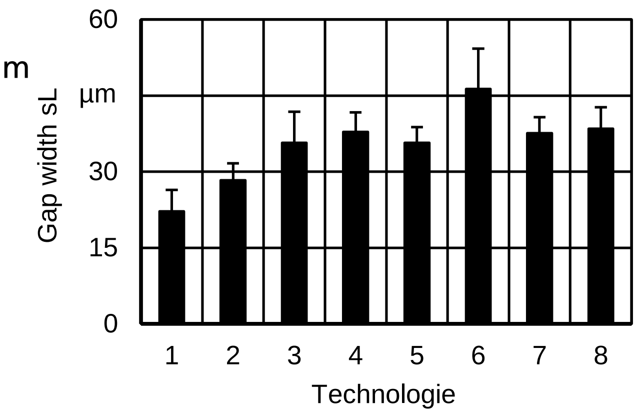
Workpiece material:	■ TiN □ TiB_2
Electrode material:	tungsten carbide d_{el} = 300 µm
Through hole:	1 mm
Dielectric fluid:	oxygen
Impuls type:	relaxation generator

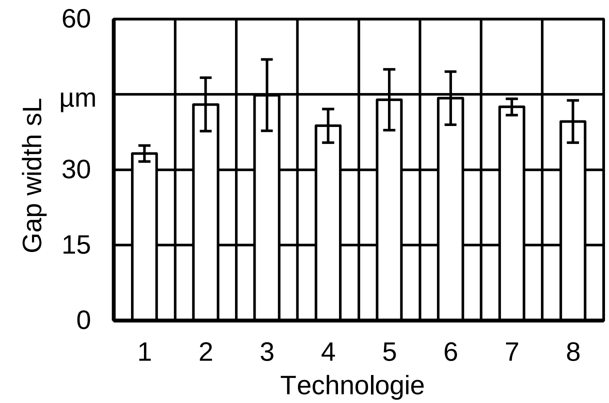


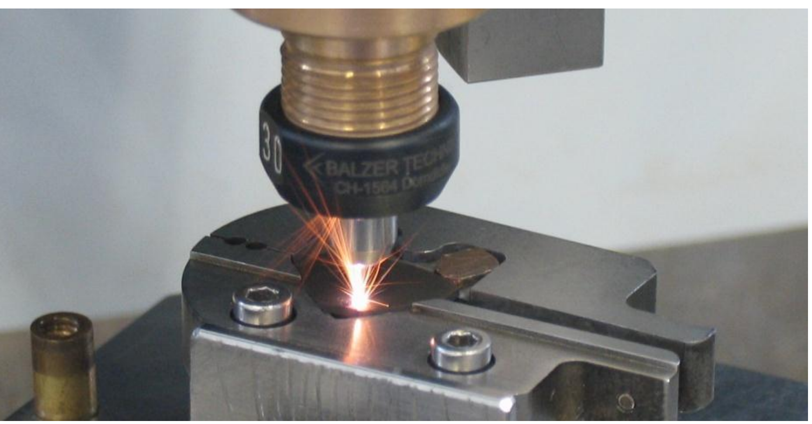


Process Optimization for Dry-EDM by means of gases

Workpiece material:	■ TiN TiB_2
Electrode material:	cemented carbide d_{el} = 300 µm
Through hole:	1 mm
Dielectric fluid:	oxygen
Impulse type:	relaxation generator





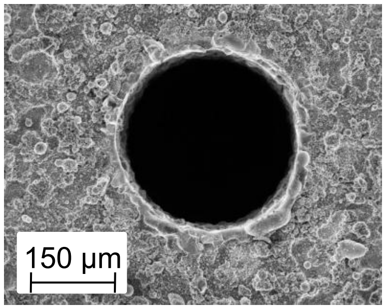


Following procedure

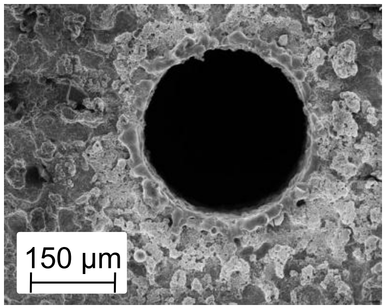
- Systematic parameter optimization, using a specially developed method by Fraunhofer IPK
- Derivation of technologies

Process Optimization for Dry-EDM by means of gases

Results of TiN

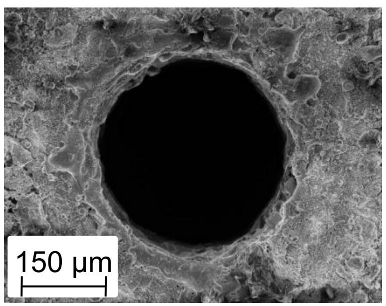


Inlet



Outlet

- Finishing parameter
  - Machining time t_{ero} = 160 s
  - Rel. tool electrode wear ϑ < 0,9 %
  - Gap width s_L = 10 µm
  - Process gas: argon



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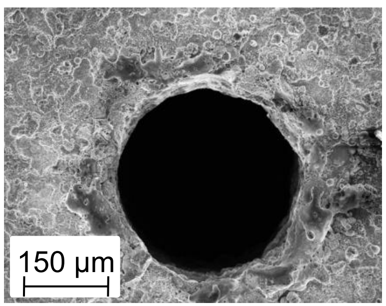
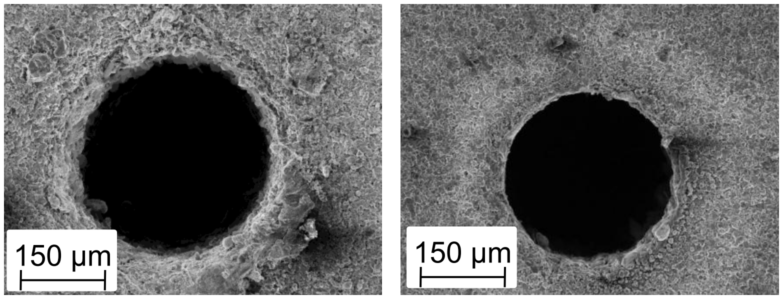


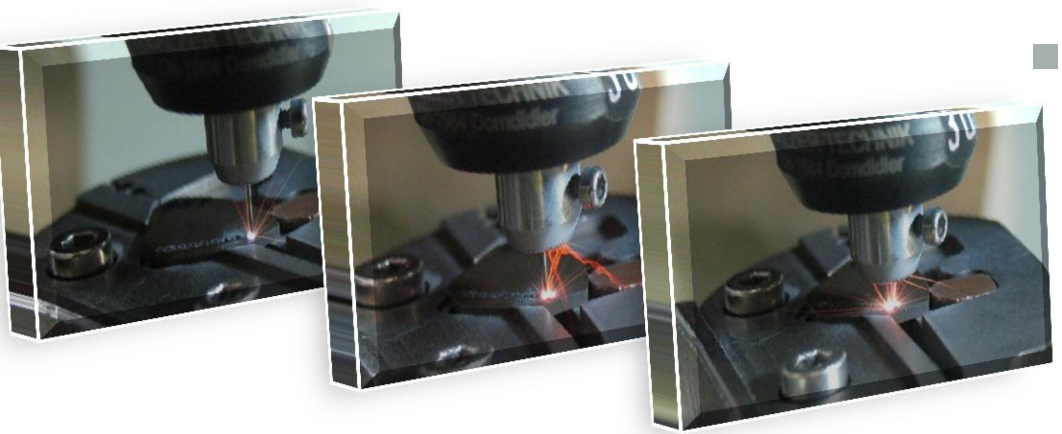
Outlet

- Roughing parameter
  - Machining time t_{ero} = 3,5 s
  - Rel. tool electrode wear ϑ = 29 %
  - Gap width s_L = 27 µm
  - Process gas: oxygen

Process Optimization for Dry-EDM by means of gases

Results of TiB_2

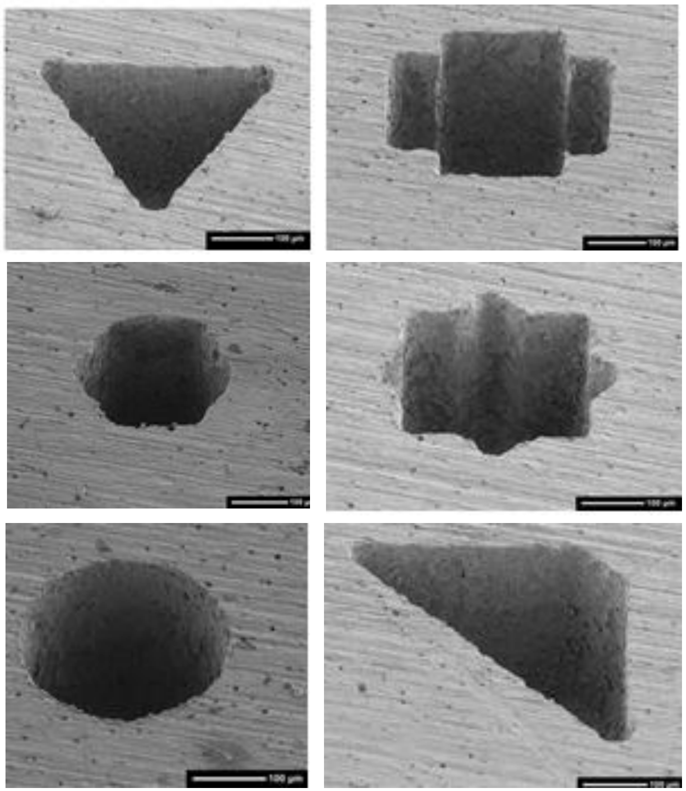




- Finishing parameter
  - Fail (we don't need any finishing!)
- Roughing parameter
  - Machining time t_{ero} = 41 s
  - Rel. tool electrode wear ϑ = 105 %
  - Gap width s_L = 9 µm
  - Process gas: oxygen

Our next goals with the Dry-EDM process

Our next goals with the Dry-EDM process



Complex micro holes manufactured by an combinated LASER-EDM process

Development of production technologies for manufacturing complex micro holes

- Using finishing parameters and process gases for maufacturing high precision profile holes
- Using the dry-EDM milling process
- Development of a robot based EDM process
  - High precision
  - High geometrical freedom of the robot, possible because of the dry-EDM process

Thank you for your attention!

Contact:

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