VACUUM AND MULTIPLE INSULATING GLASS UNITS: A COMPARISON

European Smart Windows Conference

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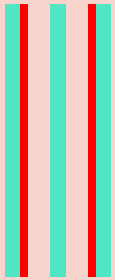
AGENDA

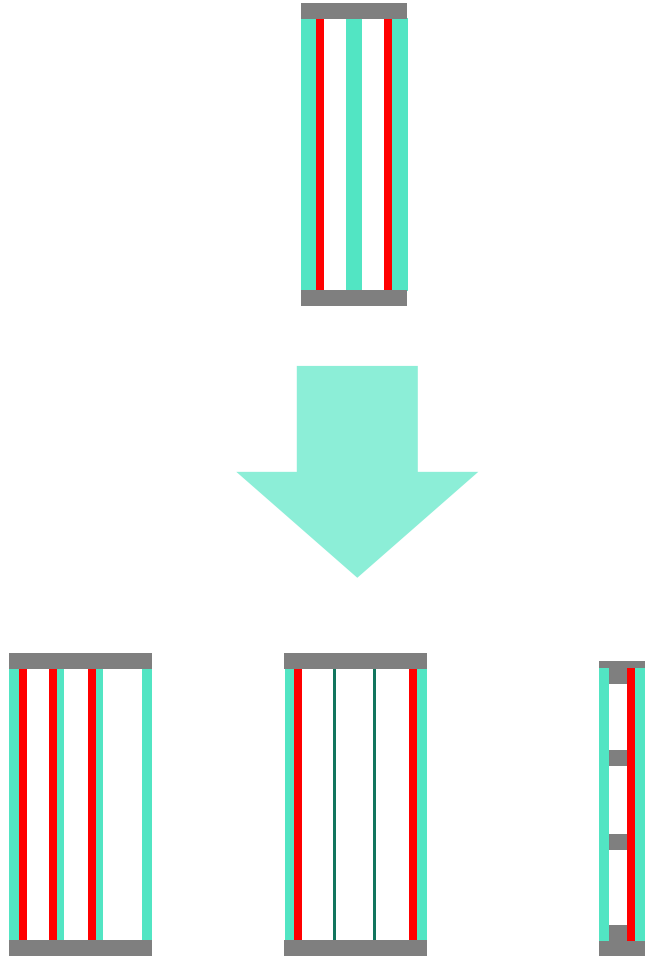
- Evolution of insulating glass
- Multiple insulating glass units
- Vacuum insulation glazing
  - Rigid edge seal
  - Flexible edge seal

Evolution of insulating glass

System	Single pane 4 mm	Double pane 4/12L/4	Insulation glazing 4/ 16Ar/ 4	Triple pane 4/ 12Ar(Kr)/ 4/ 12Ar(Kr)/ 4	Wall 200 mm mineral wool
Geometry					
Ug [W/ m^2K]	4.7	2.7	1.1	0.7 (0.5)	0.15
L_T [%]	91	84	80	71 (75)	0
g [%]	87	77	62	51 (64)	0
weight [kg/m^2]	10	20	20	30	

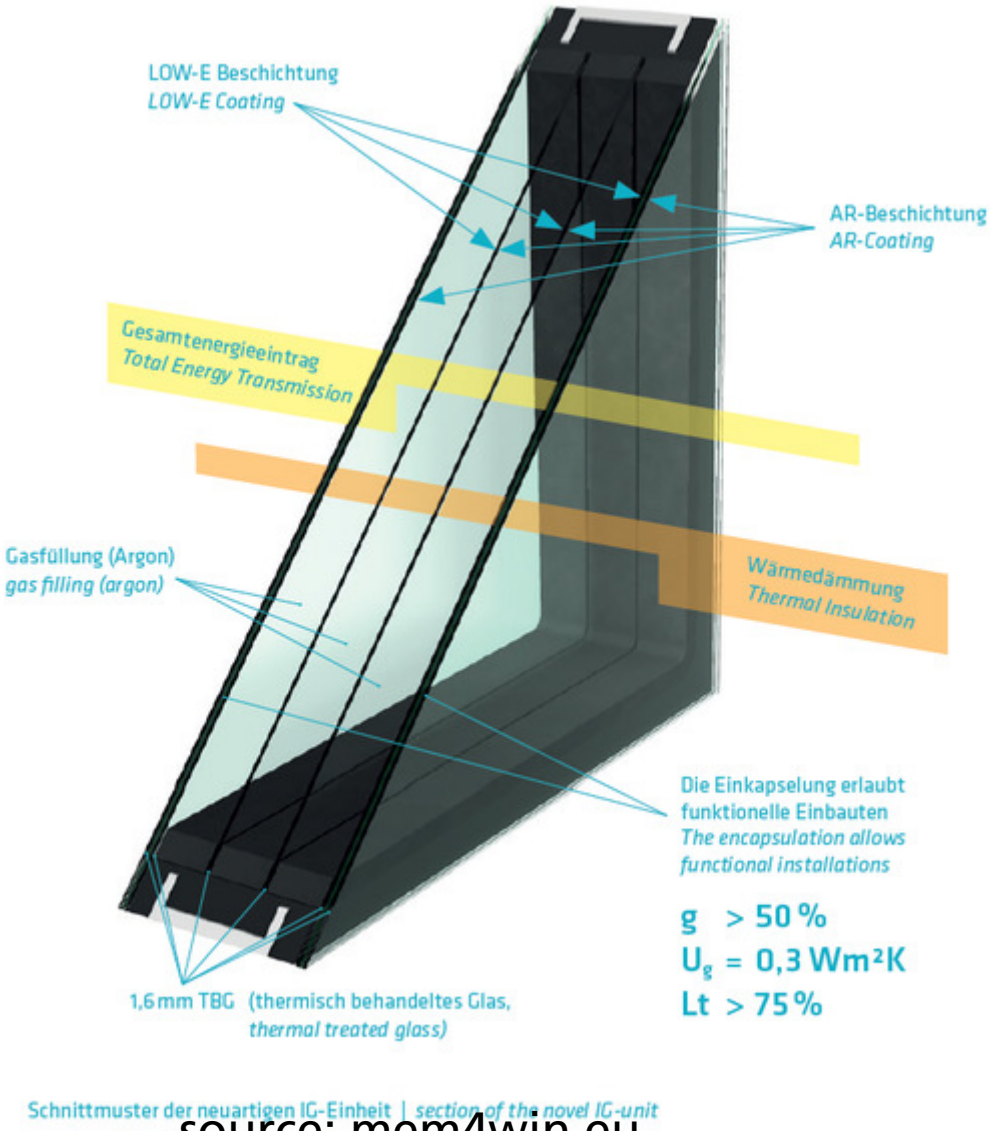
Beyond commercial triple glazing

- Triple glazing are industrial state of the art
- Potential for impromentt:
  - lower Ug
  - higher L_T and g-value
  - lower weight
  - lower thickness
- Approaches
  - slim quadruple glazing
  - application of films in spacer
  - vacuum insulation glazing



Slim quadruple glazing

- Approach: thin heat treated glass (2mm) for the two center panes
- Lightweight: better than standard triple glazing
- Ug = 0.3 W/m²K
- L_T and g optimized using AR layers: L_T >75%, g>50%
- Under development by Mem4Win consortium
- Integration of smart technology
- Close to commercialisation; similar product by energy glass



source: mem4win.eu

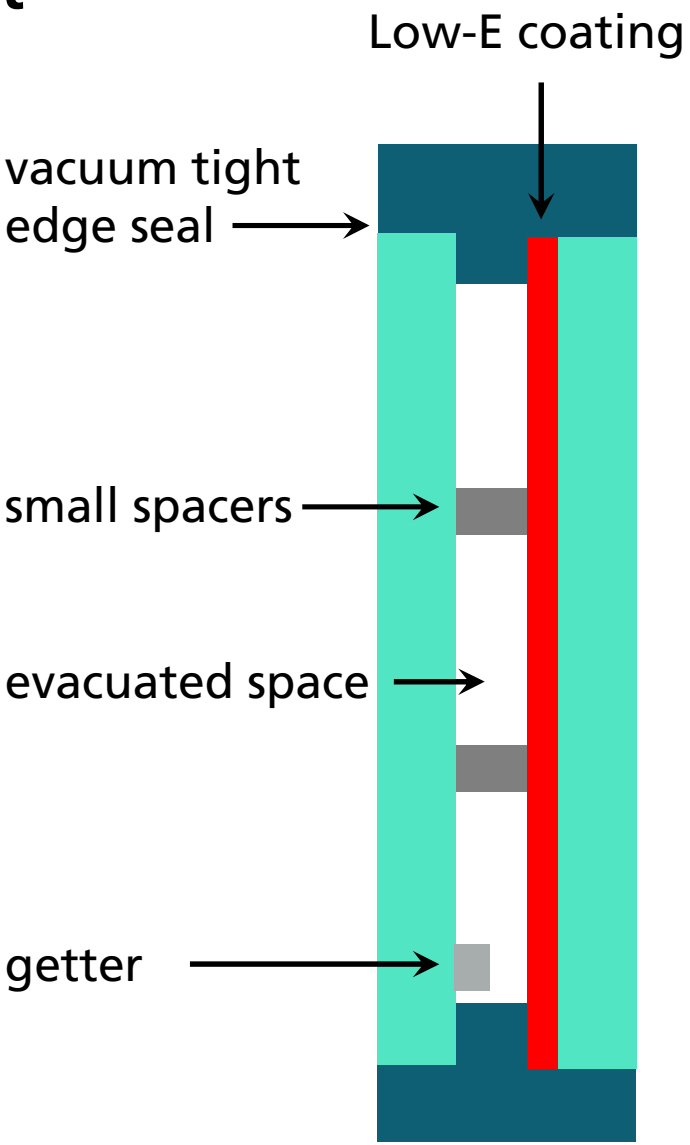
Quadruple glazing incorporating films

- Approach: Films in place of glass for center panes
- Almost same weight as double glazing
- Smaller thickness than quadruple glazing
- Ug = 0.3 W/m^{2}K for two films
- L_T and g below quadruple glazing
- Durability and mechanical stability of foil essential
- Similar system available in US

source: energyin.cz

Vacuum insulation glazing – concept

- Space between panes pumped to <1e-3 mbar
- Small spacers and vacuum-tight edge seal required
- Very slim set-up: 7-9 mm thickness
- Very light: same weight as double glazing
- Ug ~0.3-0.5 W/m^{2}K
- High L_T and g-value possible as for double glazing
- Application possible both in new buildings and for retrofitted existing windows

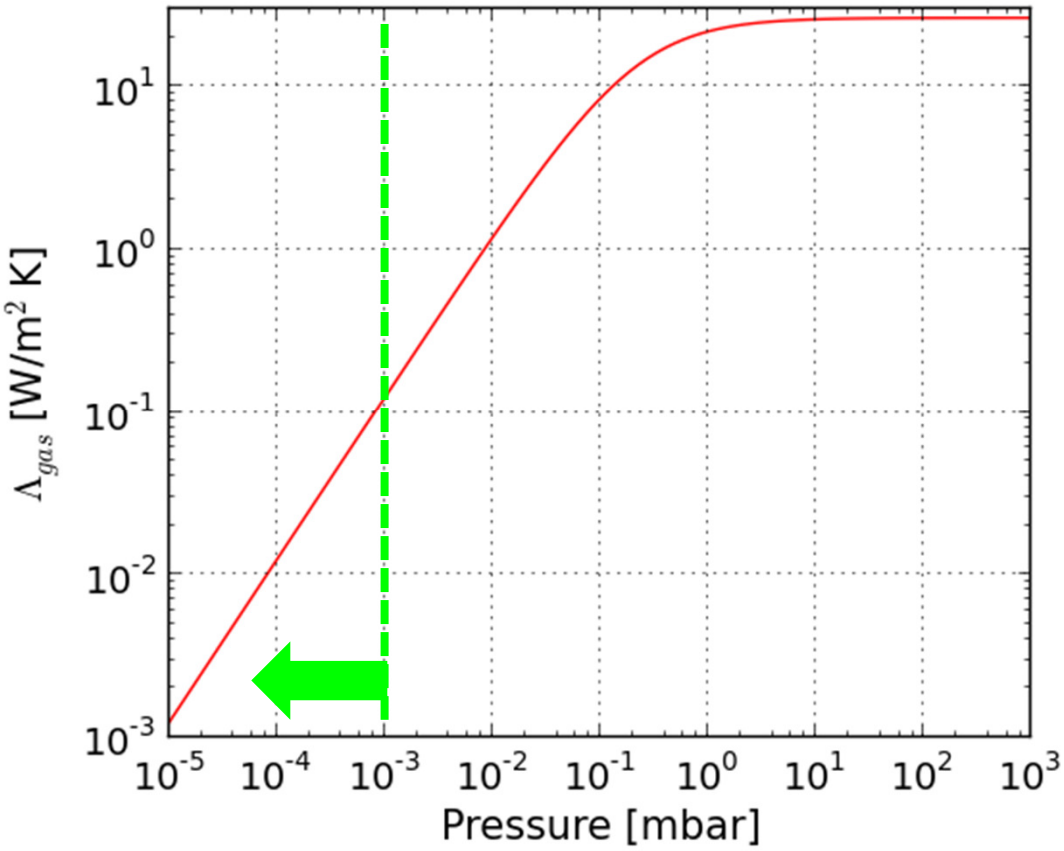


VIG – Heat transfer mechanisms

- Residual gas conduction
- Spacers
- Radiation
- Edge seal / frame

- Frame design very important

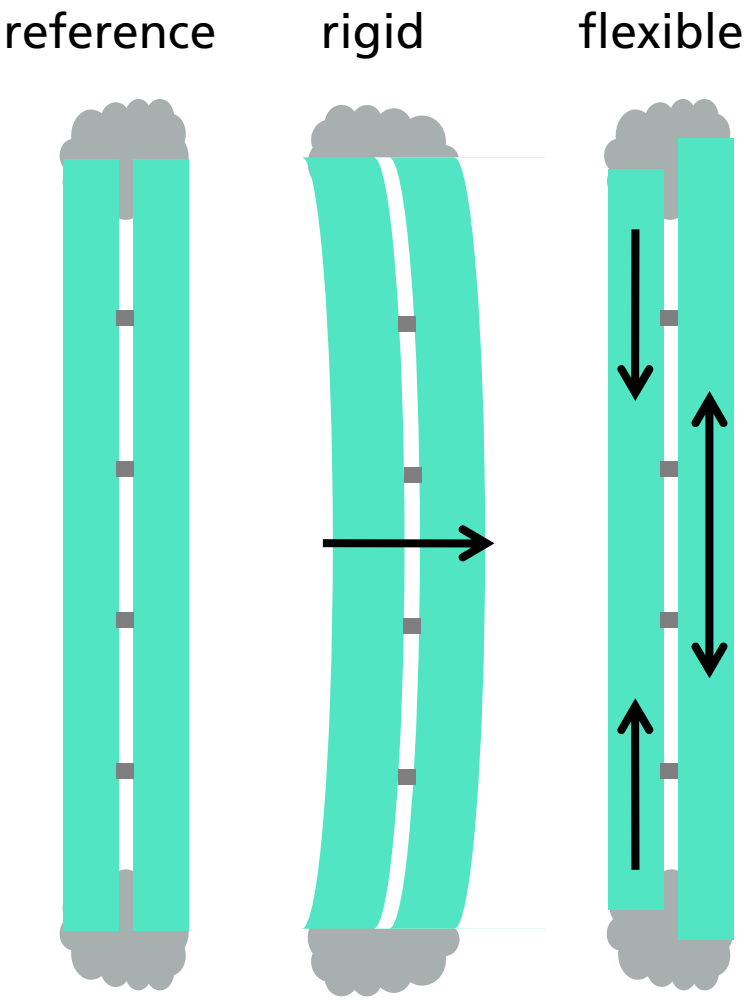
Gas conduction for 1 mm spacing



VIG – Edge sealing concepts

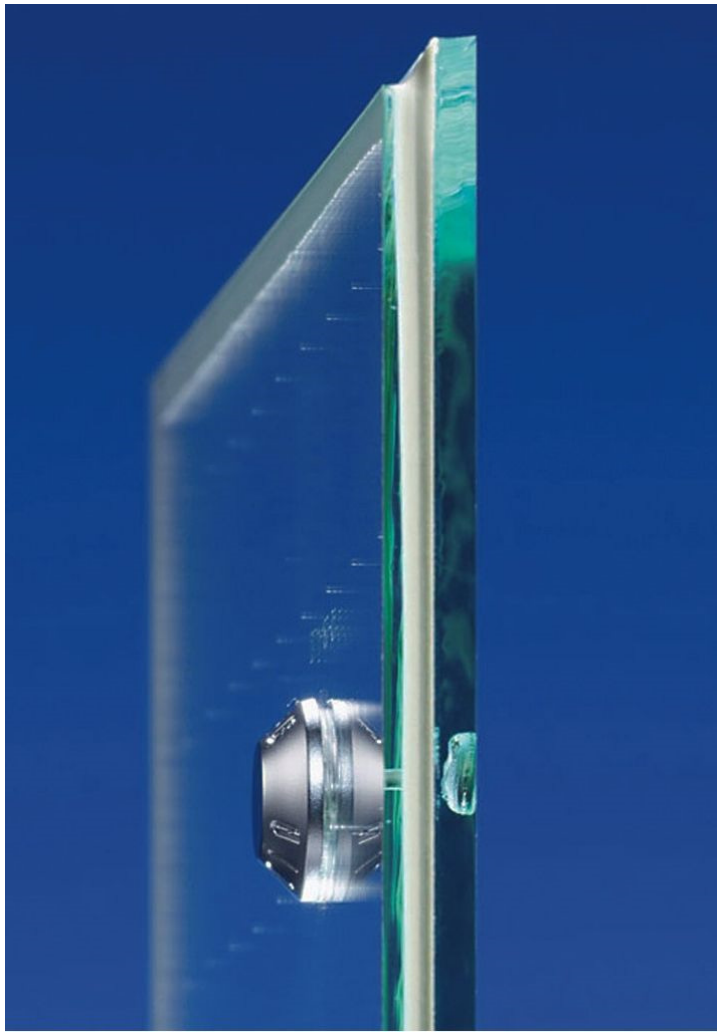
- Rigid versus flexible edge seal
- With soda lime glass and ΔT=50 K differential dilation of 0.5 mm per m
- Rigid edge seal leads to bending of both glass sheets
- Flexible edge seal absorbs differential dilation, glass slides over spacers
- Thermal losses over edge seal

VIG with rigid and flexible edge seal under thermal load



VIG with glass solder – conventional approach

- Conventional approach
  - High process temperature for melting glass solder
  - Degassing after soldering => visible pumping port
  - Use of hard coat low-E => Ug ~1.0 W/m^2K
  - Commercially available from various manufacturers (NSG, Synergy, …)



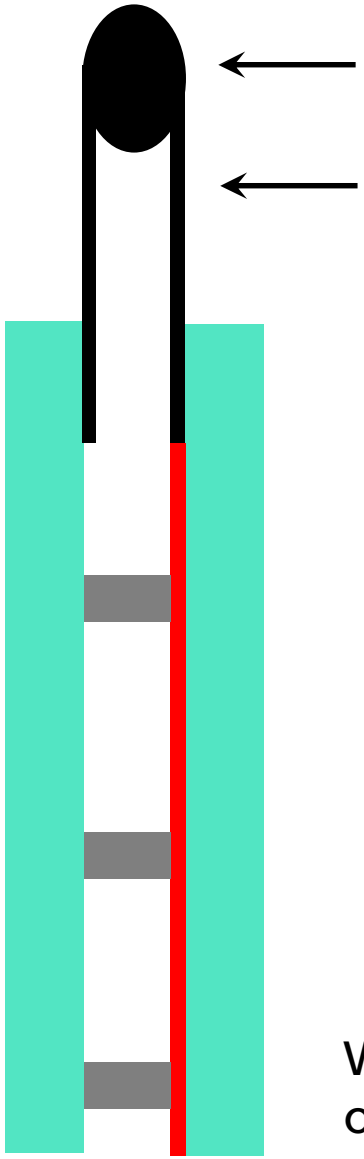
source: pilkington.com

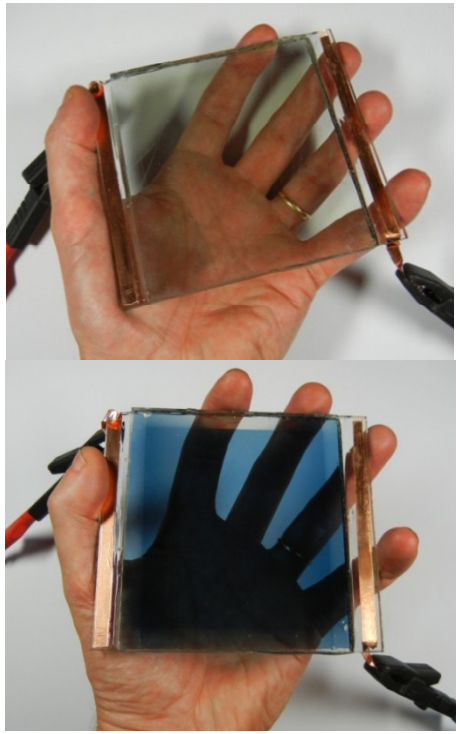
VIG with glass solder – recent work

- By decreasing process temperature, time and/or custom soft coat low-E: Ug~0.5 W/m²K possible
- According to Synergy:
  - Ug ~0.43 W/m²K
  - L_T = 64%
  - g-value: 42%
  - Total thickness down to 6 mm
  - Size 2.8 x 1.8 m2 can be produced
  - hardened glass
- Integration in hybrid glazing recommended

VIG with flexible edge seal

- Concept: Thin metal ribbon attached to glass pane in air
- Two glass panes with ribbon aligned in vacuum and laser-welded
- Goal: large-size stand-alone VIG
- Various concepts for glass-to-metal bonding:
  - Anodic bonding (WinSmart)
  - Ultrasonic soldering (VIG-S)
  - Thermal soldering (VIG-S)
- Similar approaches: EverSeal, …

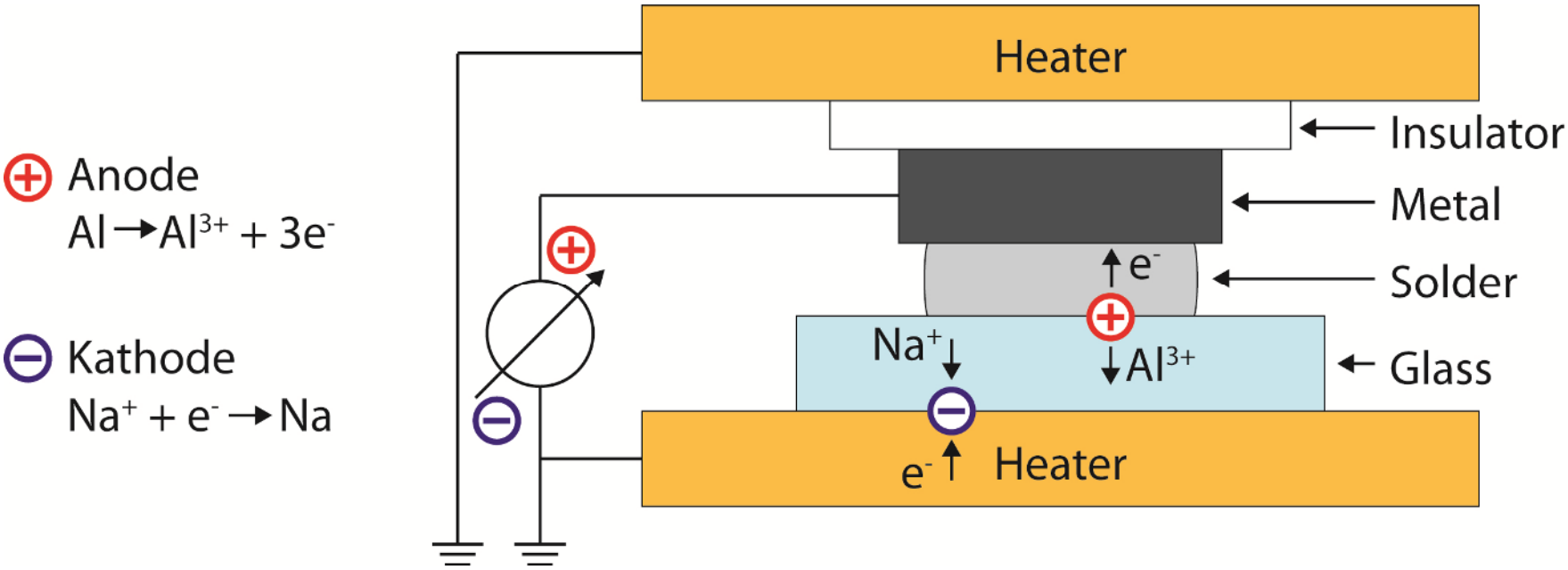




WinSmart: combination of VIG with smart switchable elements

Activated Liquid Tin Solder Anodic Bonding (ALTSAB)

- Approach followed within Project WinSmart
- Courtesy of Wim J. Malfait and Matthias M. Koebel, EMPA



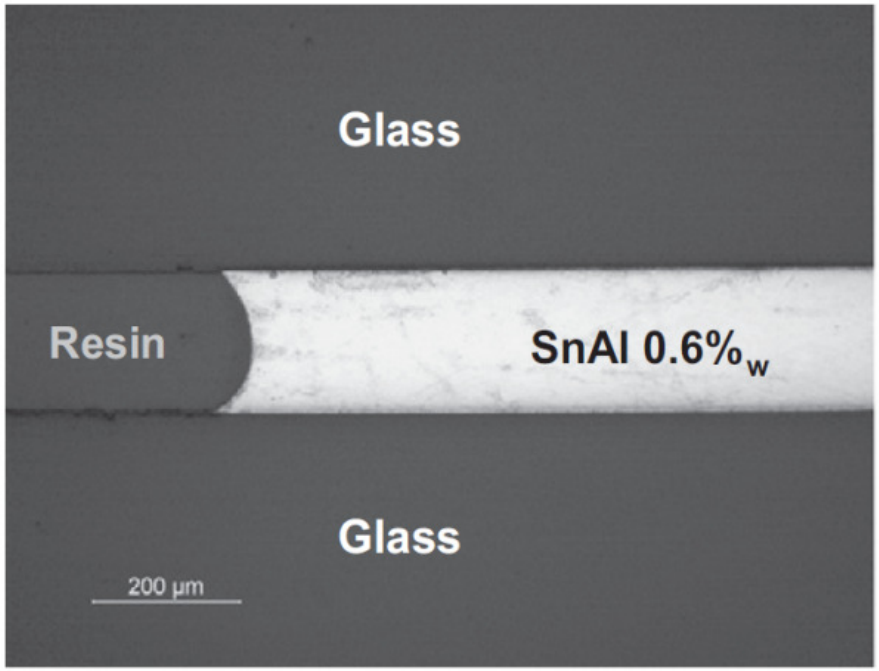
Koebel et al. (2011) Solar Energy Materials & Solar Cells

US 2011/0151157 A1: "Composite object and method for the production thereof"

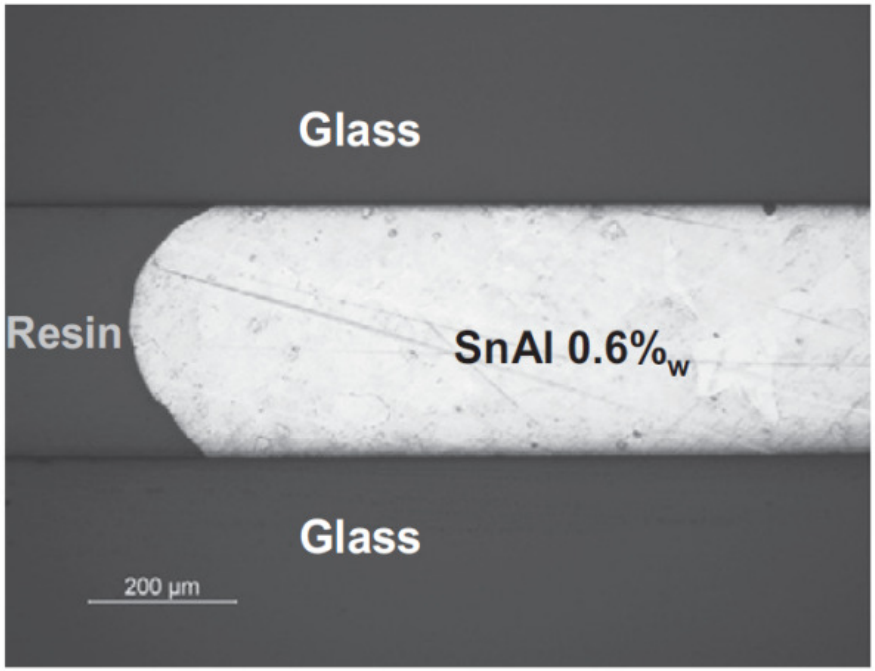
Anodic Bonding – Wetting behaviour

- Application of high voltage enhances wetting of glass

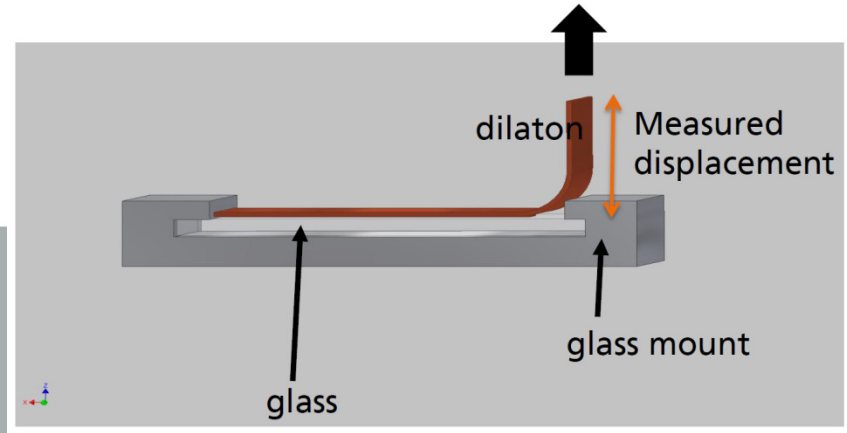
With high voltage



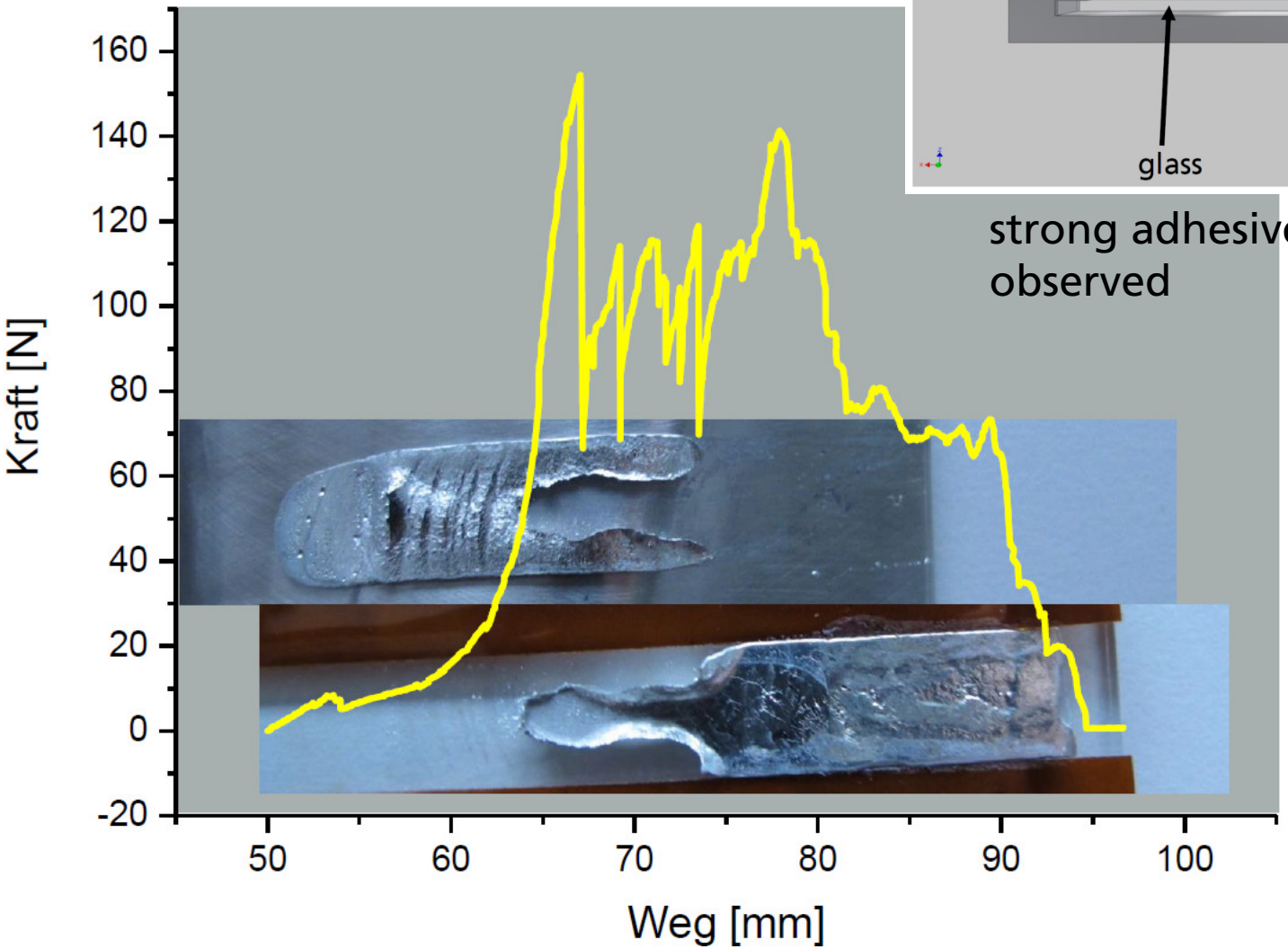
Without high voltage



Anodic Bonding – Adhesion



strong adhesive forces observed

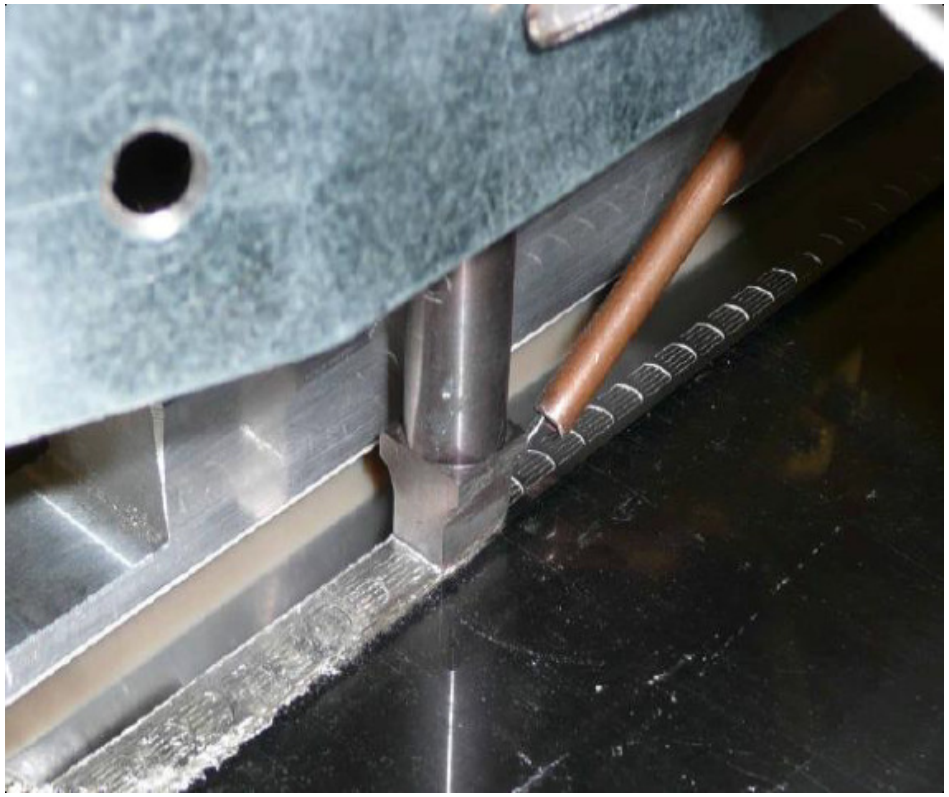


images and characterization courtesy of Fraunhofer IWM

Ultrasonic soldering

- Glass pre-tinned using ultrasonic soldering and active solder
- Metal ribbon attached to glass using ultrasonic or thermal soldering

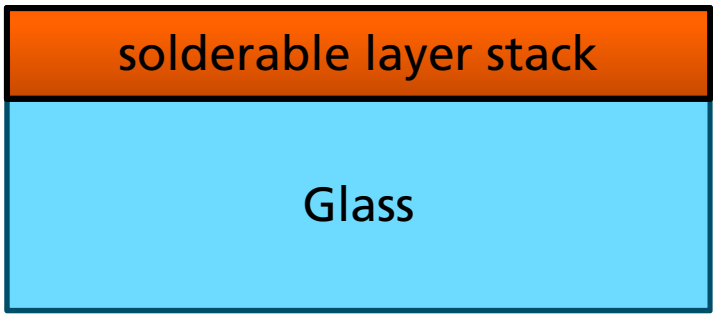
Ultrasonic soldering of metal ribbon

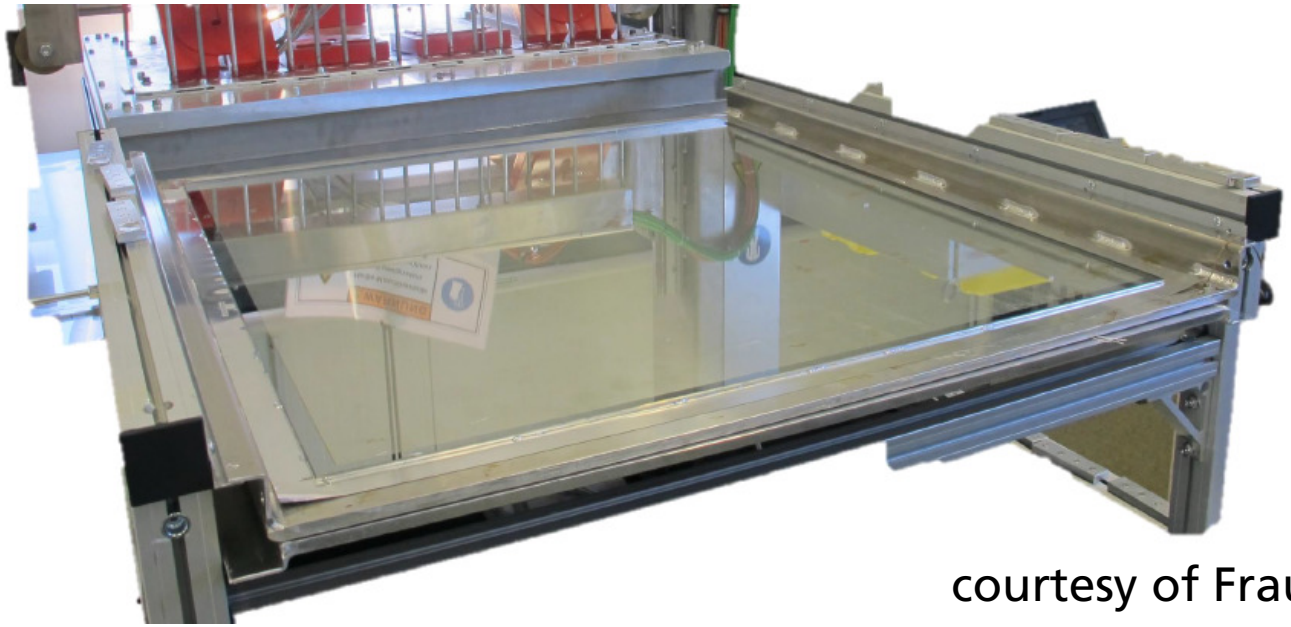


courtesy of ZAE Bayern

Thermal soldering

- Approach: solderable layer stack deposited by PVD on glass
- Hot plate soldering of metal ribbon onto glass using lead-free solder



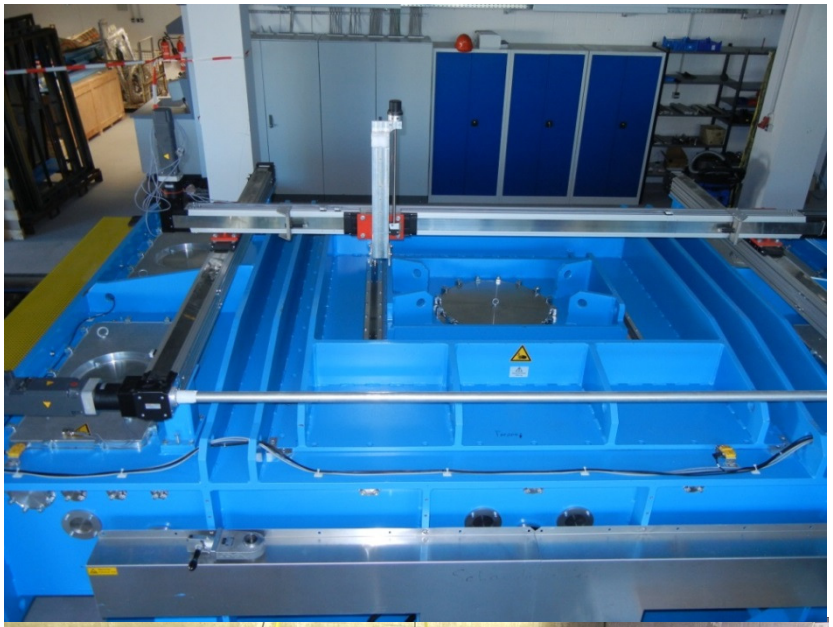


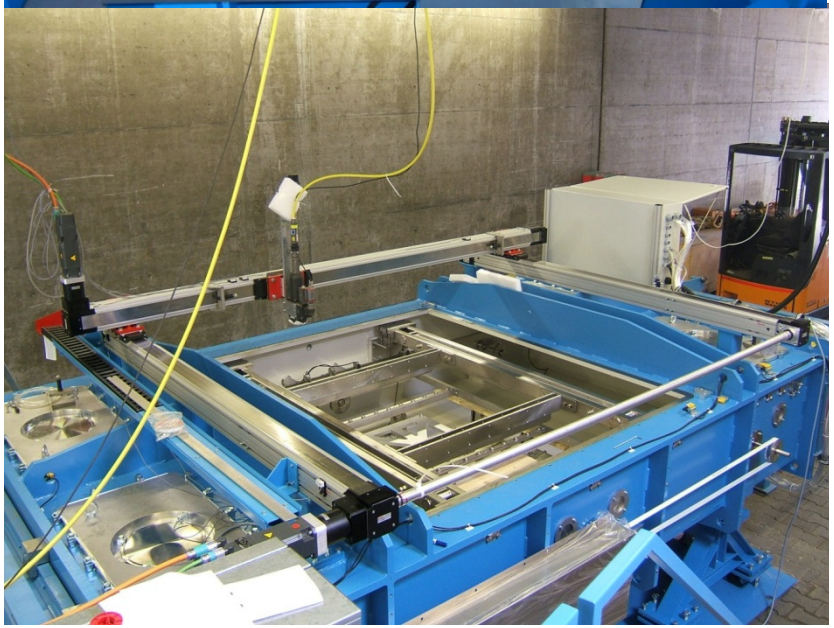
thermal soldering test stand

courtesy of Fraunhofer IWM

Laser welding

- Alignement of two glass panes with metal ribbon in vacuum
- Fast degassing by plasma etching
- Laser welding through vacuum window inside chamber

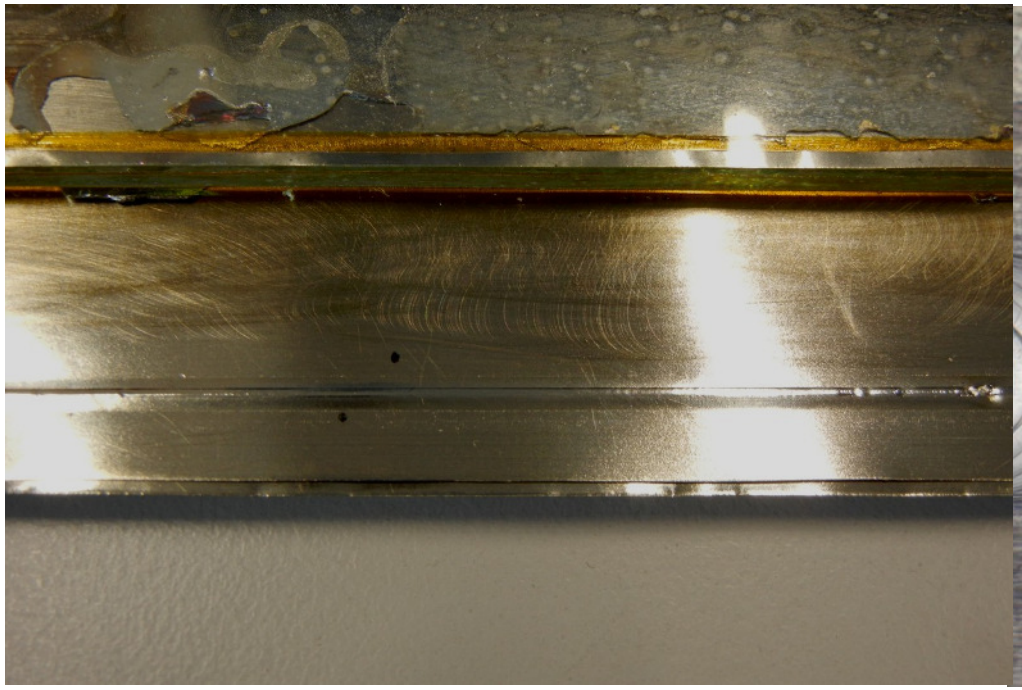




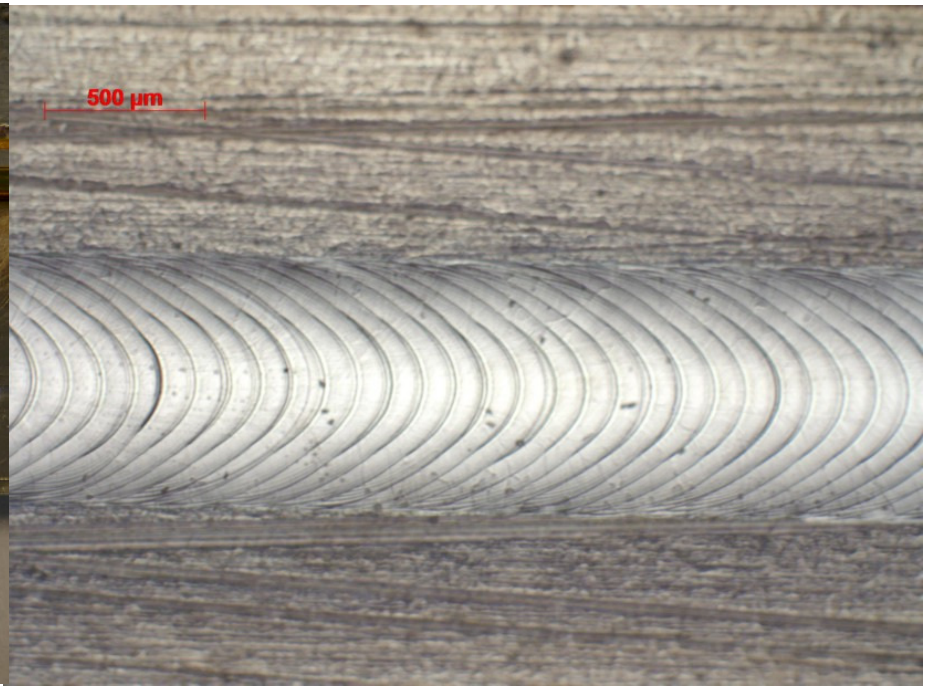
WIN SMART VIGS Fraunhofer ISE

Laser welding

- Planarity of metal ribbons after bonding to glass crucial for welding



good welding seam

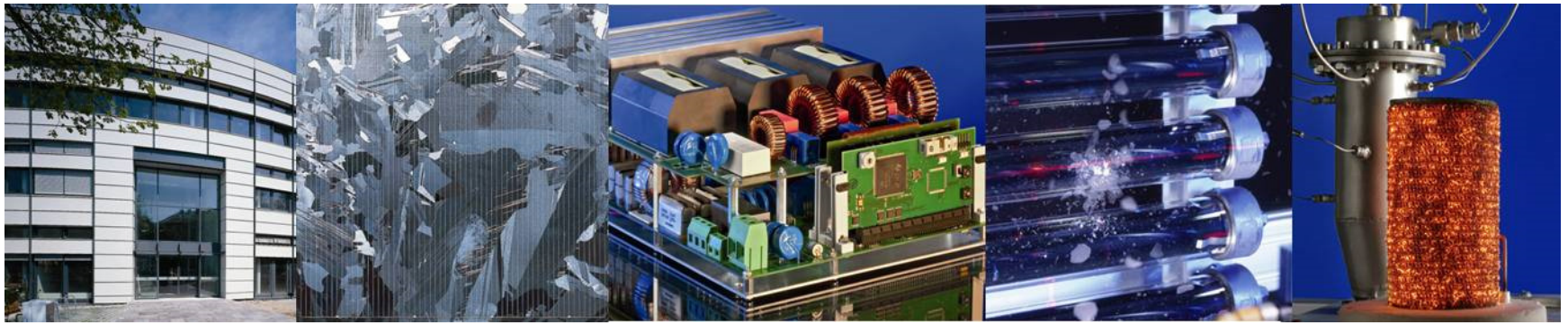


welding seam in optical microscope

Conclusion

- Future developments in insulating glazing hold great promise
- Novel quadruple glazing offers very good Ug and L_T for relatively low weight; close to commercialization
- VIG very attractive due to extremely slim design, in particular for retrofitting
- First large size and low Ug VIGs with rigid edge seal coming to the market
- Flexible edge seal could unleash potential for large scale stand-alone VIGs. Development ongoing…

Thank you for your attention!



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