



# e-Mobility Applications of Nanocrystalline (NC) Materials

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Materials & Components

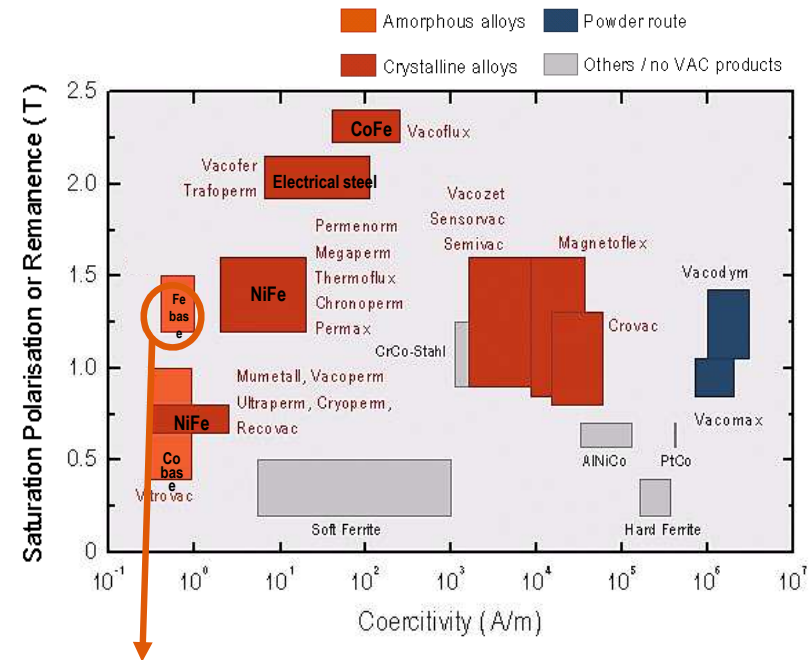


# VAC: Global leader in magnetic materials



## Who we are

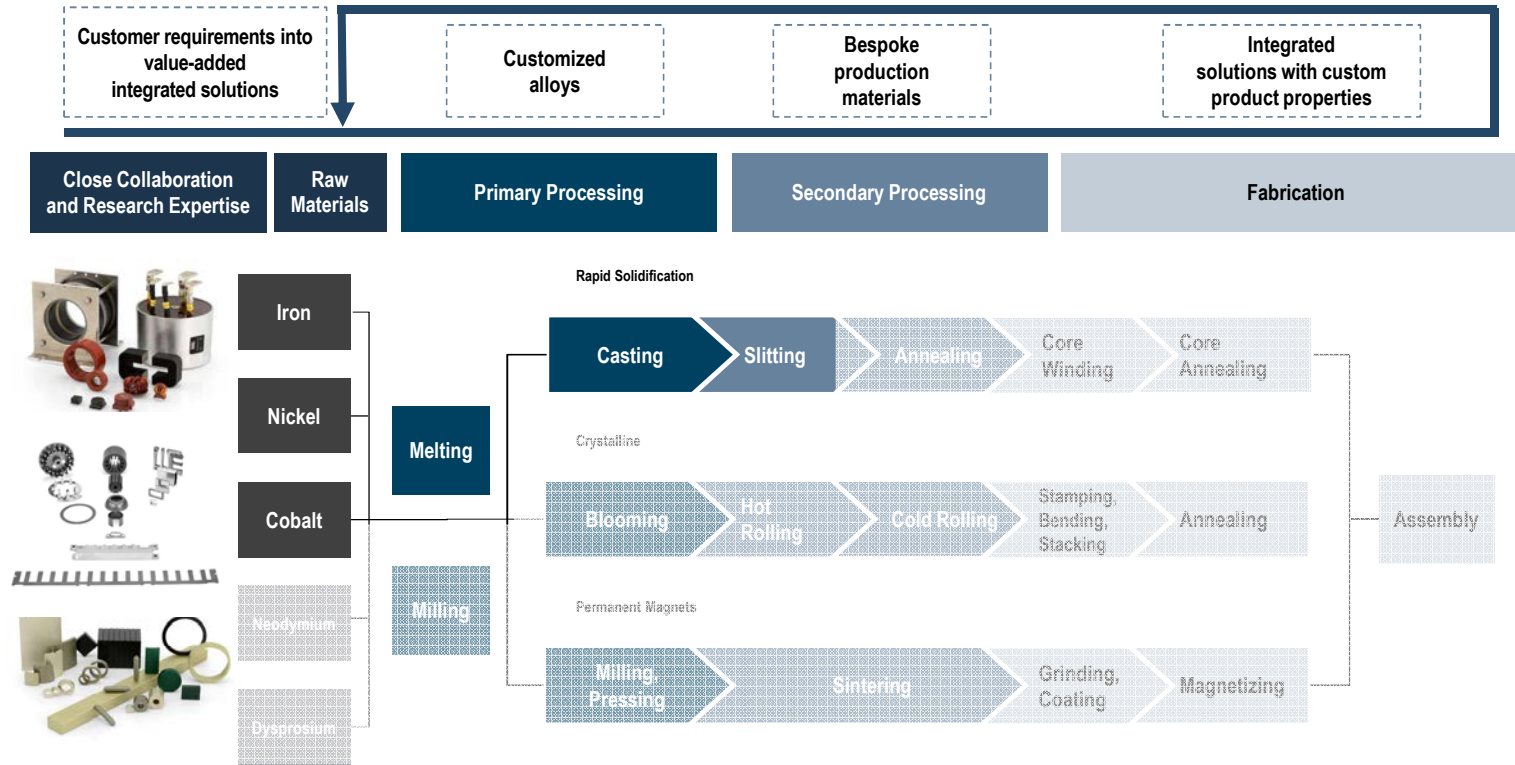
- VAC's portfolio of magnetic materials consists of more than 120 different alloys and materials
- VAC produces the full range of magnetic materials of soft, semihard and permanent magnetic materials
- Several key materials are developed by VAC
- VAC has production know how for all important key production technologies used for magnetic materials
  - Rapid solidification technology for amorphous and nanocrystalline materials
  - Melting and hot & cold rolling of crystalline materials
  - Powder technology for permanent magnets



**VITROPERM®** → Nanocrystalline alloy  
→ High saturation polarization  
& low coercivity

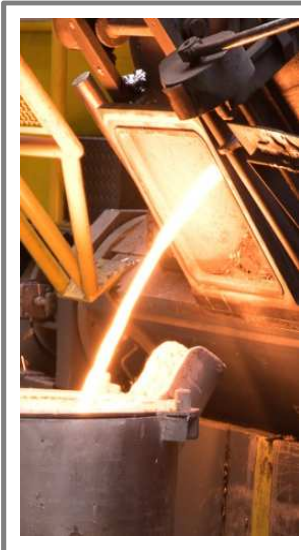
# VAC Value Chain Integration

- Collaborative design process with clients to develop customized products specified to their long-term needs

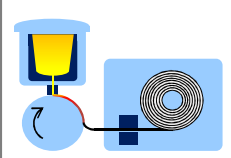


VAC features a close-knit and client-focused design and production process

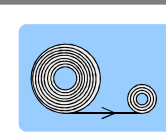
# Production Process of Amorphous Foils at



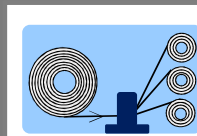
melting



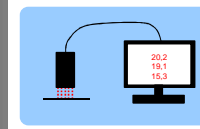
casting



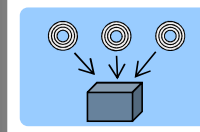
coil winding



slitting



inspection



packaging



# Impact of Productions Steps on Quality

## Melting:

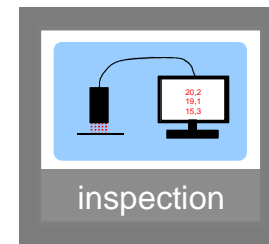
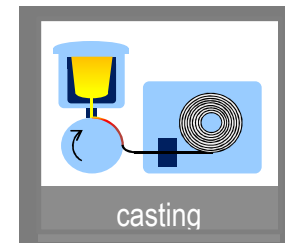
- Homogeneous chemical composition → saturation flux density  $B_s$
- Vacuum treatment → high purity & consistent composition

## Casting:

- uniform thickness
- high surface quality
- excellent ductility

## Testing

- Testing of magnetic properties for each batch:  $B_s$  and permeability  $\mu$
- Testing of width, thickness, ductility & surface quality for each coil
- High quality ensures reliable and consistent material supply for wireless power transfer (WPT) applications



# Nanocrystalline Material is VITROPERM<sup>®</sup>



# Nanocrystalline VITROPERM®

## Unique combination of material properties

- VAC was one of the **first companies in the world** starting mass production of nanocrystalline VITROPERM® in 1992
- More than **25 years experience** in the production of amorphous and nanocrystalline materials
- VAC developed **VITROPERM®** to a widely diversified **Nanocrystalline material** family covering a wide range of properties and requirements
- VAC is under development of nanocrystalline materials of the **next generation** with
  - Higher saturation flux density
  - Lower losses
  - Thinner ribbon thickness



Key properties	VITROPERM
Material base	≈ 70 % Fe
Saturation flux density $B_s$ [T]	> 1.2
Adjustable permeability $\mu_i$	4,000 – 200,000 (F), 1,000,000 (Z), Max. 600,000 (R)
Coercivity $H_c$ [A/m]	0,5
Losses $P_{Fe}$ [W/kg] (100 kHz/300mT/100 °C)	< 80
Saturation magnetostriction $\lambda_s$	≈ 0 ( $10^{-8}$ – $10^{-6}$ )
Max. operation temperature $T_{op}$	> 150°C (180°C)

**VITROPERM®** → High saturation flux density  
→ High permeability  
→ Lowest magnetic losses

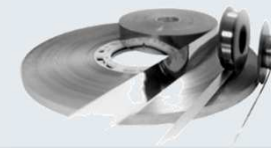
# Nanocrystalline VITROPERM<sup>®</sup> 800

## Key properties vs. other materials

	Nanocrystalline VITROPERM 800	Amorphous FeSiB	Ferrite	
Main composition	FeCuNbSiB (83 wt.% Fe)	Fe(SiB) (85-90 wt.% Fe)	NiZn	MnZn
Saturation flux density $B_s$ [T]	> 1.2	1.4 – 1.6	< 0.35	< 0.45
Saturation magnetostriction $\lambda_s$ [ $10^{-6}$ ]	$\approx 0$	25 - 35	20 - 40	20 - 40
Coercivity $H_c$ [A/m]	0.5 - 1	4 - 10	5 - 15	5 – 15
Thermal conductivity [Wm/K]	10	12	1 - 3	1 - 3
Losses $P_{Fe, typ.}$ [W/kg] (100 kHz, 200 mT)	< 35	60		
Max. operation temperature $T_{op}$	> 150°C	< 120°C	< 120°C	< 120°C

**VITROPERM<sup>®</sup>**

- High saturation flux density
- High permeability
- Lowest magnetic losses





# VITROPERM<sup>®</sup> 800 Foil Grades

For cores & components, EMI shielding and Wireless Power Transfer (WPT) applications



Foil thickness:		19 µm	18 µm	17 µm	16 µm
Thickness tolerance	(µm)	± 2	± 3	± 2	± 2
Foil width „as cast“	(mm)	25 – 60	25 - 66	60	25 - 108
„as cast“ width tolerance	(mm)	± 0.5 / ± 1.0			
Foil width „slit“	(mm)	3 - 56	3 - 56	-	3 - 102
„slit“ width tolerance	(mm)	± 0.10 / ± 0.15			

- VAC standard VITROPERM<sup>®</sup> grade - 18 µm - is used for WPT application, too
- Fulfillment of WPT quality requirements are confirmed by several customers
- VAC has best long-term experience of high volume deliveries for WPT applications (since 2014 more than 600 t)
- VAC produces and sells wide ribbons (66 mm and more) since 2013

# Benefits of VITROPERM<sup>®</sup> 800

vs. competitor materials

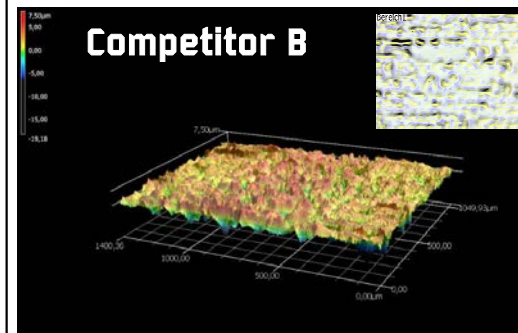
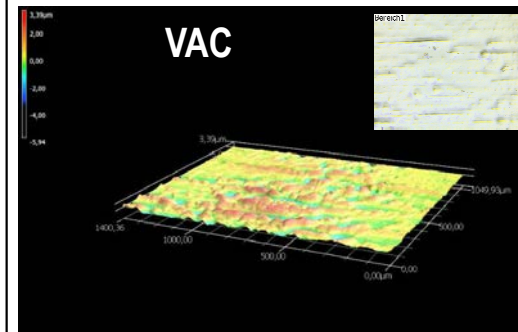
Typical values for some key features		VAC	Competitor A	Competitor B
Brittleness of foil	Ribbon breaks per 100 km	< 3	>100	>10
Holes (size)	Diameter in mm	< 0.3	< 0.3	1-5
Holes (amount)	Counts per km ribbon	< 100	> 1000	> 10000
Surface roughness	Ra (air side)	0.7	0.7	1.1

**VITROPERM<sup>®</sup> is best in class material**

- Highest surface quality
- Lowest size and amount of holes
- Best in class consistency of mechanical properties
- Best homogeneity of chemical composition

## Surface structure of as cast nano foils

3D laser scanning microscope images  
Typical air side surface of nano ribbon



# WPT Applications

# Wireless charging – Applications / Markets

## Wireless Charging Technology



- Wireless charging is a method for transferring electrical energy from a charger to a device without the need for a physical wire connection
  - Requires coupling of wireless charging pad with compatible device with built-in receiver
  - Provides convenience by removing need to physically plug-in device to cable

## Wireless Charging Applications

- Consumer electronics



- Medical devices



- Electric vehicle charging



- Household appliances



- Military/Aviation





# Wireless Charging: Product Differentiation

## Special requirements

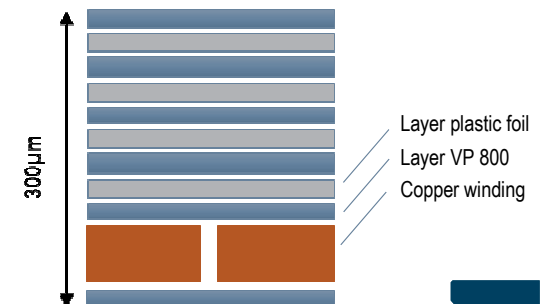
- High ductility in amorphous state
  - Leads to higher yield in processing
- Excellent surface quality
  - No holes or pimples
  - No scratches or splits
  - No wavy surface or rippled edges
- Consistent thickness
  - No wedge shape or thicker edges
- Low stacking thickness
  - High filling factor
  - Trend goes to thinner material
- Flat winding condition of coil
  - No damaged ribbon edges
- Greater foil width
  - 60 mm → 66 mm → 100 mm

## VITROPERM<sup>®</sup> 800 unique selling points

- Outstanding ductility
- Highest surface quality
  - Lowest size and amount of holes
- Best in class consistency of mechanical properties
- Highest filling factor
- Best homogeneity of chemical composition

### VITROPERM<sup>®</sup> 800

- Best-in-class WPT properties are confirmed by customers
- VAC delivered more than 600 t into WPT applications since 2014



# Wireless EV Charging

## Special requirements (additional)

- Consistent magnetic properties over a broad temperature range (for Rx)
  - - 40 ... 85 (120) °C
- High mechanical stability
  - Resistant to shocks and vibrations
- High WPT efficiency
  - Short charging times
- Low losses at high power levels
  - No heating up of WPT system
- Easy assembly and low weight
  - No 'chess board' assembly
  - Low total thickness of Rx

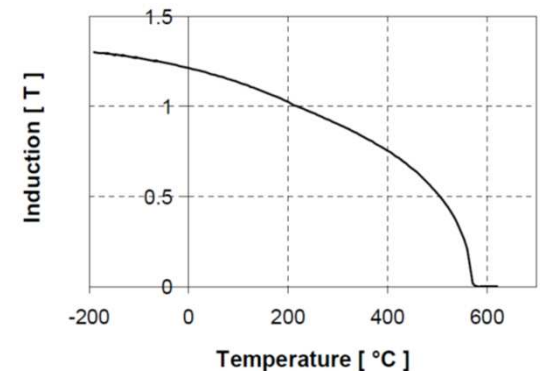
## VITROPERM® 800 unique selling points

- High thermal stability and wide range of operating temperature
  - Curie temperature  $T_c \approx 600$  °C
- Multilayer lamination of VITROPERM 800
  - Unbreakable
- WPT system with VITROPERM 800 has same or higher WPT efficiency like ferrite systems
- Higher permeabilities of VITROPERM 800 (1,000 – 3,000 @ 85...125 kHz) lead to higher coupling factors vs. ferrite systems
- Multilayer lamination of VITROPERM 800
  - Wider due to its robustness
  - Thinner due to its robustness vs. ferrite systems



**VAC**<sup>®</sup>  
VACUUMSCHMELZE

	Inductive charging
<b>Mode</b>	-
Standard	IEC 61980-3
Power class	2...5.5 kW 11...22 kW
Connection	Schuko / CCE
Communication	Wireless



# Key Take Aways

# Key Take Aways VITROPERM®

- Nanocrystalline VITROPERM® 800 has unique and outstanding combination of properties vs. other technical solutions:
  - Outstanding shielding performance
  - Excellent power transfer efficiency
  - Better thermal conductivity and stability than ferrite solutions
- Consistent material properties & excellent ductility in amorphous state = high yield in processing
- Over 600 mT of VITROPERM® 800 shipped to market since 2014 for WPT and shielding applications
- VITROPERM® 800 is preferred and benchmark material for WPT applications

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