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# A wide sprayed field of application for very low energy electron irradiation in European industries

## One Tool – All-round Application

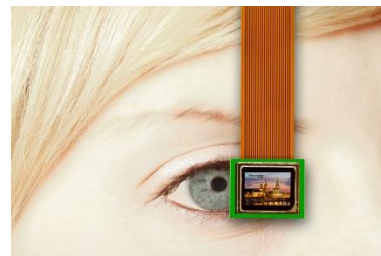
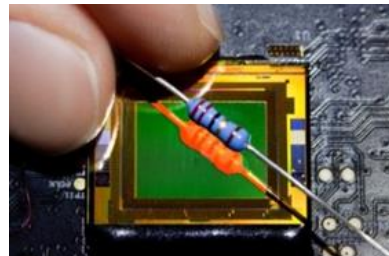
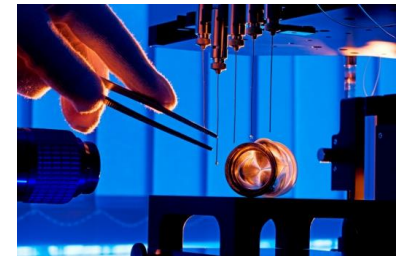
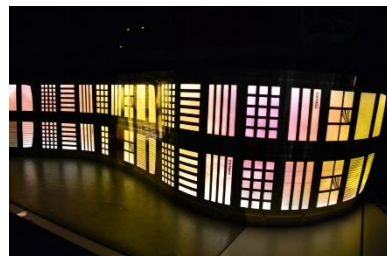
ARIES, Kick-Off WP3 – September 13/14, 2017 – Cracow (PL)

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Frank-Holm Rögner



# Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP



VERSION 2015-03-13

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ARIES



WP3

 **Fraunhofer**  
FEP

# Fraunhofer-Gesellschaft

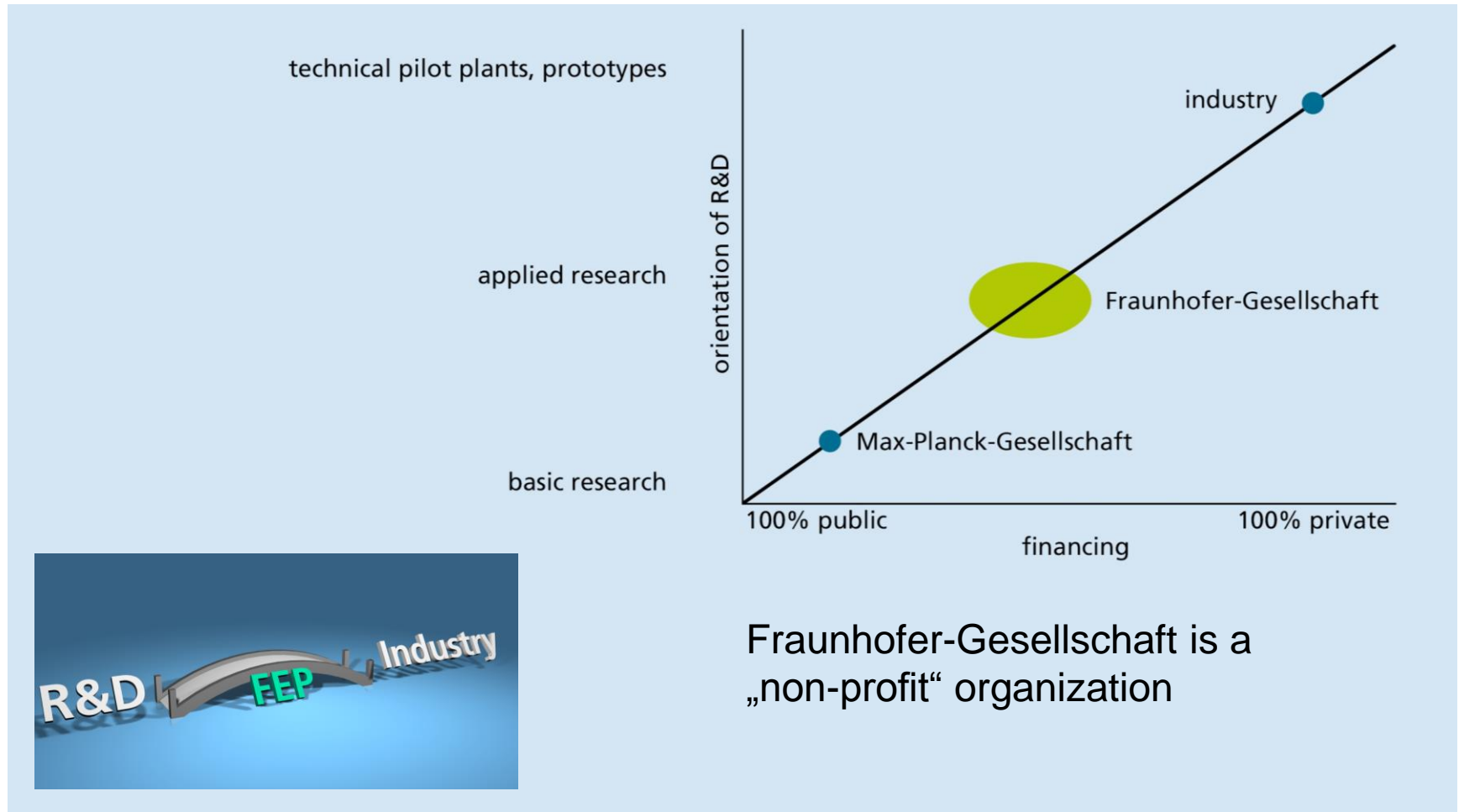
- is Europe's largest application-oriented research organization
- was set up in 1949
- 69 institutes and independent research units with 24,500 employees all over Germany
- the headquarters is located in Munich
- each institute has its own core competences
- the individual institutes act as profit centers on the market



Headquarters  
in Munich



# Fraunhofer-Gesellschaft – We Forge the Future



# Core Competencies



**ELECTRON BEAM TECHNOLOGY**



**PLASMA-ACTIVATED HIGH-RATE DEPOSITION**



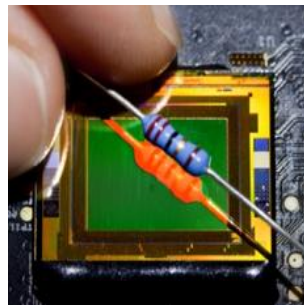
**SPUTTERING TECHNOLOGY**



**HIGH-RATE PECVD**



**TECHNOLOGIES FOR ORGANIC ELECTRONICS**

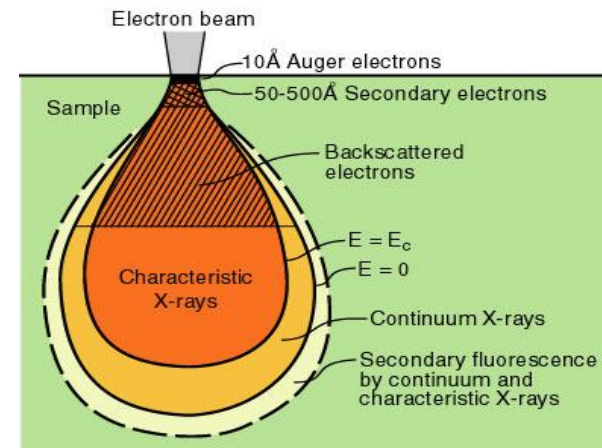
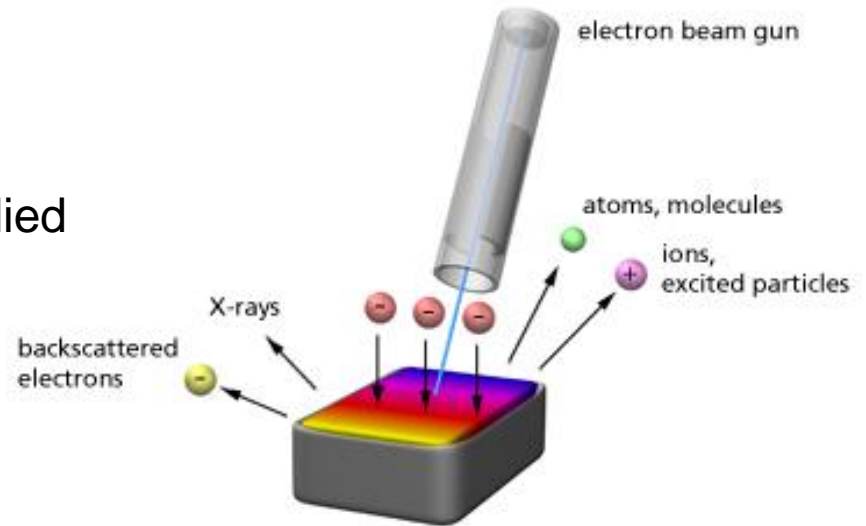
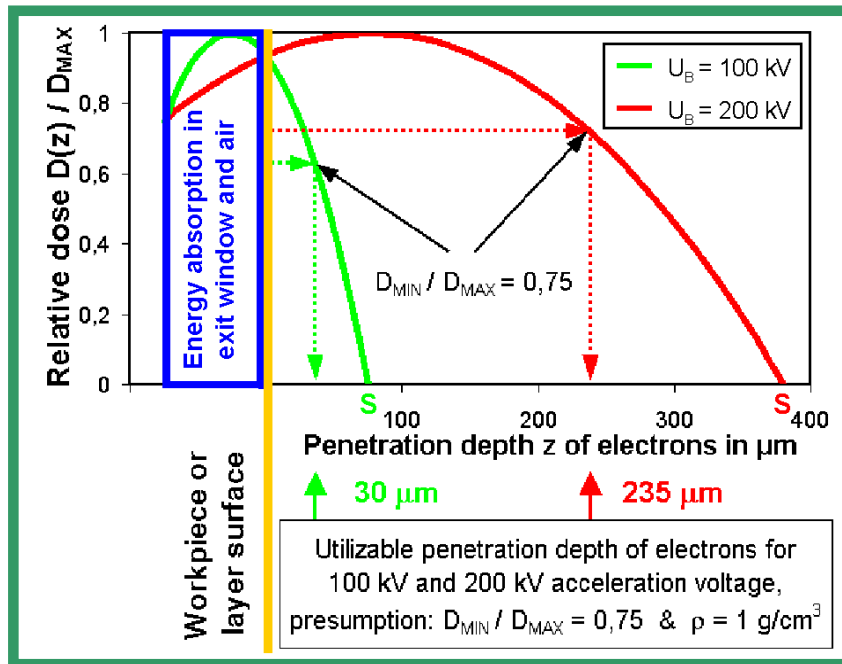


**IC AND SYSTEM DESIGN**



# Electron Beam Processing - General

- Different interactions of accelerated electrons with matter
- Each interaction is technological applied



# Electron Beam Processing - General

## Effects of Electron Beam Interaction

### Thermal Processes

#### Heat Production

Vacuum

- Evaporation
- Melting
- Welding / Joining
- Hardening
- Micro- structuring

### Non-thermal Processes

#### Chemical Reactions

Atmosphere

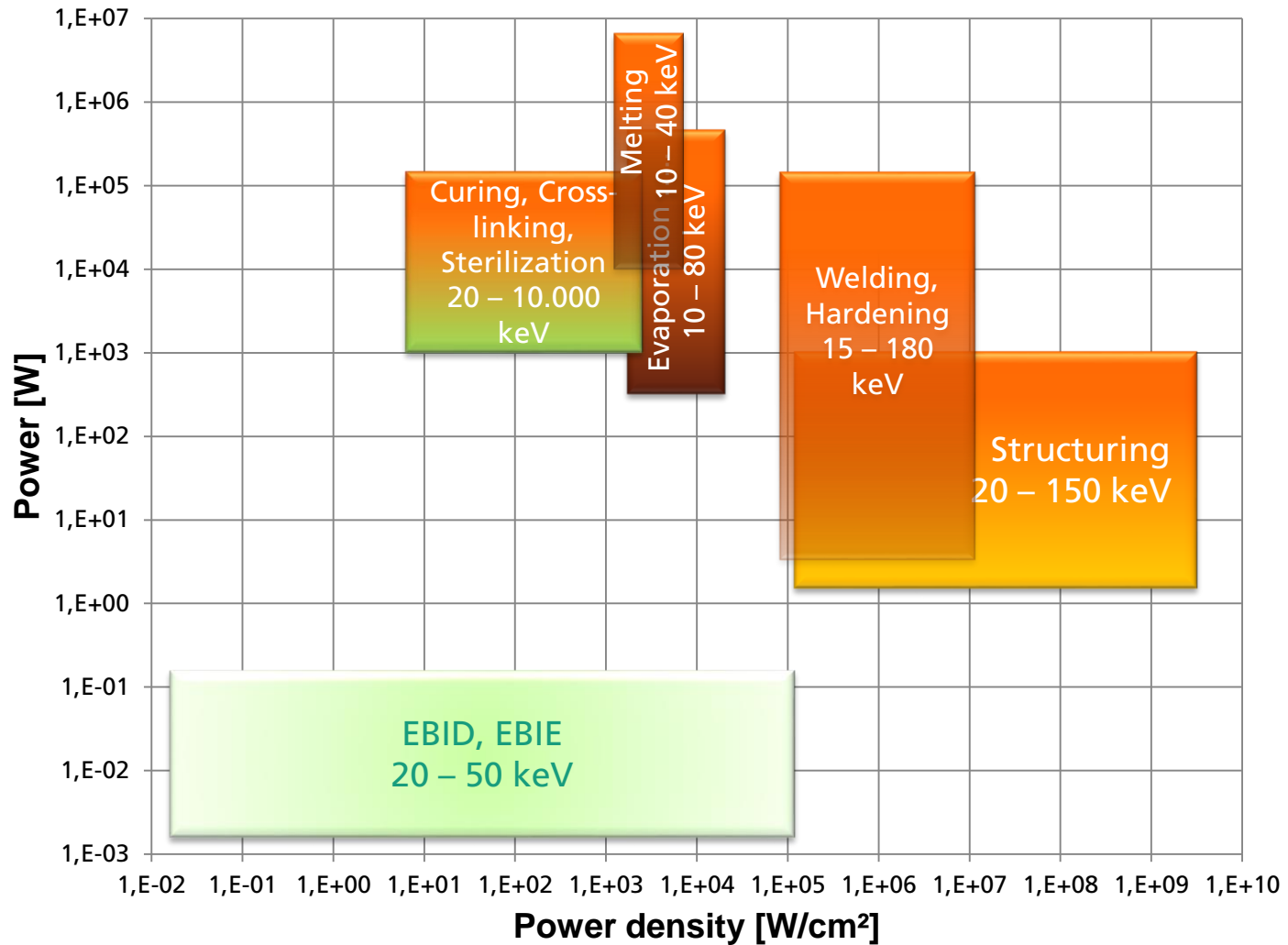
- Curing
- Crosslinking
- Drying print-inks
- Surface modification (Grafting)

#### Biocidal Effects

Atmosphere

- Disinfection of animal feed
- Seed treatment
- Sterilisation of products
- Sterile packaging
- Inactivation of pharma waste

# Electron Beam Processing - General





# Very-Low-Energy E-Beam Processing

## Present Situation – A Survey

Understanding of “Very-Low-Energy E-Beam”:

### *Low-Energy*

- 0.5 – 5.0 MeV (according Mr Shvedunov, Lomonosov Moscow State University, lecture in 2011)

### *Very-Low-Energy*

- 0.01 – 0.3 MeV (according FEP, like most appliers in Europe)

Acceleration voltage differs concerning application processes

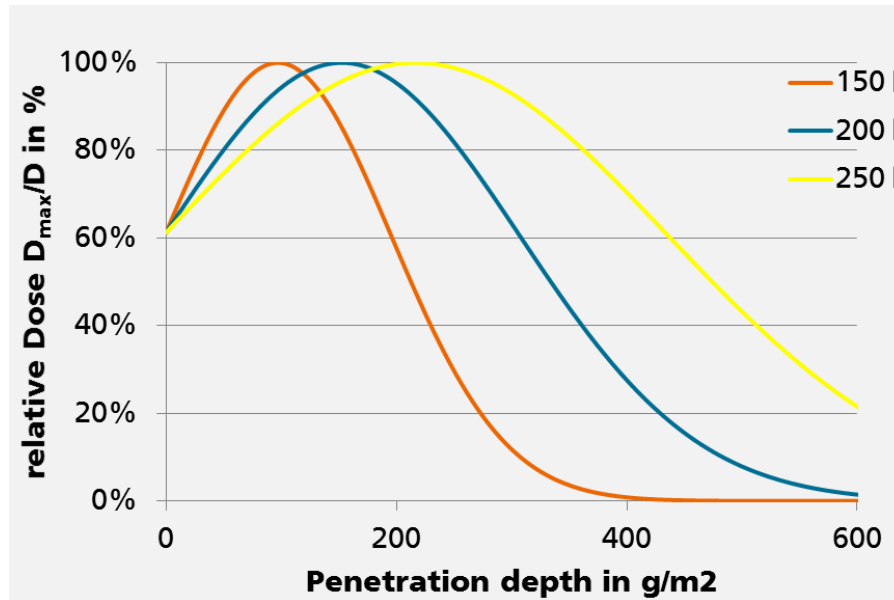
- Processes on ambient atmosphere: 80 – 300 kV
- Processes in vacuum: 10 – 150 kV

# Very-Low-Energy E-Beam Processing

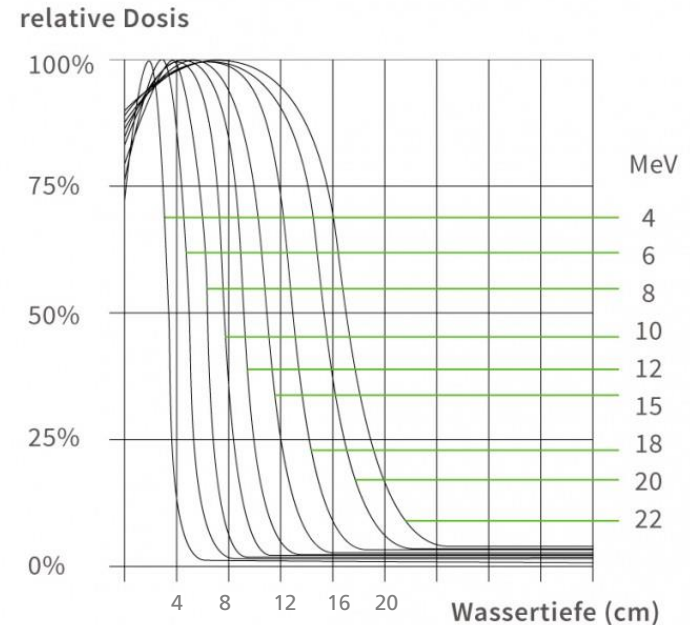
Penetration (working) depth according to electrons energy (keV)

„Dose-Depth Diagram“ -> Energy transfer to mater

*very-low-energy*



*low-energy*



[http://www.onmeda.de/strahlmedizin/onisierende\\_strahlung\\_reichweite-reichweite-von-elektronen-alpha-teilchen-amp-neutronen-2413-9.html](http://www.onmeda.de/strahlmedizin/onisierende_strahlung_reichweite-reichweite-von-elektronen-alpha-teilchen-amp-neutronen-2413-9.html)

# Electron Beam Processing – „Non-thermal“

## Effects of Electron Beam Interaction

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### Non-thermal Processes

Chemical Reactions

Biocidal Effects

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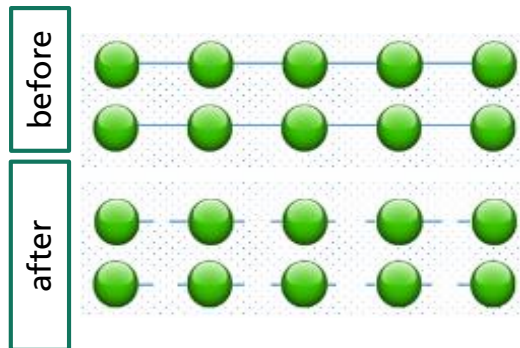
- Disinfection of animal feed
- Seed treatment
- Sterilisation of products
- Sterile packaging
- Inactivation of pharma waste

# Electron Beam Processing – „Non-thermal“

Braking bonds open, and then ...

A

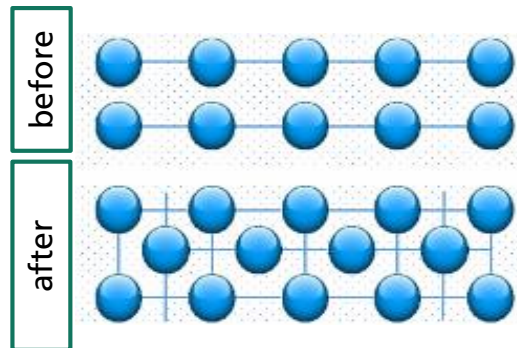
... leave it cut



degradation

B

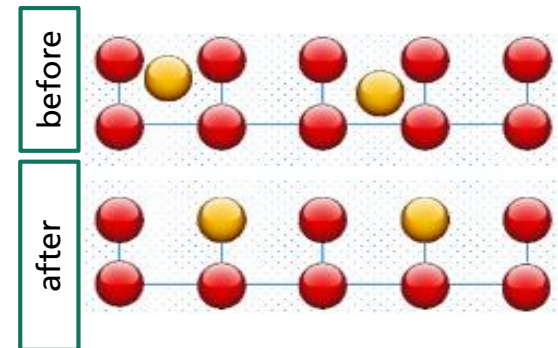
... let it bond among each other and with neighbors



cross-linking, curing

C

... let it bond to new partners



reactive compounding,  
polymer grafting  
(adhesion of coatings)

# Electron Beam Processing – „Non-thermal“

## Film Crosslinking

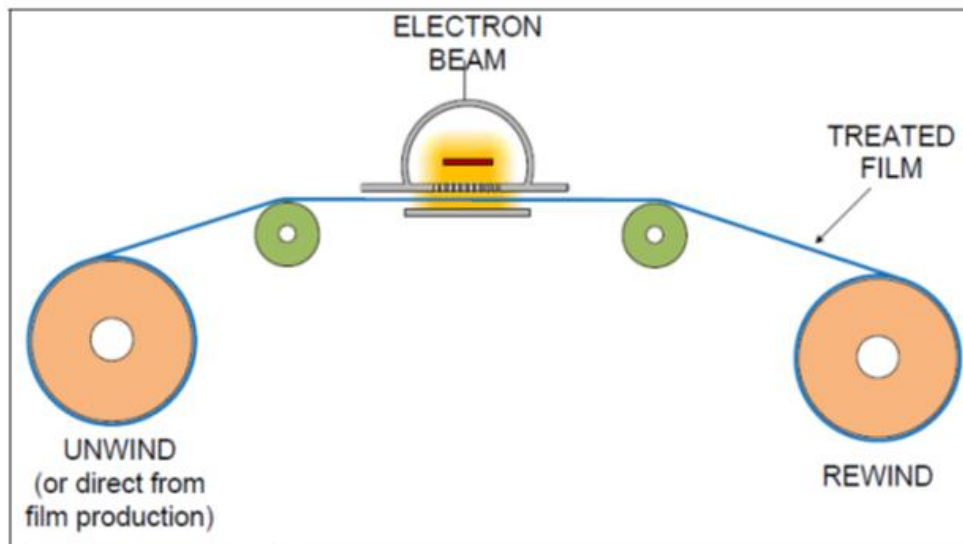


Figure 2. Film Crosslinking

(PCT-Flyer)

# Electron Beam Processing – „Non-thermal“

## Film Pressure Sensitive Adhesives (PSA's)

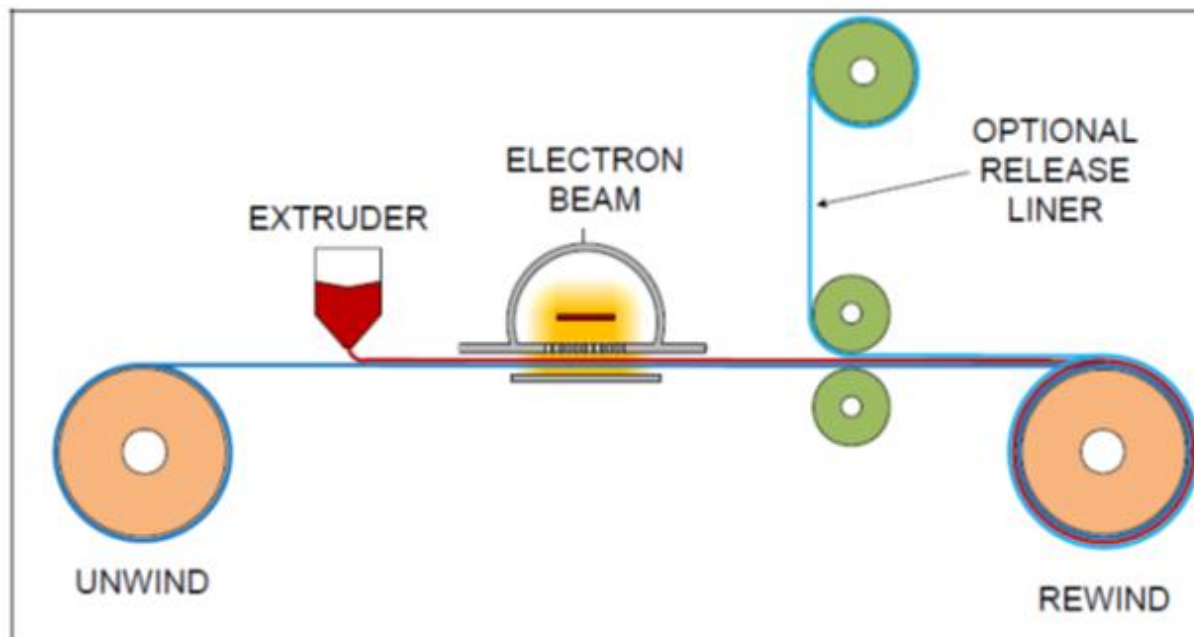


Figure 3. Pressure Sensitive Adhesive Crosslinking

(PCT-Flyer)

# Electron Beam Processing – „Non-thermal“

## Adhesive Laminating

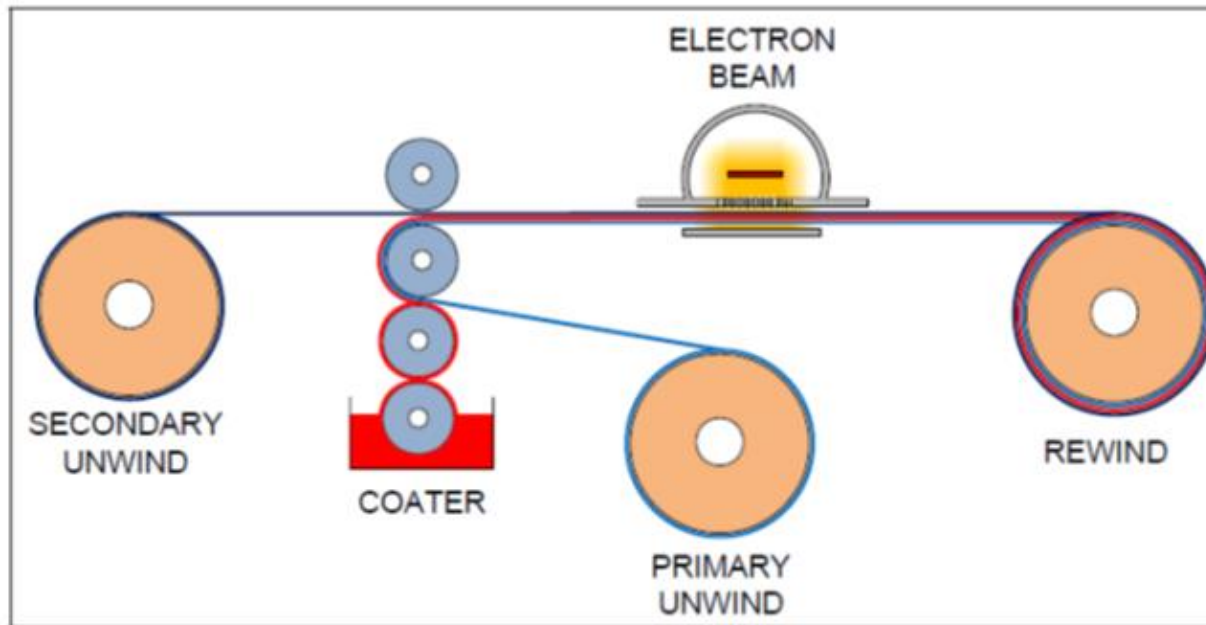


Figure 5. Adhesive Laminating

(PCT-Flyer)

# Electron Beam Processing – „Non-thermal“

Direct Coating (Lacquers, Dyes, Inks) of Sheets, Webs, 3D-Products

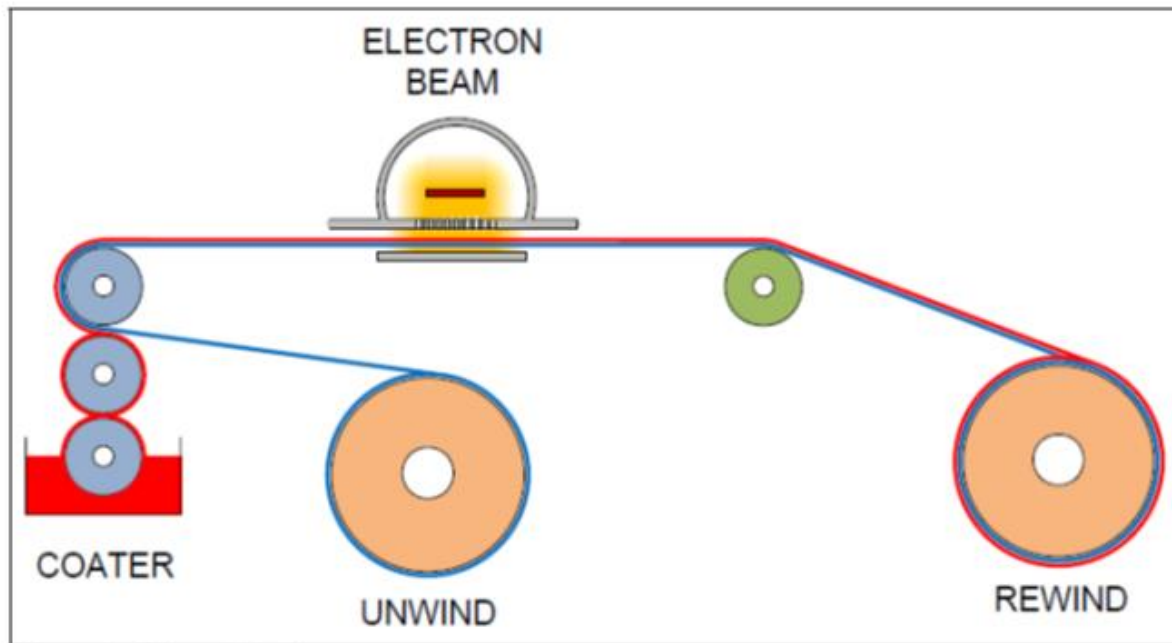


Figure 4. Direct Coating

(PCT-Flyer)



# Electron Beam Processing – „Non-thermal“

## Transfer Coating

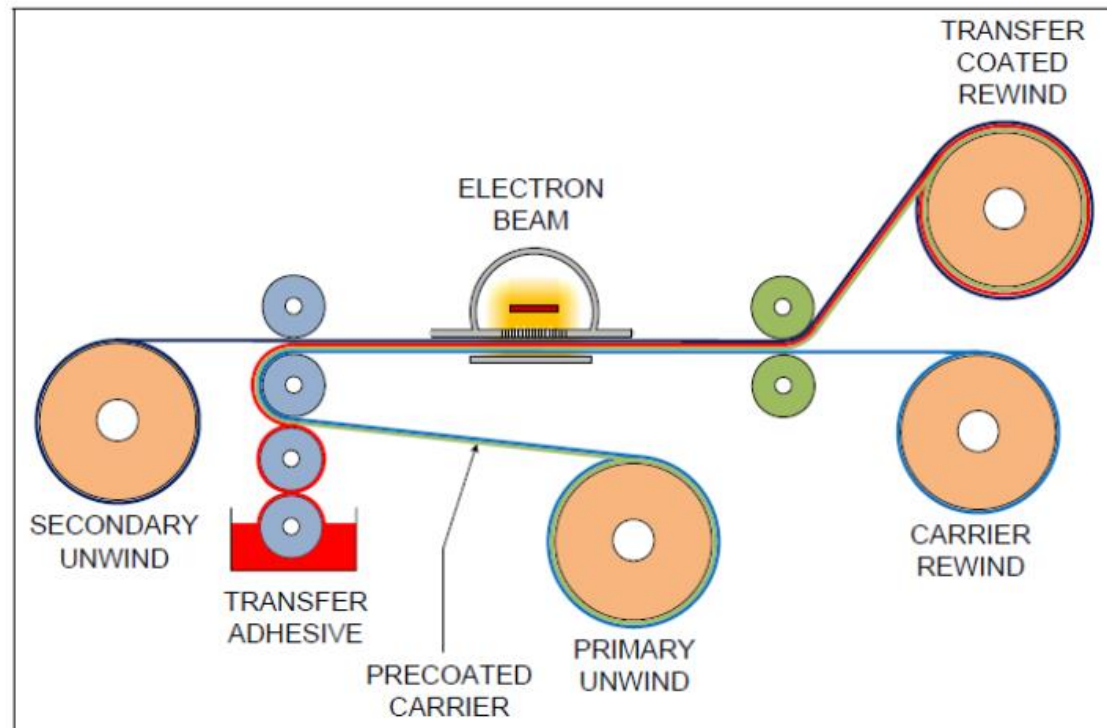
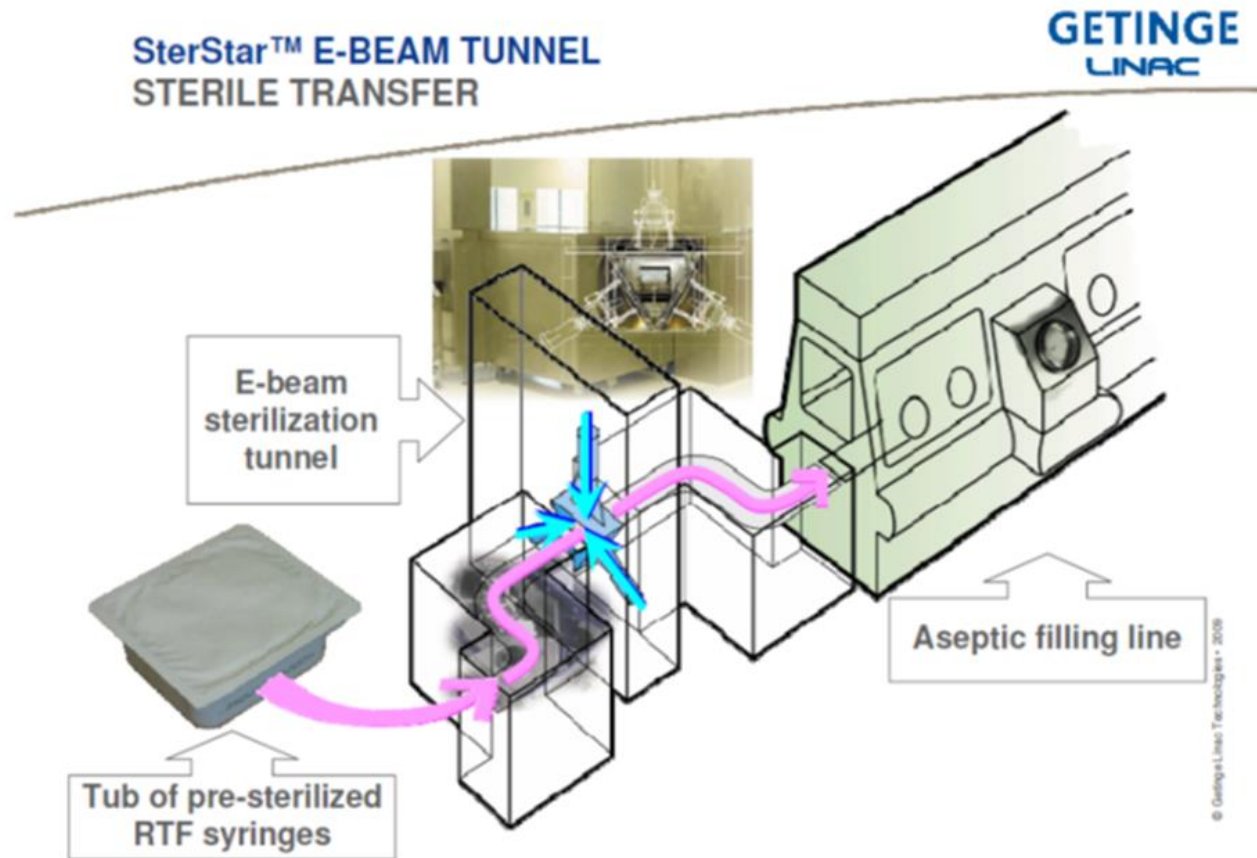


Figure 6. Transfer Coating

(PCT-Flyer)

# Electron Beam Processing – „Non-thermal“

## Sterilization of Pharmaceutical Syringe Filling Tubs



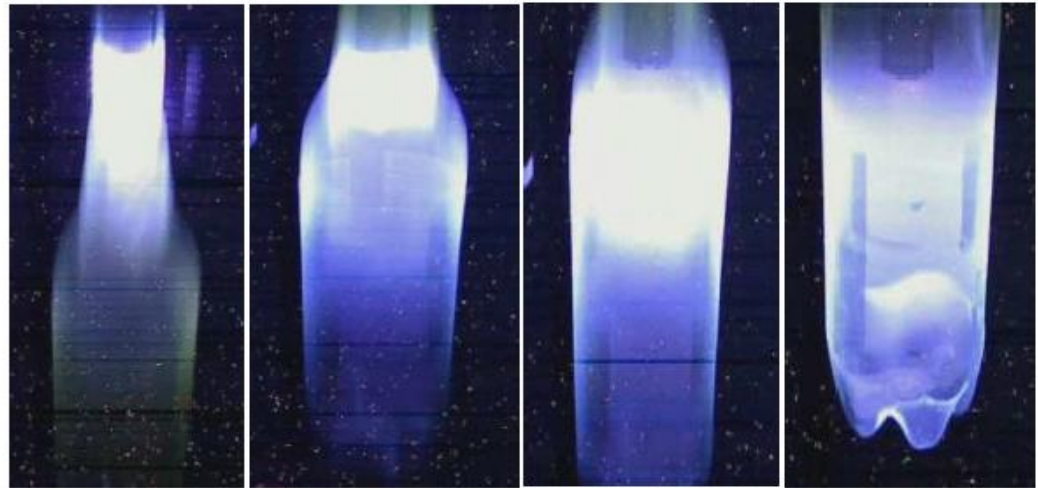
# Electron Beam Processing – „Non-thermal“

## Sterilization of Bottles for aseptic filling lines



EB-glowing atmosphere in preformed 1,5 L PET bottles.

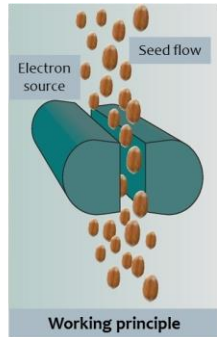
Throughput 1 bottle/sec,  
Sterility Assurance Level (SAL)  $10^{-6}$   
(25 kGy)



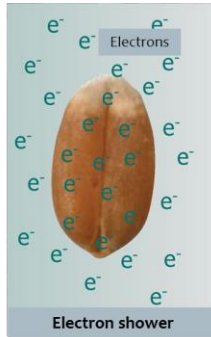
Source: Kronen AG, Hitachi Zosen Corp.

# Electron Beam Processing – „Non-thermal“

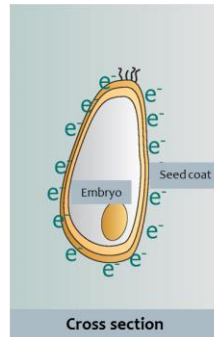
## Seed treatment for disinfection



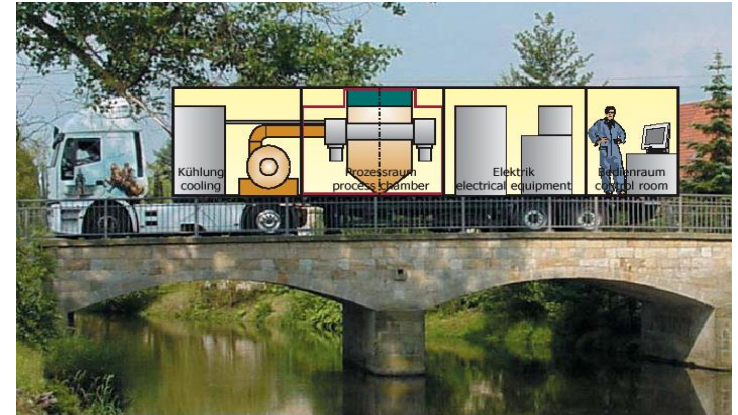
- Working principle**
- Acceleration of electrons
  - Gapping and singling of seed



- Electron shower**
- All-over exposure by electrons
  - Disinfection of total surface layer



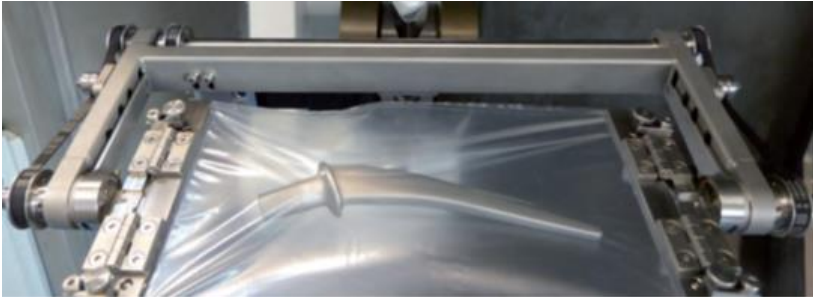
- Cross section**
- Penetration of epispem by electrons with precise depth control
  - Embryo keeps untouched



2 FEP emitters  
 100 – 145 keV, 5 – 200 mA,  
 12 kGy / 20 – 25 tons/hour,  
 diverse seeds

# Electron Beam Processing – „Non-thermal“

On-site sterilization of medical products – SteriHealth®



- demo-status available
- ready for implementation steps



- miniaturized eb-source
- available on-demand and on-site
- ready for new theranostic implants
- dose monitoring
- limited by geometrical reasons

# Electron Beam Processing – „Thermal“

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#### Vacuum

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- Melting
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- Hardening
- Micro- structuring

### Non-thermal Processes

#### Chemical Reactions

#### Biocidal Effects

#### Atmosphere

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# Electron Beam Processing – „Thermal“

Remelting / refining of metals



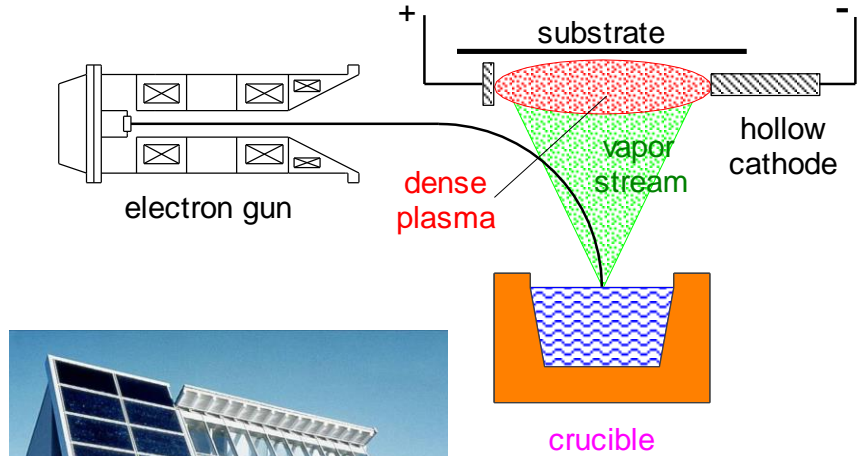
- 20 - 40 keV
- 0.8 – 3.6 MW
- Refractory metals
- Super alloys



Source: [www.dirctindustry.com](http://www.dirctindustry.com), [www.stc-paton.com](http://www.stc-paton.com), [www.ald-vt.de](http://www.ald-vt.de)

# Electron Beam Processing – „Thermal“

## PVD coating by evaporation



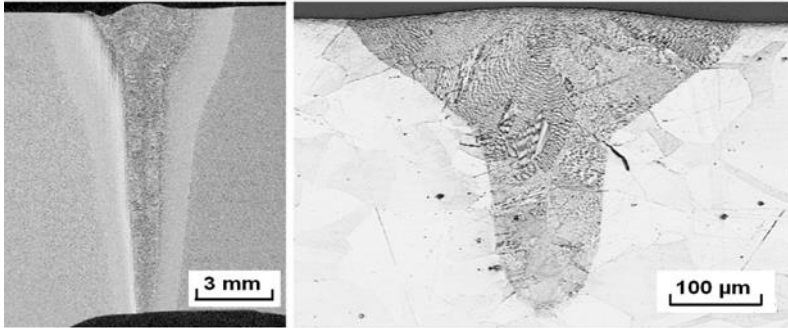


# Electron Beam Processing – „Thermal“

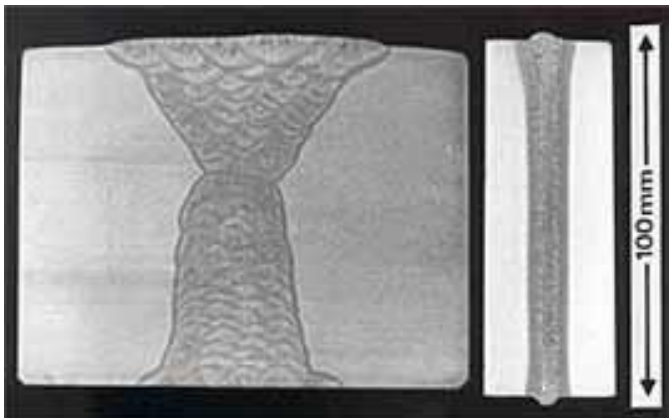
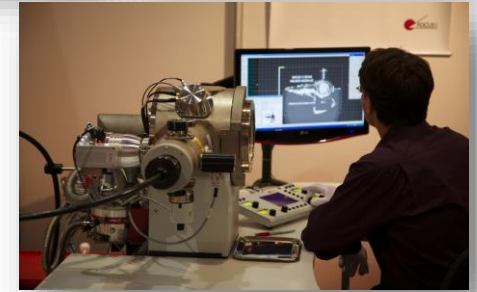
## Welding / Joining / Engraving

EB Deep-Welding

EB Micro-Welding



one tool -  
different scales,  
thousand  
possibilities



MAW welding

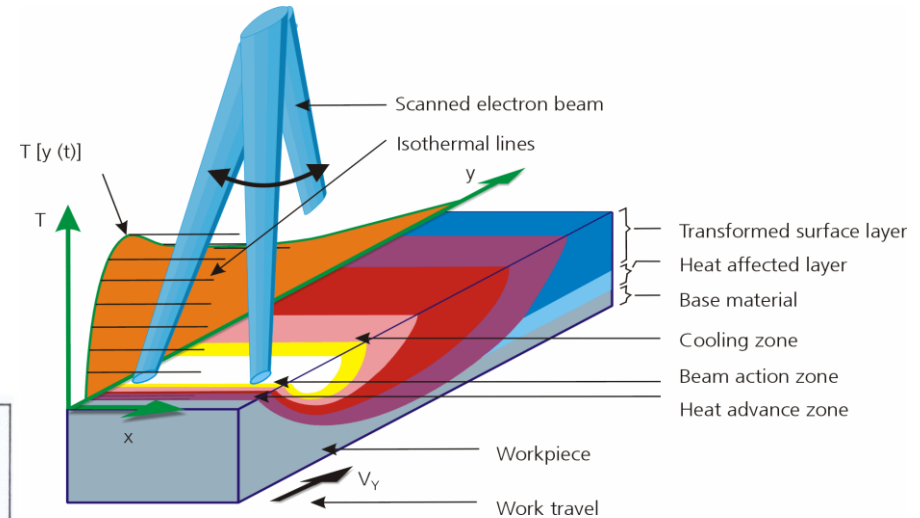
eb-welding



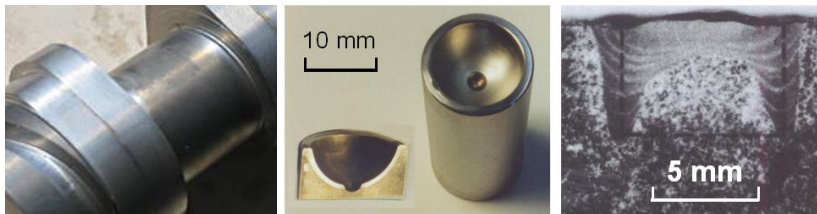
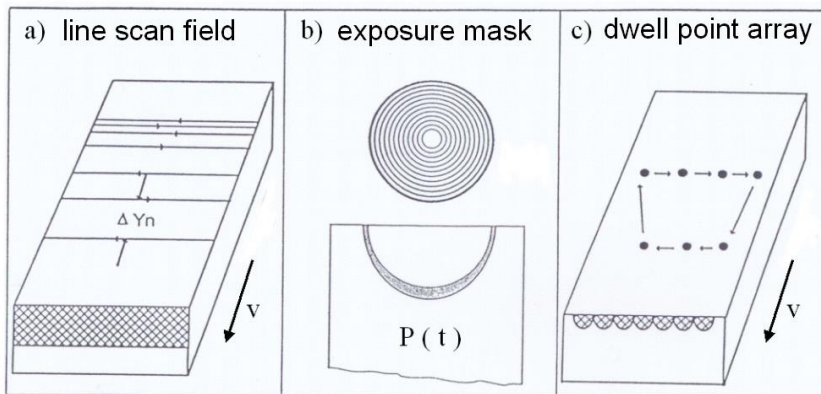
Source: [www.twi-global.com](http://www.twi-global.com), probeam, Steigerwald Strahltechnik, Focus

# Electron Beam Processing – „Thermal“

## Surface hardening / melt refining

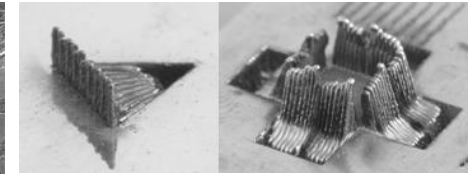
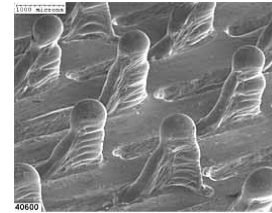
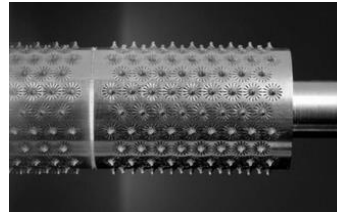


- Partial surface hardening
- Surface heating only
- Self quenching

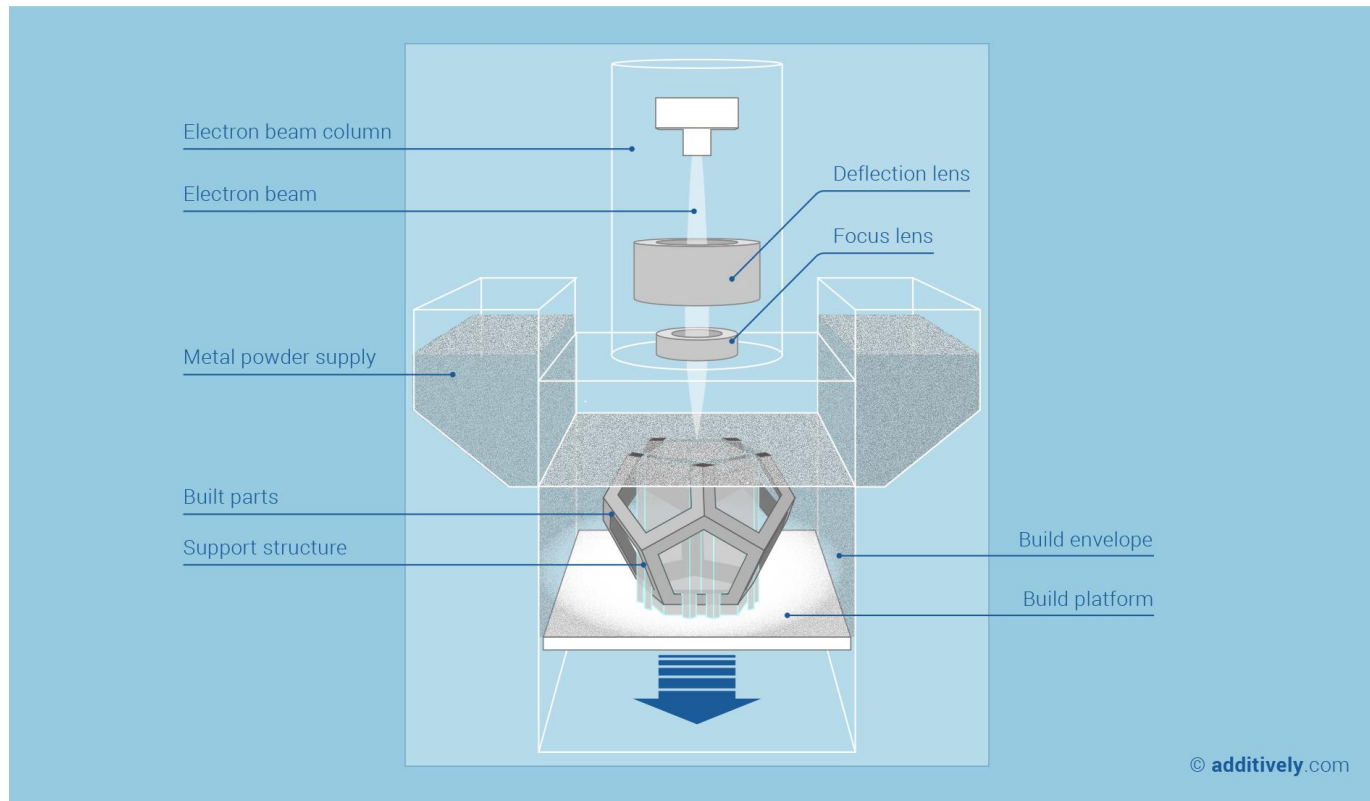


# Electron Beam Processing – „Thermal“

## Additive manufacturing



Your partner for certifiable additive manufacturing solutions



# Summary

- Electron beam technology is an **all-round tool** for application in different branches
- Processing by electron beam means:
  - energy efficiency
  - very high processing speed
  - environmental friendly
  - long term stability
  - Vacuum or non-vac processing
- We are ready to develop **your** special electron beam technology
  - Feasibility study
  - Technology development
  - Key component delivery

# Very-Low-Energy Electron Beam Processes

## Our Expertise – Your Benefit!

Frank-Holm Rögner

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