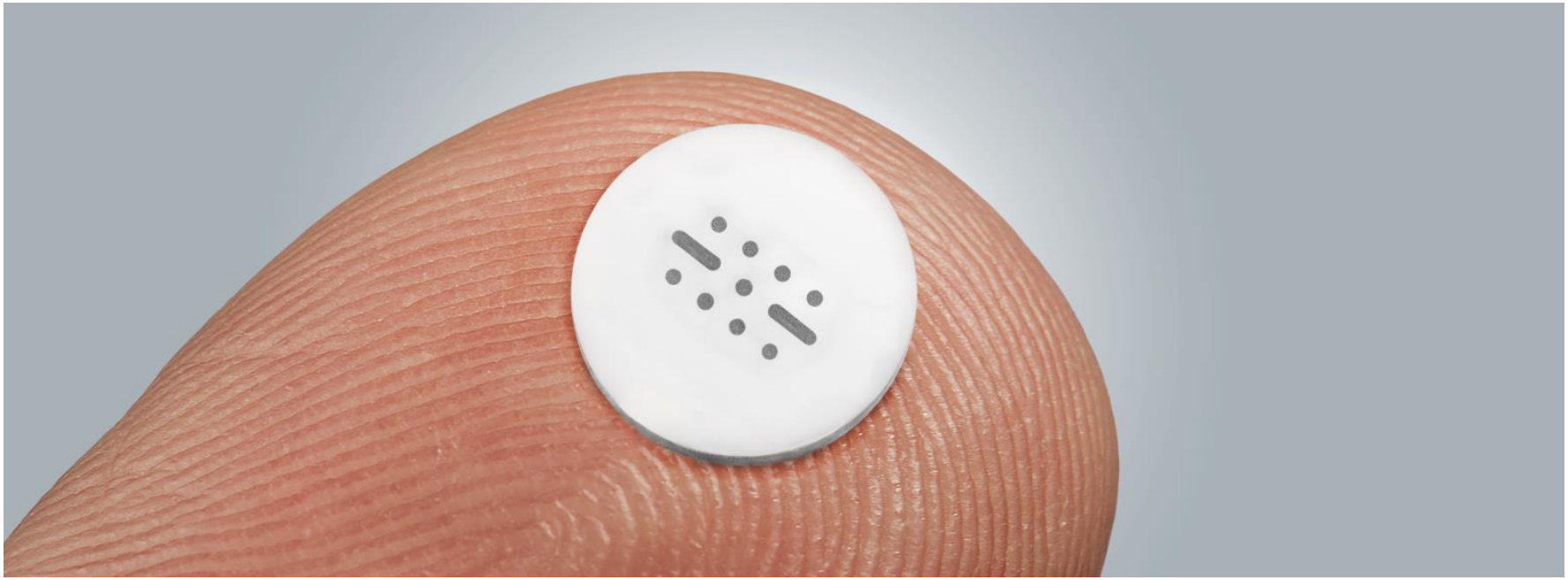

Keramik-Metall-Komposite Innovative Lösung zur Herstellung biokompatibler Feedthroughs

Jens Trötzschel, Dr. Robert Dittmer, Ulrich Hausch

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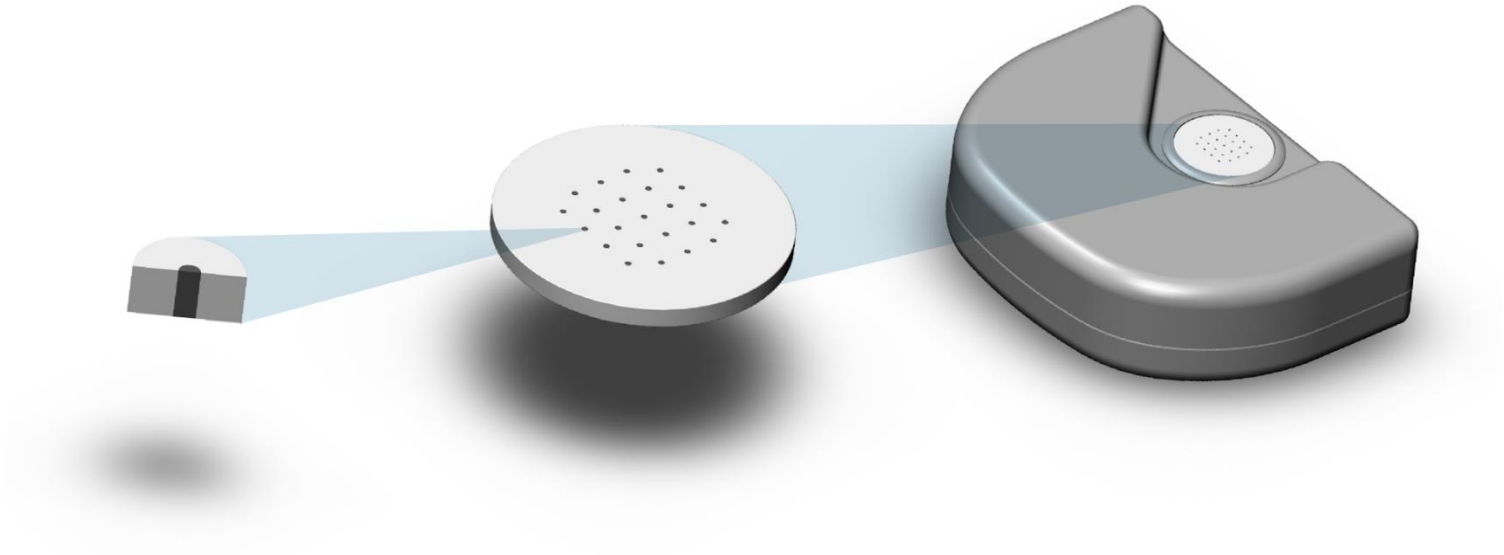
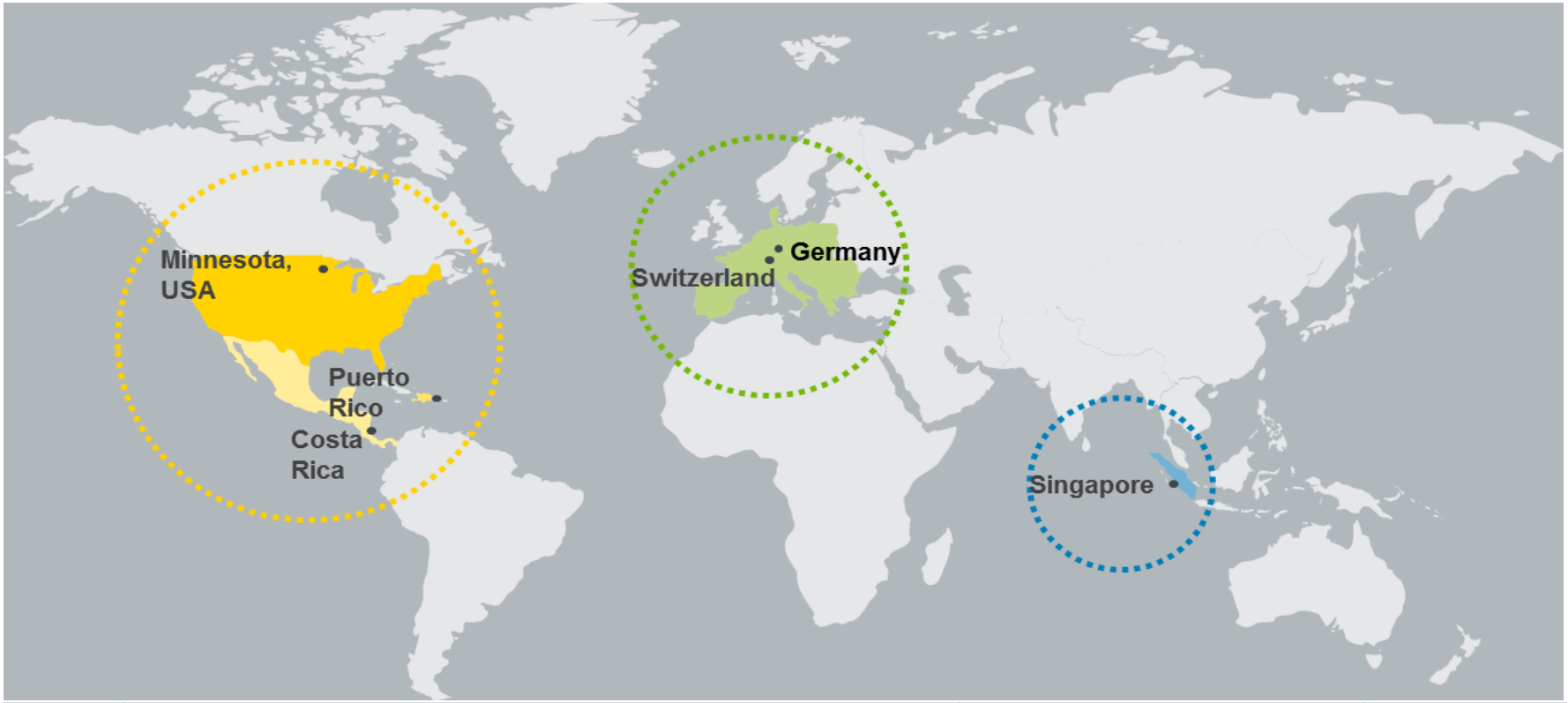


1. Heraeus Medical Components at a Glance

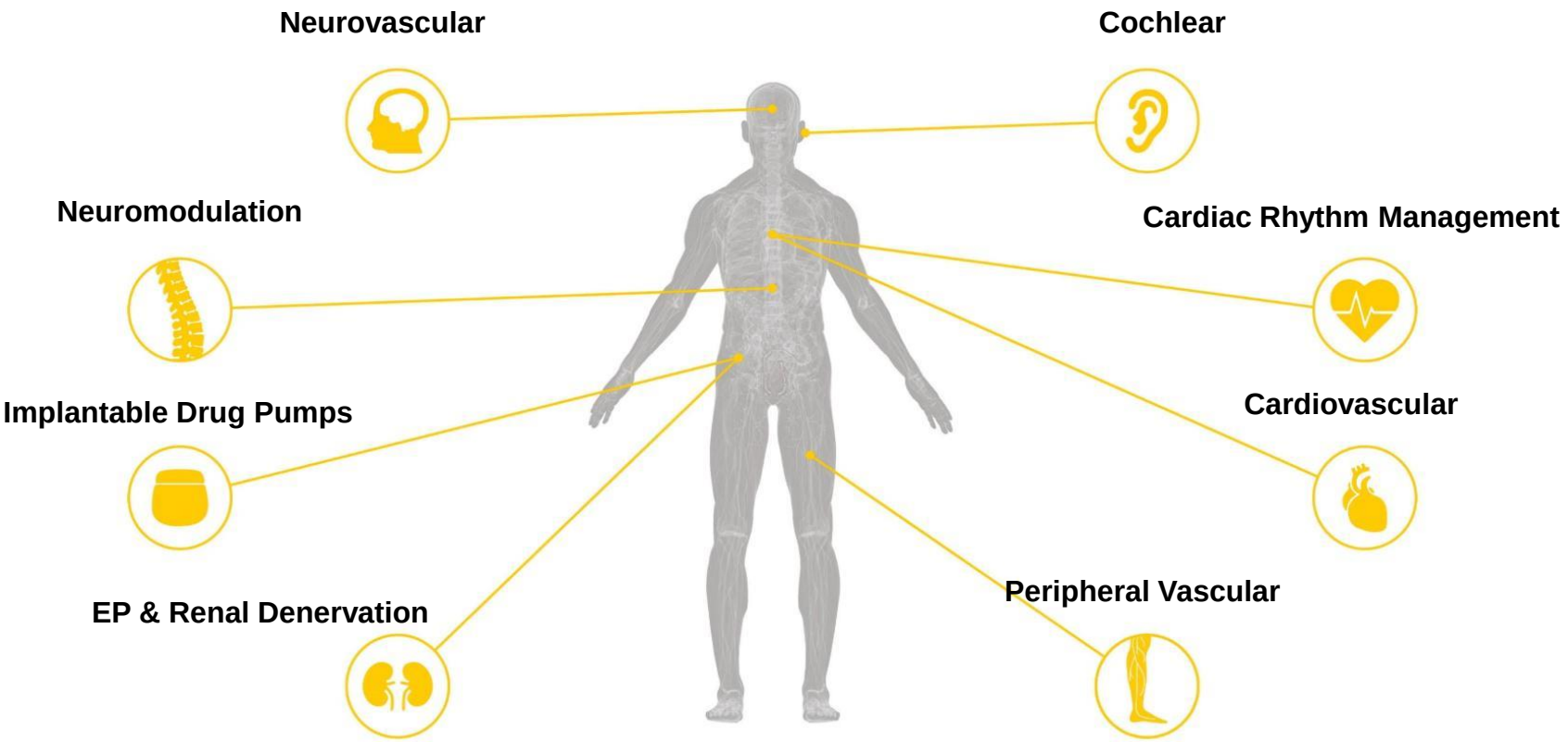
- HMC is the leading source of metal components for medical devices
- based on our technological excellence in R&D, product development and manufacturing we provide solutions in:
  - materials
  - micro components
  - wires and tubes
  - coiling
  - assemblies
  - cases

Global Footprint



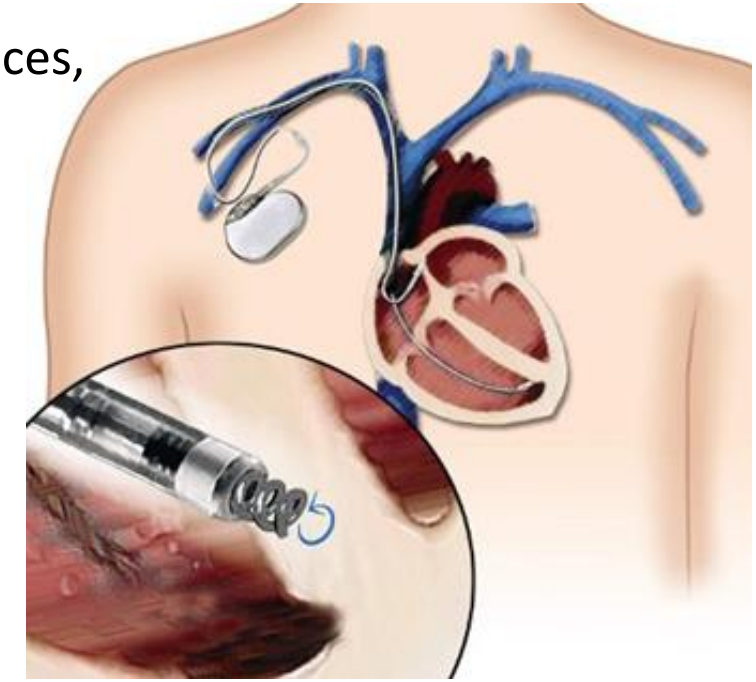
	Americas				Europe		Asia
Location	St. Paul, MN USA	Plymouth, MN USA	Dorado, Puerto Rico	Costa Rica	Hanau, Germay	Yverdon, Switzerland	Singapore
Staff	400	120	50	60	250	80	50
Facility	100,000 sq ft	34,500 sq ft	22,100 sq ft	16,000 sq ft	65,000 sq ft	60,000 sq ft	25,000 sq ft
Quality Sys	ISO: 13485	ISO: 13485	ISO: 13485	ISO: 13485	ISO: 13485	ISO: 9001	ISO: 13485
		ISO: 11070			ISO: 14001	ISO: 13485	

Heraeus Medical Components - Markets -



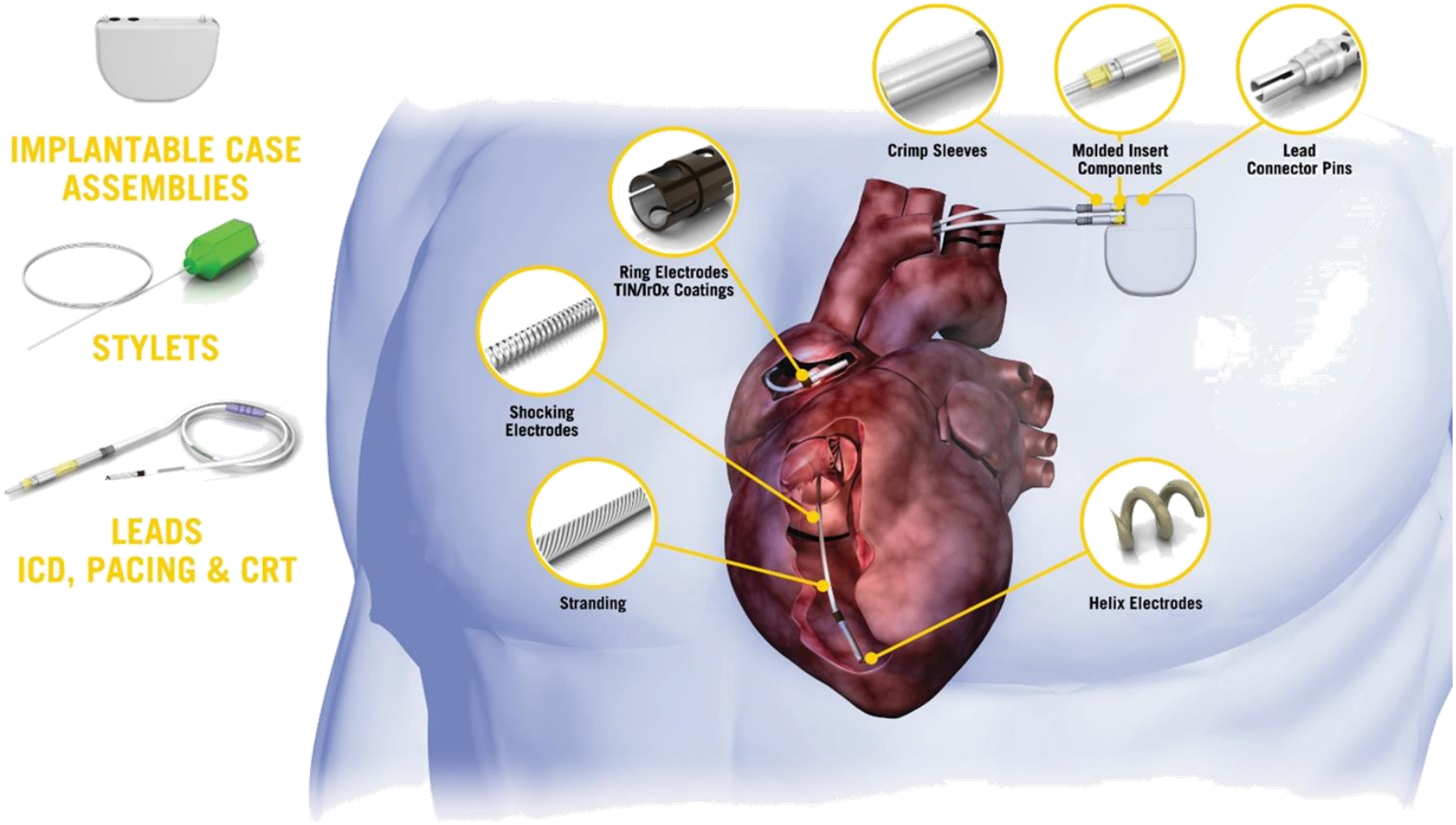
2. Feedthroughs for Medical Implants

- Cardiac Arrhytmias
  - Pacemaker, Defibrilator, CRT-Devices, Biomonitors
- Incontinecy
- Pain Therapy
- Parkinson, Epilepsy
- Sleep Apnea
- Deafness or Hearing Loss
- Patient Monitoring Needs



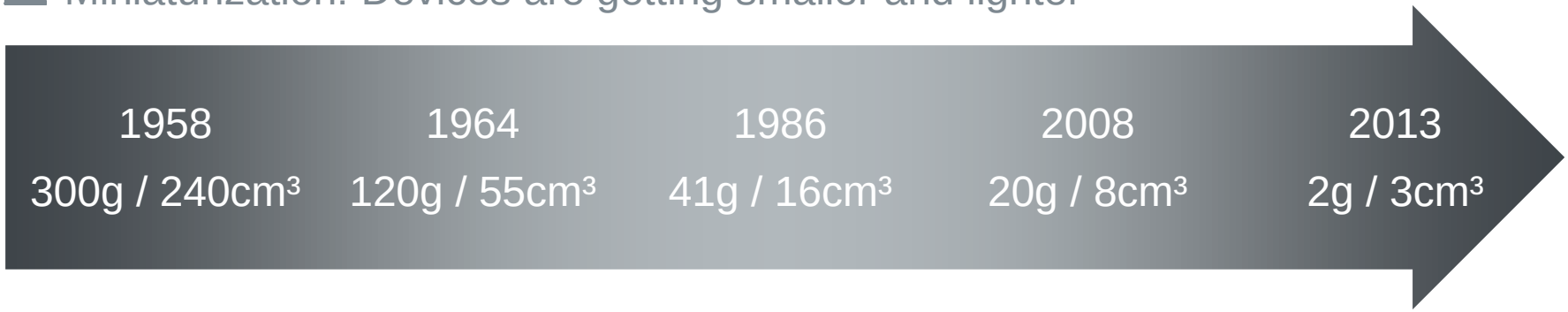
Active implantable devices of high importance for manifold medical therapies!

Heraeus Components for Implantable Devices

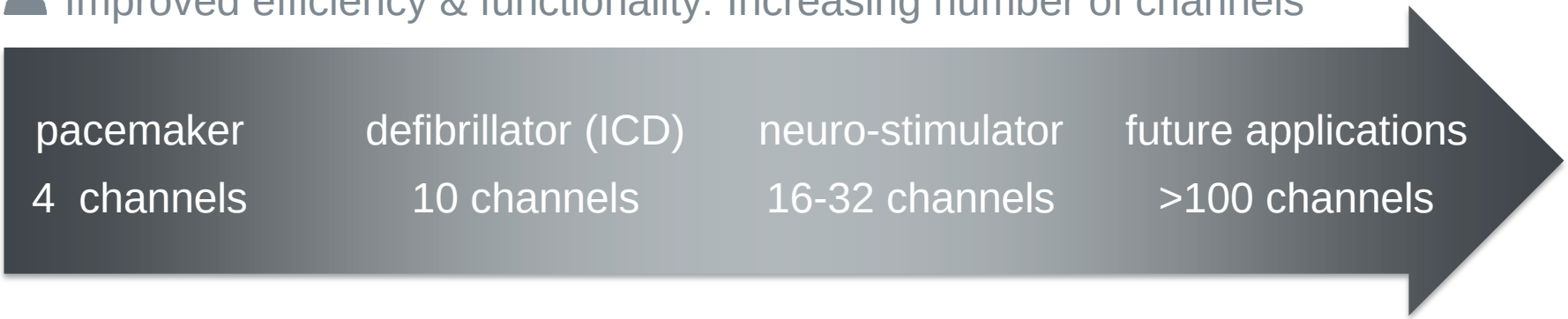


Megatrends in AMI

- Miniaturization: Devices are getting smaller and lighter



- Improved efficiency & functionality: Increasing number of channels



Current feedthrough technology fails to support these trends!

Requirements for Feedthroughs

- devices typically with 4-16 channels

- requirements for feedthroughs
  - hermetic sealing
  - conductivity and insulation
  - high reliability for 10+ years

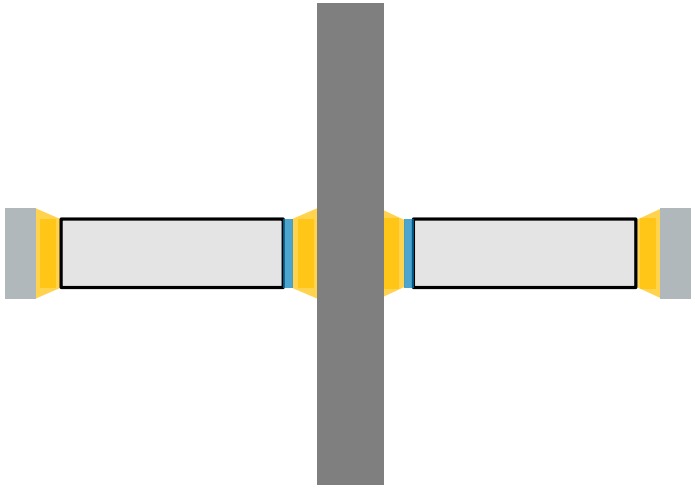
[8] [9]

[8] Tekna Seal, LLC [9] Technische Universität München

Conventional Feedthrough Assembly

- many single parts reduce overall reliability and robustness
- labor-intense assembly
- expensive parts especially for many channels
- limitation of maximum number of pins per part
- only straight through-channels (no bifurcations, etc.)

Simpler and more flexible design highly desirable!



1. alumina insulator with core hole
2. sputtercoat inside w/ Nb coating
3. slide brazering in
4. slide feedthru Pin in
5. slide ferrule over
6. slide ferrule braze in
7. braze

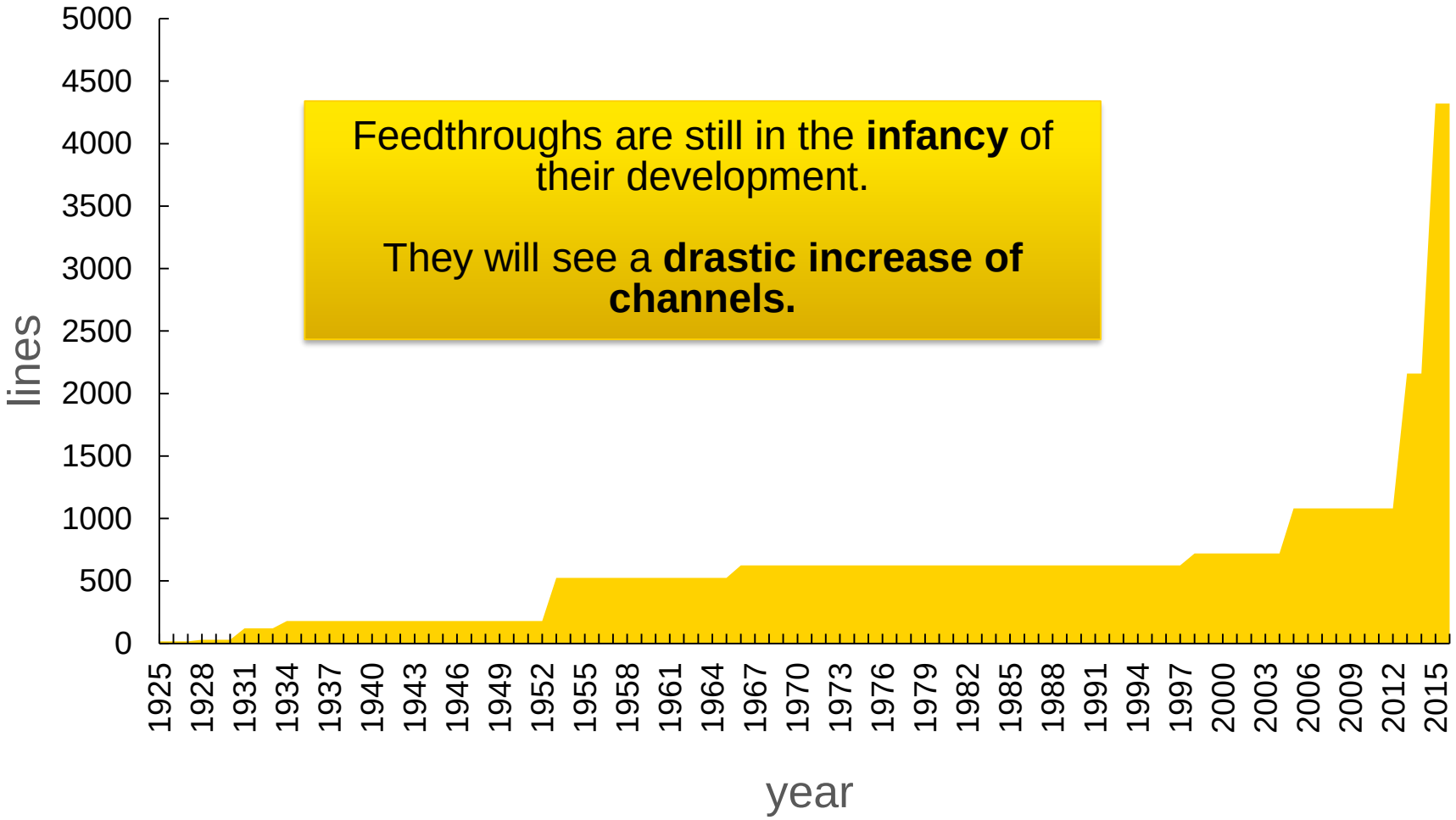
The benefit of high resolution and more channels

- effective therapy requires stimulation and sensing at the right point
- the higher the resolution of the therapy, the better the effect for the patient
- comparable with TVs: the higher the resolution, the better the picture

Higher resolution in future AMIs essential for effective therapies:

Hearing
Seeing
Neurostimulation
brain reader
…

Evolution of TV resolution



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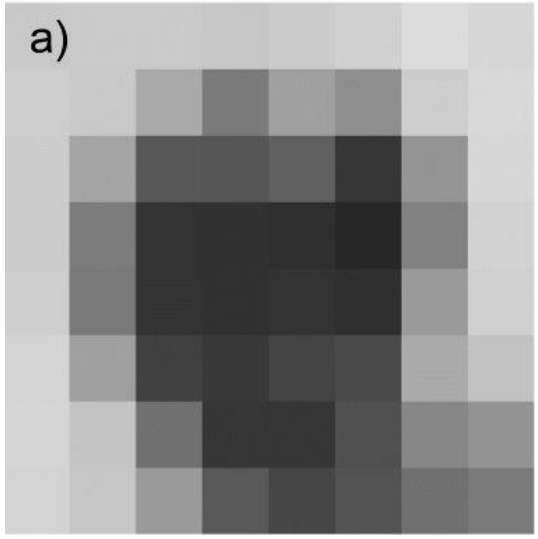
Resolution of retinal implants

8x8



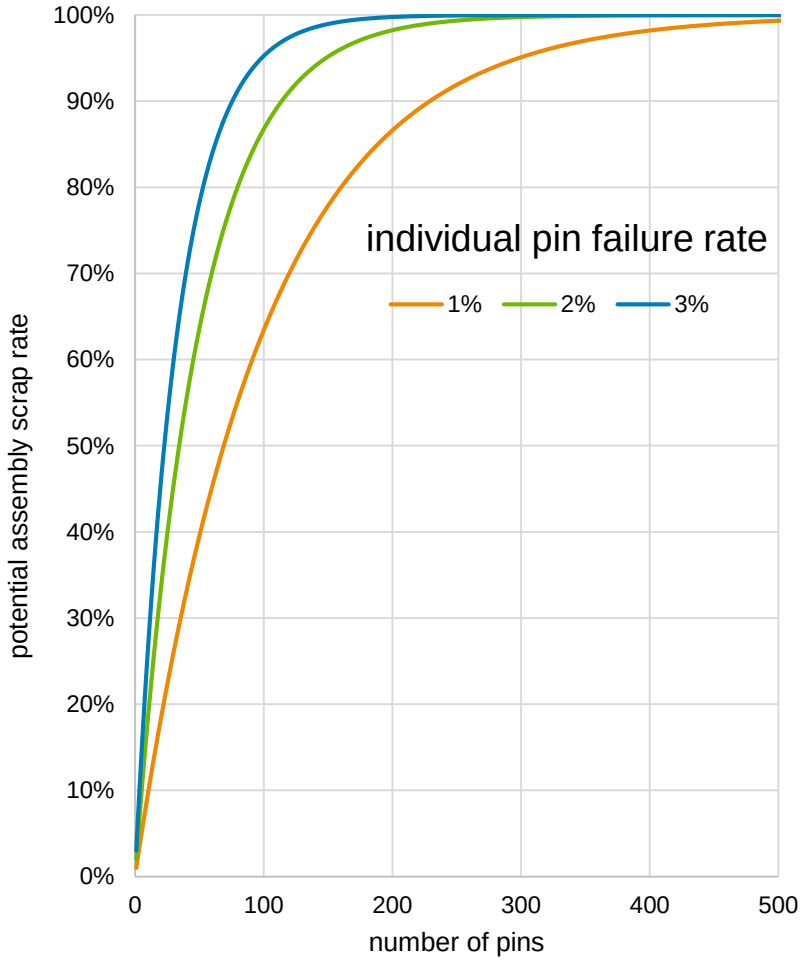
64 channels
current state-of-the-art
basic orientation

Heraeus

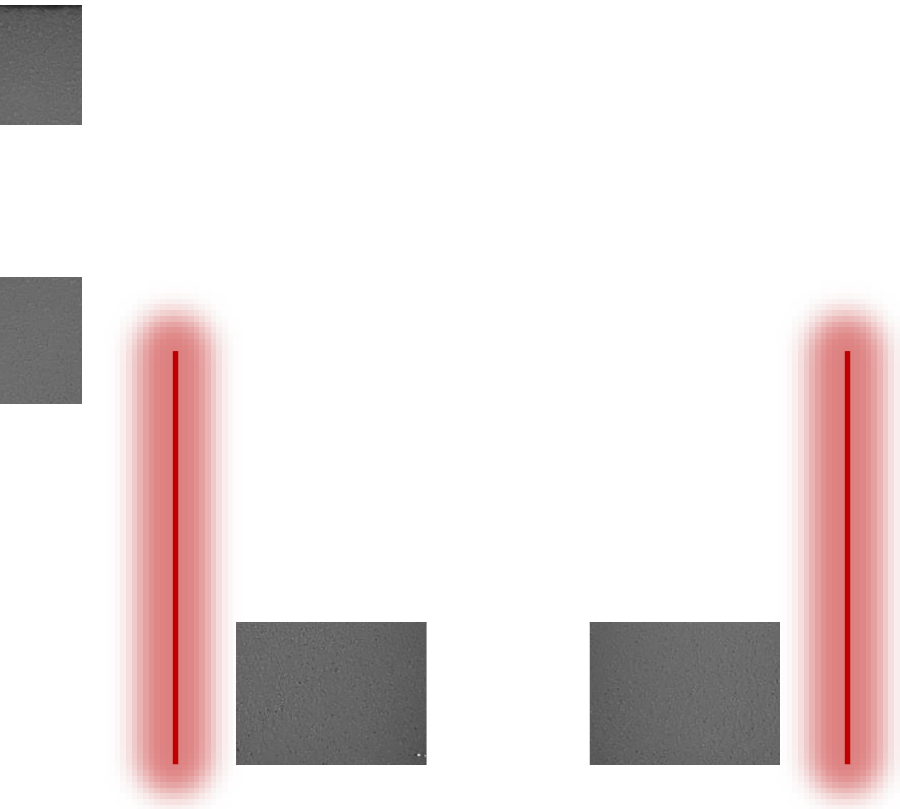
Challenge of many channels

Pin-based feedthroughs limit future development of active medical implants.

- a feedthrough with hundreds of channels:
  - too large due to limited miniaturization potential of pin-based approach
  - Technologically + economically challenging
    - failure of a single pin causes failure of whole feedthrough
    - even for low individual pin failure scrap rates add up fast for 100+ channels
  - risk associated with such a part is not acceptable for the patient



3. A New Feedthrough Technology

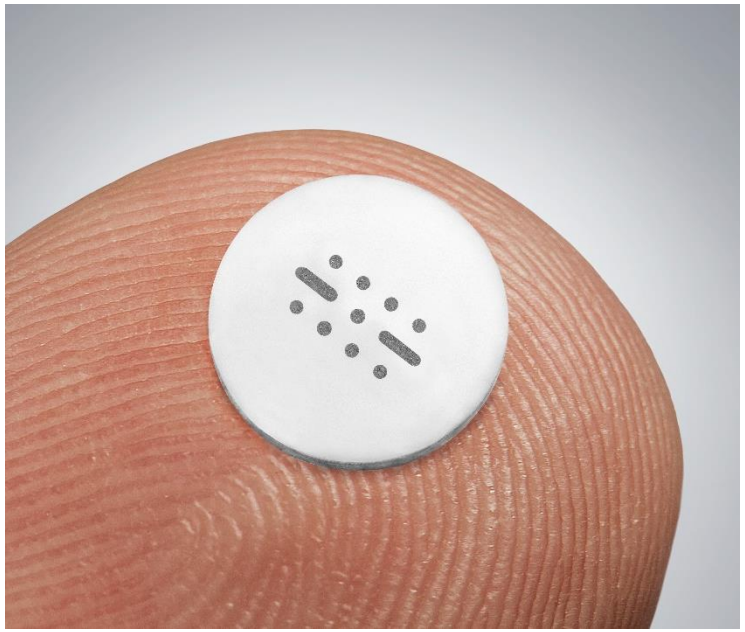


- idea: layered assembly
  - using high-temperature co-fired ceramic (HTCC) technology
    → established method of mass production in electronics industry
  - ceramic green tape gets punched according to desired design
  - filling of conductive paste into ceramic tape by a printing process
  - stacking several individual layers
  - co-firing for densification

Comparably simple process adapted that had been used successfully for decades to produce robust, reliable parts (HTCC).

CerMet as an Enabler

- CerMet = Ceramic + Metal
- used in many industries such as aerospace, light industry, machining, etc.
- combines the advantages of ceramics with the advantages of metals
  - high hardness
  - superior wear resistance
  - high heat resistance
  - metallic conductivity despite ceramic
  - low density for lightweight designs



CerMet for bio-compatible applications: combining Platinum and Alumina!

[11] Torralba et al., 2014 [11] The Wire [12] Heraeus
[13] Indiamart [14] Everyday Health

Heraeus

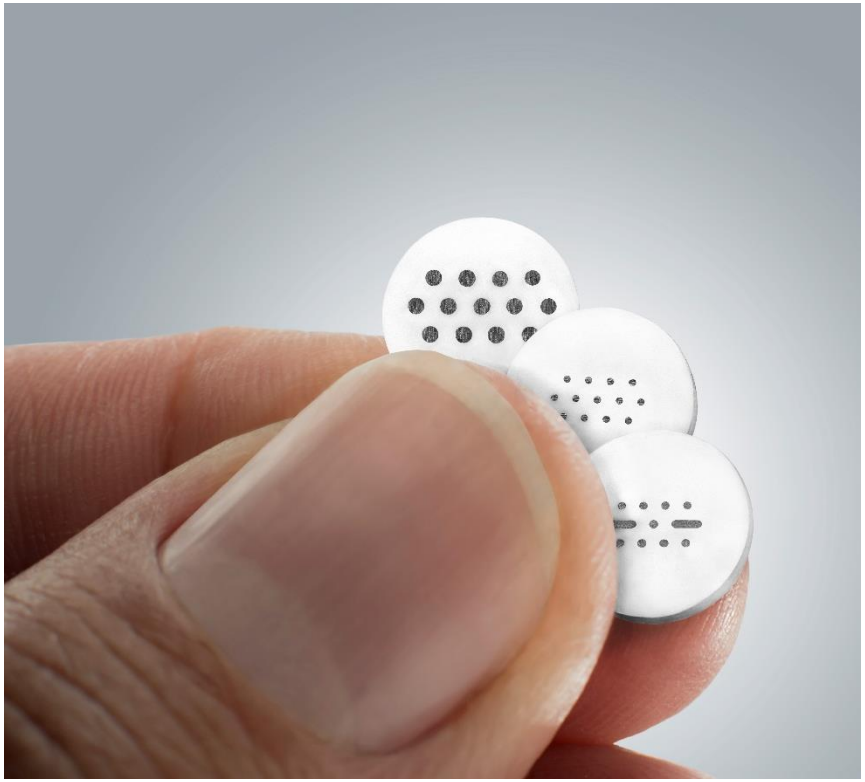
Paradigm change: No more pins in feedthroughs

Conventional technology → New CerMet Technology

Almost 100 patents protect the Cermet Technology.

Features of the Heraeus CerMet Technology

- **Hermeticity:** absolutely leak-tight feedthroughs
- **Conductivity:** channels with metal-like conductivity
- **Insulation:** high electrical insulation resistance between vias
- **Biocompatibility:** platinum and alumina with excellent biocompatibility and successfully used for decades in implants
- **Cost Efficiency:** HTCC technology can be scaled up easily

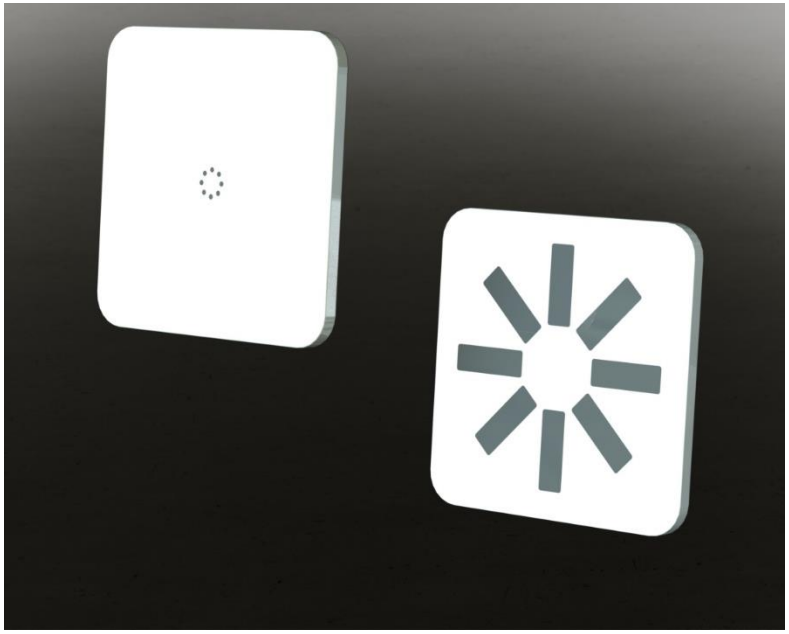


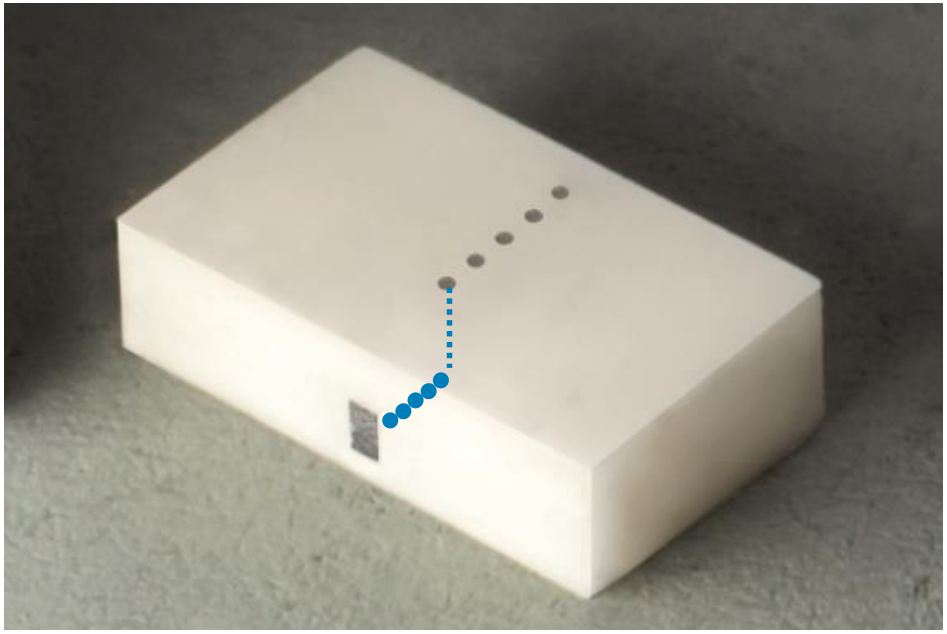
Cermet Technology fulfills all requirements!

Freedom to Invent

- enables more complex designs with a much higher degree of freedom
  - internal bifurcations and steps of vias
  - internal re-routing
  - non-circular cross-sections
  - 3-dimensional shapes

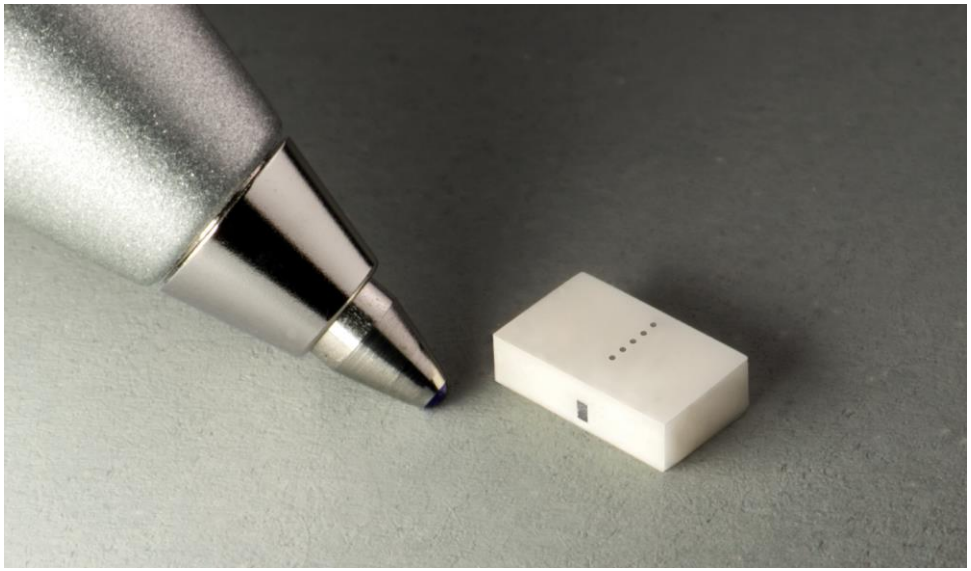
Unprecedented design freedom!





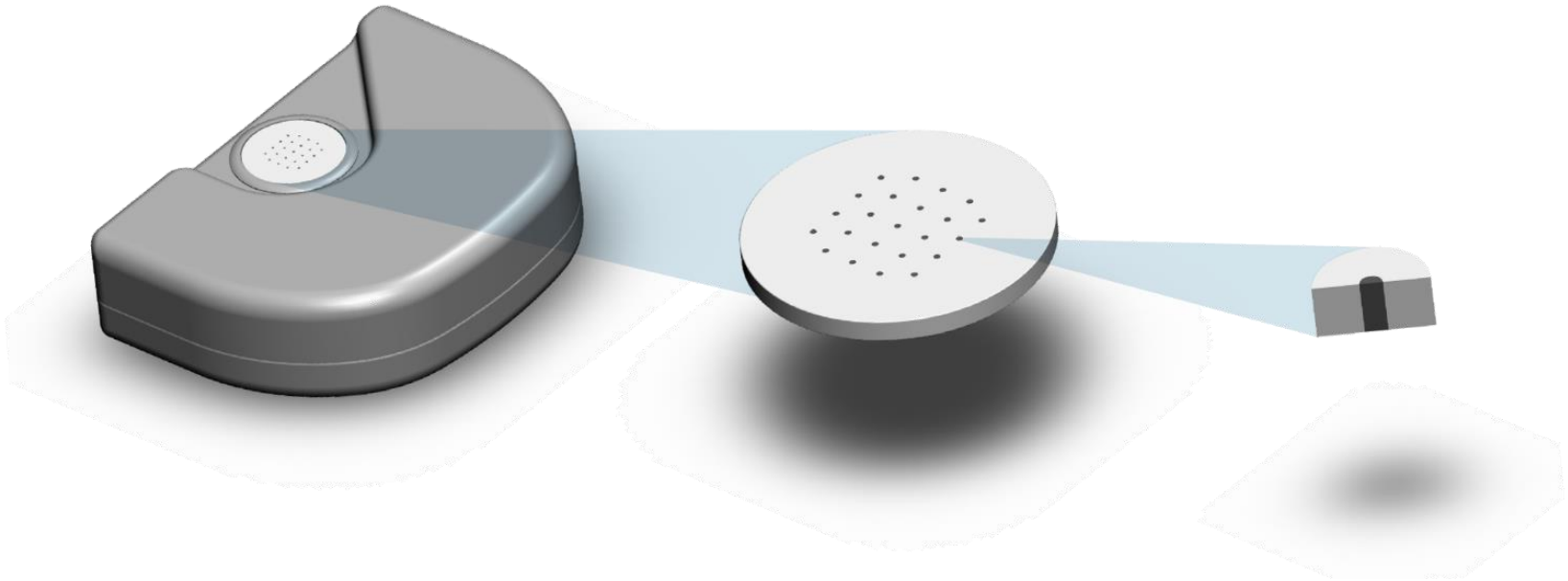
Freedom to Invent

- offers unparalleled miniaturization potential
- vias as small as 150 µm in diameter
- up to 800 vias per cm² possible
- drastic downscaling of today's feedthroughs or increase of via count



Cermet Benefits

- **Generation of additional cost savings**
  - costs are reduced significantly, especially for parts with a high number of channels
- **Development of devices with integrated functionality**
  - amount of components and assembly steps of device reduced, eventually reducing the assembly costs



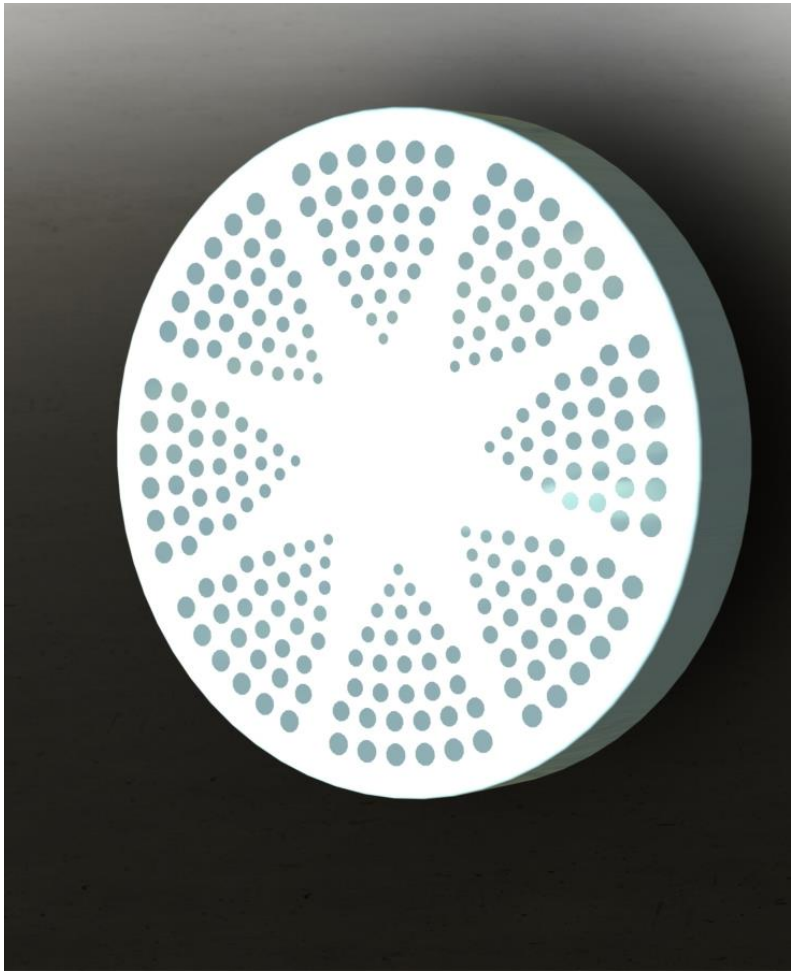
Cermet Benefits

Design more efficient devices

- significantly increased number of channels for sensing and stimulating
- more reliable, more accurate, and more efficient therapy
- reduced number of unintended stimulation

Production of safer devices

- one monolithic composite part instead of a plethora of single parts
- potential reason for leaks is eliminated, yielding more robustness and reliability
- risk for failure is significantly reduced as there is no macroscopic interface between conductor and insulator

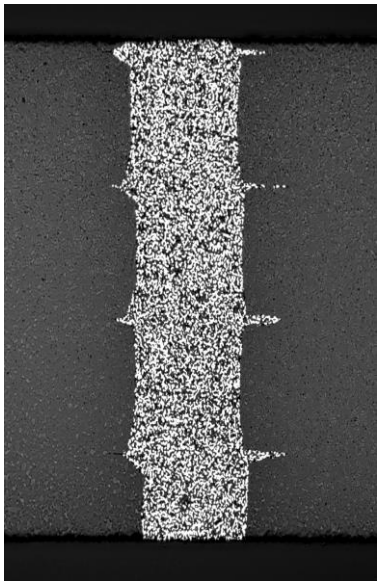


Heraeus

The Dual Composite on Different Size Scales

1,000 µm scale

100 µm scale



10 µm scale

1 µm scale

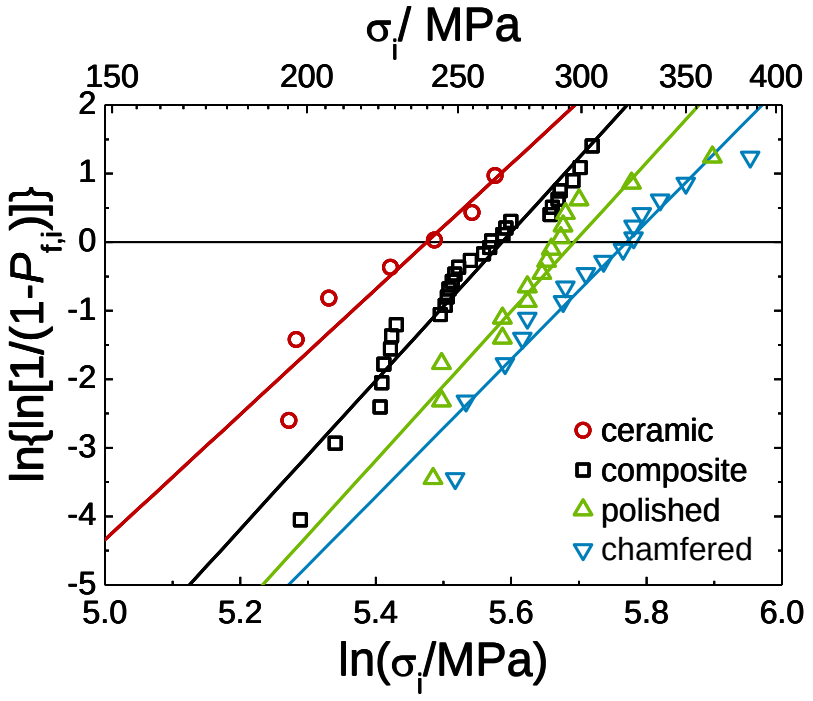
- interpenetrating network microstructure within cermet via
- no interface between matrix and via but interconnected ceramic phase

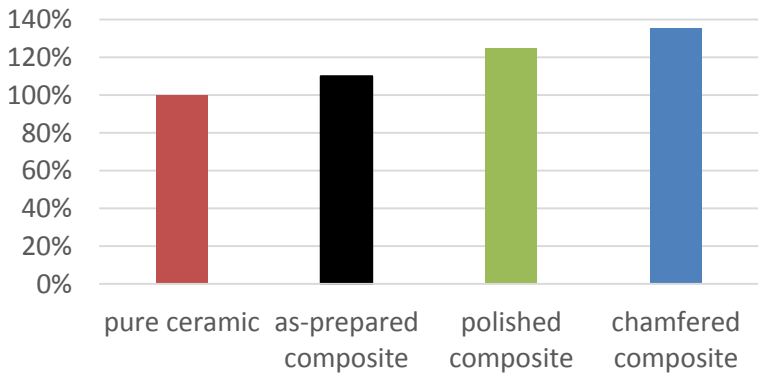
Is strength of composite affected by via?
Is conductivity of via sufficient?
Is the composite leak-tight?

4. Physical Properties

- pure ceramic sample with a characteristic strength of 232 MPa
- as-prepared composite around 10 % (24 MPa) stronger than ceramic!
  → cermet yields strengthening!
  → fractography reveals that failure occurs mostly in ceramic matrix
- further mechanical enhancement of composite by
  - polishing: +36 MPa (+14 %)
  - chamfer: +60 MPa (+23 %)

Composite unexpectedly more robust than pure ceramic!

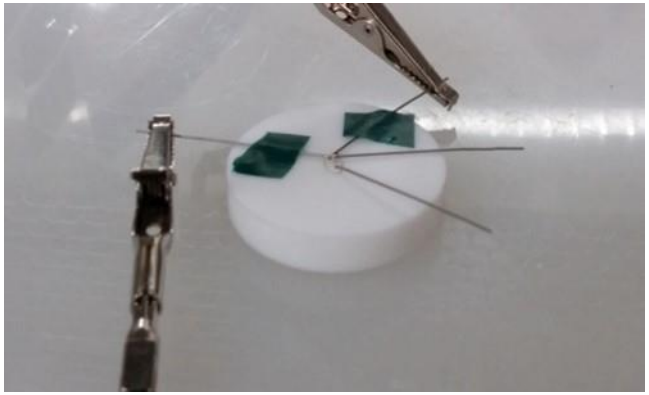


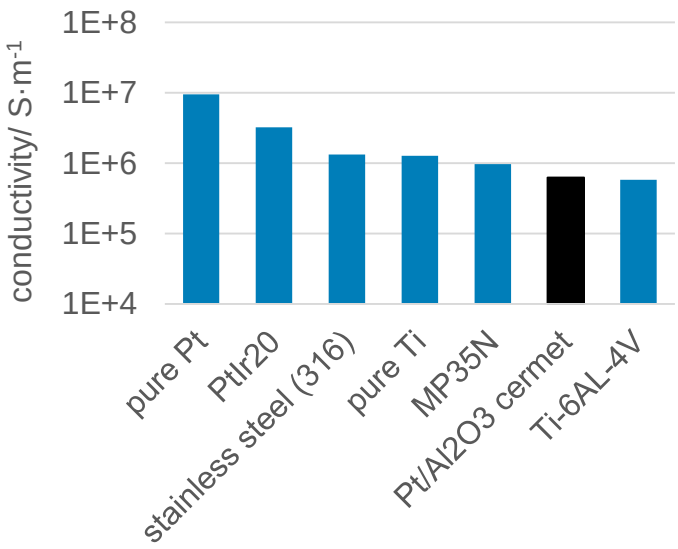


Electrical properties

- insulation resistance at 1 kV_{DC}
  - between two adjacent vias with ca. 1mm pitch
  - only minute currents on the order of 10^{-11} A
  - insulation resistance of 10.000 GΩ
    → as high as expected for pure alumina
    → great potential to further decrease pitch
- conductivity of the vias on the order of 10^5...10^6 S/m
  - comparable to some metal conductors such as titanium, stainless steel, and other alloys
  - great potential to further decrease via diameter

Insulative and conductive properties of composites much better than currently necessary!

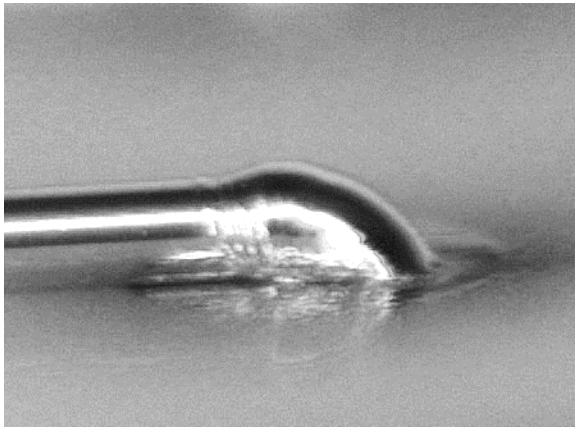


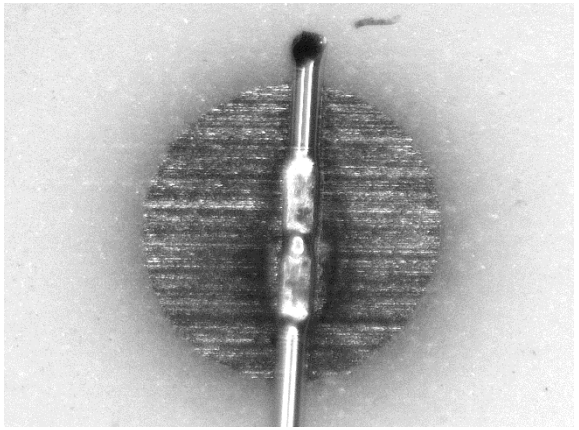


Electrical integration

Attaching wires for electrical connection feasible with many methods.

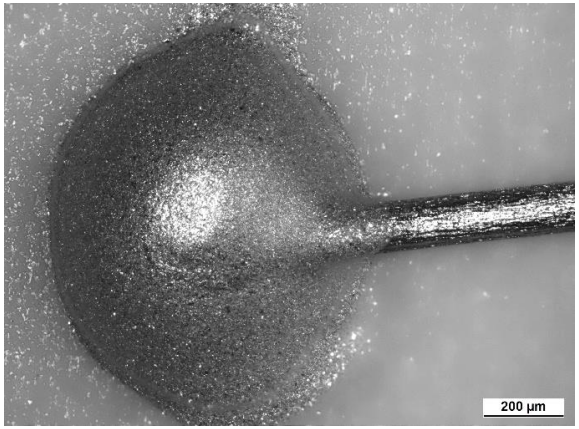
laserwelding
PtIr20, Nb, Ti, MP35N,…

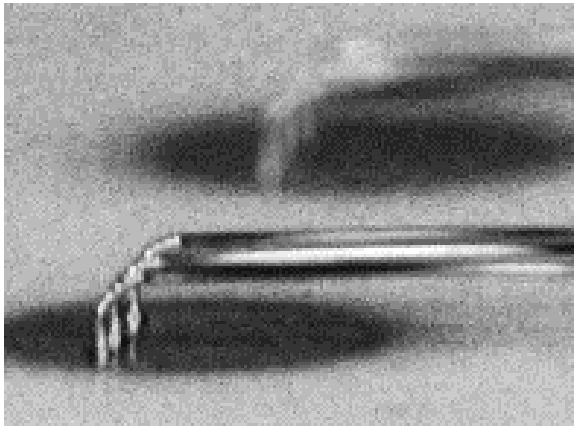




resistance welding
directly on cermet feasible

conductive adhesive
very fast and flexible method

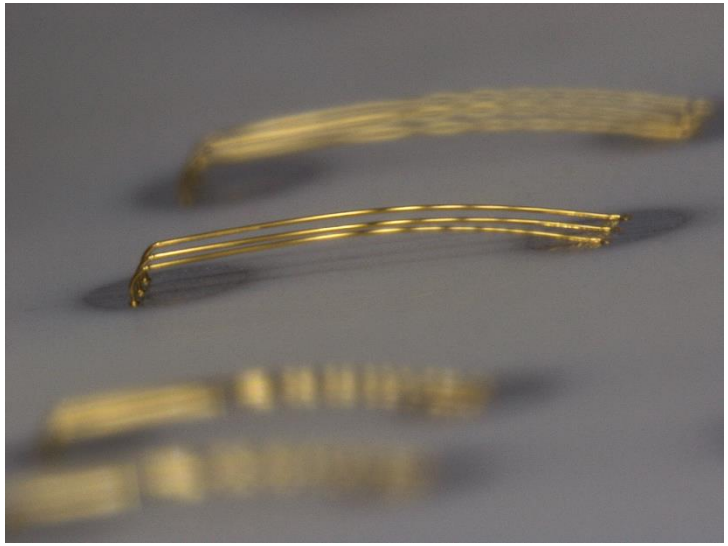


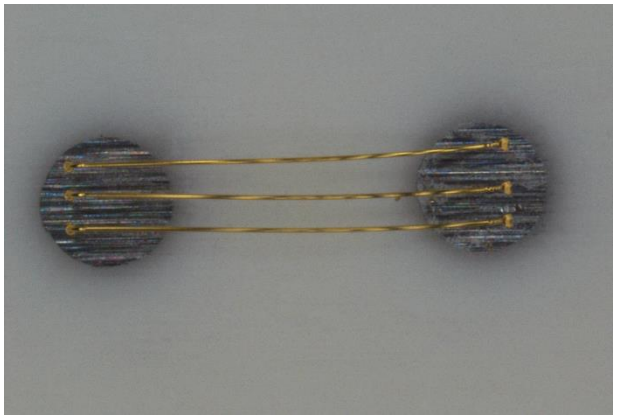


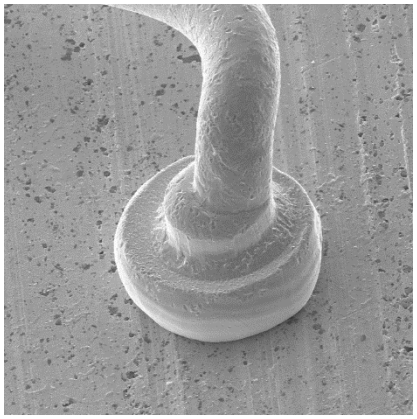
wire bonding
directly on cermet

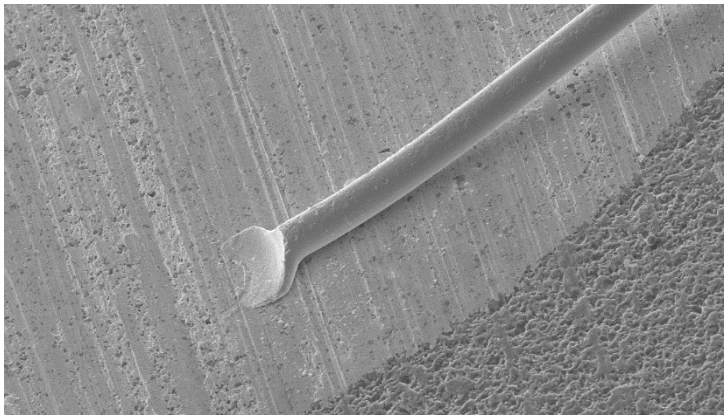
Direct Wire Bonding on Cermet

- method for 30 µm gold wires developed by Heraeus Electronics (HET)
- even multiple wires per via feasible
- no contact pad required









4. Summary and conclusions

1) innovative new method introduced to produce feedthroughs for implants

2) material system with unique property profile
   - biocompatible
   - conductive
   - insulating
   - hermetic
   - mechanically robust
   - non-magnetic (MRT)
   - heat-resistant
   - easy to integrate

3) more flexible, miniaturized design with higher number of vias feasible

4) highly robust composite with strength exceeding pure ceramic

5) also non-medical application possible, *e.g.*, for harsh thermal/chemical conditions

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Thank you for listening!

References

[0] http://www.coadydiemar.com/html/rb_volume11_2014.html
[1] Heraeus Deutschland GmbH & Co. KG
[2] Technical University of Denmark
[3] http://www.socalpain.com/spinal-cord-simulator-implant/
[4] http://neurosciencestuff.tumblr.com/post/89976181644/deep-brain-stimulation-improves-non-motor-symptoms
[5] http://www.medgadget.com/2014/01/inspire-obstructive-sleep-apnea-therapy-shows-promising-results.html
[6] https://commons.wikimedia.org/wiki/File:Cochlear_implant.jpg
[7] http://www.isarherzzentrum.de/biomonitor
[8] http://www.teknaseal.com/ceramic-to-metal-feedthroughs.html
[9] http://www.med1.mri.tum.de/de/node/151
[10] http://revistademetalurgia.revistas.csic.es/index.php/revistademetalurgia/article/viewArticle/1323/1372
[11] http://cdn.thewire.com/media/old_wire/img/upload/2013/07/05/AP81359373584_1/lead_large.jpg
[12] Heraeus Deutschland GmbH & Co. KG
[13] http://www.indiamart.com/durga-trading-corporation/metal-halide-lamps.html
[14] http://www.everydayhealth.com/healthy-living-pictures/quiz-whats-your-body-iq.aspx