OKMETIC

Silicon wafers enabling 5G and 6G technologies

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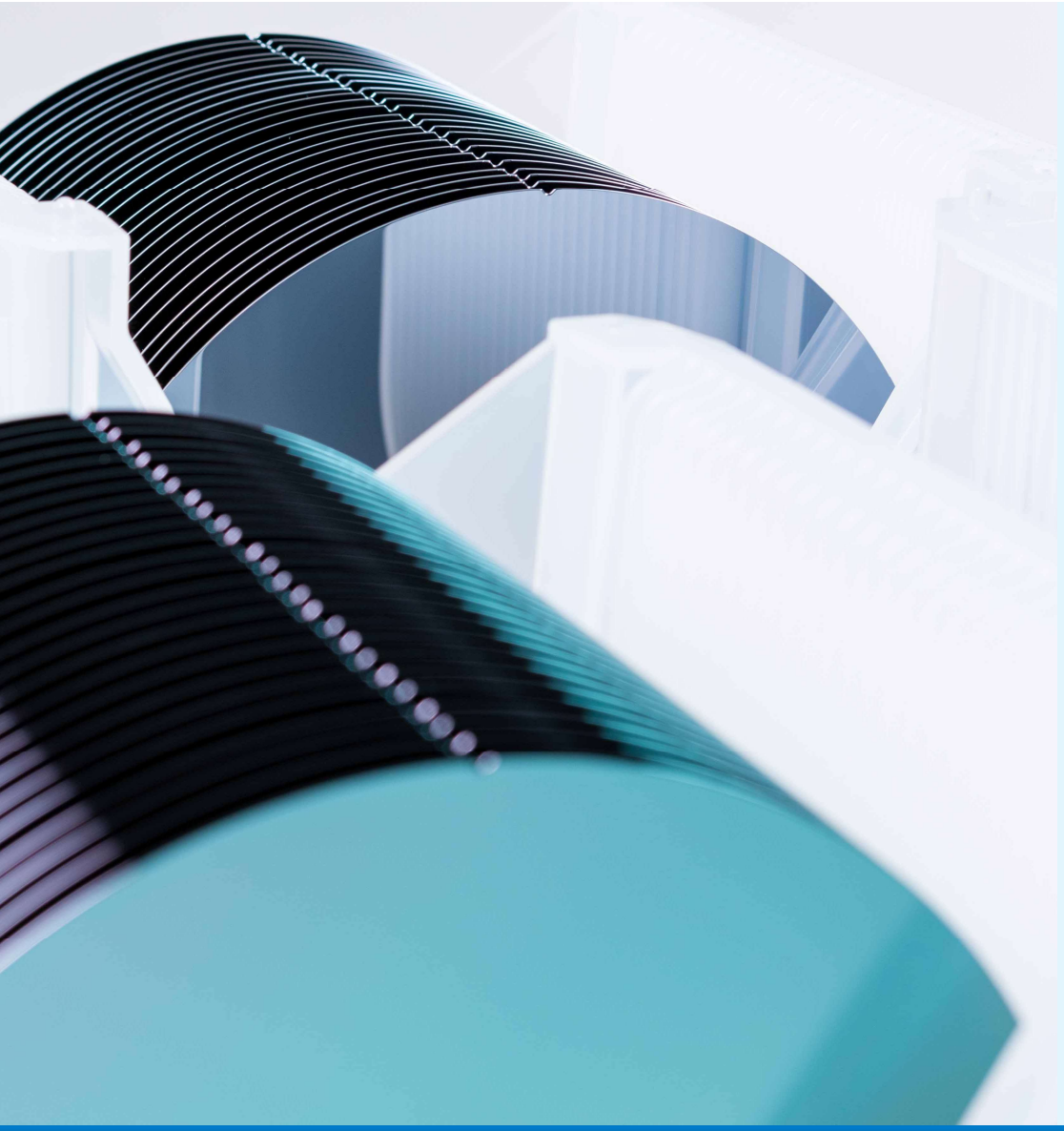
Sr. Product Development Engineer



Katja Parkkinen

Sr. Product Development Engineer, R&D at Okmetic

M.Sc. Physics

- With Okmetic since 2019
- Product development of silicon wafers for the RF market
- Okmetic project management in EU & national project consortiums
- Tech expertise from various fields prior Okmetic

Outline

- Brief introduction to Okmetic
- Trends in 5G and beyond
- Silicon wafers enabling 5G and 6G technologies

OKMETIC

Leading supplier of advanced silicon wafers for RF, MEMS and Power devices

Okmetic

- Established in 1985 as JV of Nokia and Outokumpu
- HQ and production in Finland
- Sales and Tech support worldwide
- Supplier to world's leading RF device manufacturers

Focusing on 150-200 mm wafers:

- Magnetic CZ (MCz), A-MCz®
- Very high and very low resistivity
- Customized solutions in volumes
- Bonded SOI with & without Cavities

NET SALES in 2022	INVESTMENT for fab expansion	PERSONNEL
146 M€	~400 M€	~ 640

Fab expansion will more than double the Vantaa site production capacity

Existing fab

Crystal growth
150 mm and 200 mm SSP and DSP wafers
SOI wafers
Patterned wafers

Fab expansion

200 mm crystal growth
200 mm SSP and DSP wafers

In production in early 2025

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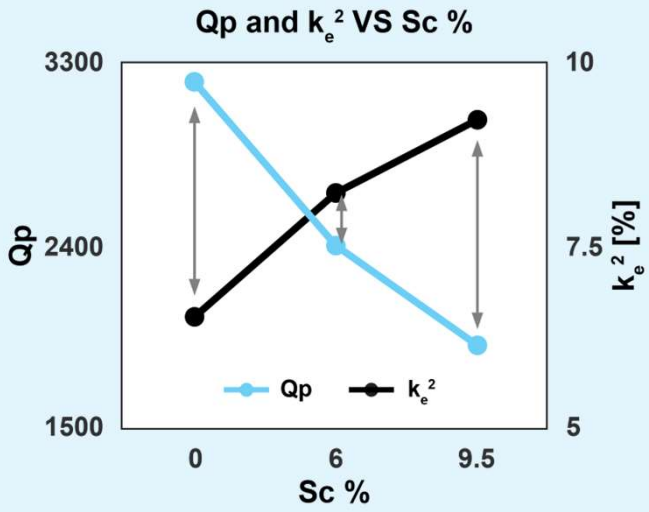
Trends and challenges with new bands

- Achieving steep skirts, low insertion losses, and wide bandwidths simultaneously for the new 5G bands poses a significant challenge
  - Wide bandwidth BAW filters with a higher Sc-doping in AlScN compromise Qp, insertion loss (IL), and steepness
  - Combining acoustics with LC circuits also degrades filter selectivity

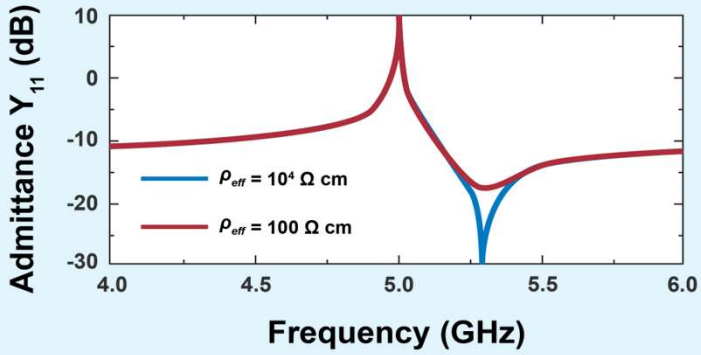
- Advanced Si wafers help alleviate the trade-offs
  - Substrate losses have a large impact on resonator antiresonance Q. Engineered Ultra High Resistivity wafers facilitate superior device performance.
  - Improvements in losses also at higher frequencies, and with IPDs/combining acoustics with LC

Higher Sc-doping in AlScN degrades Q-factors



A. Tag *et al*., 2022 doi: 10.1109/IUS54386. 2022.9958625

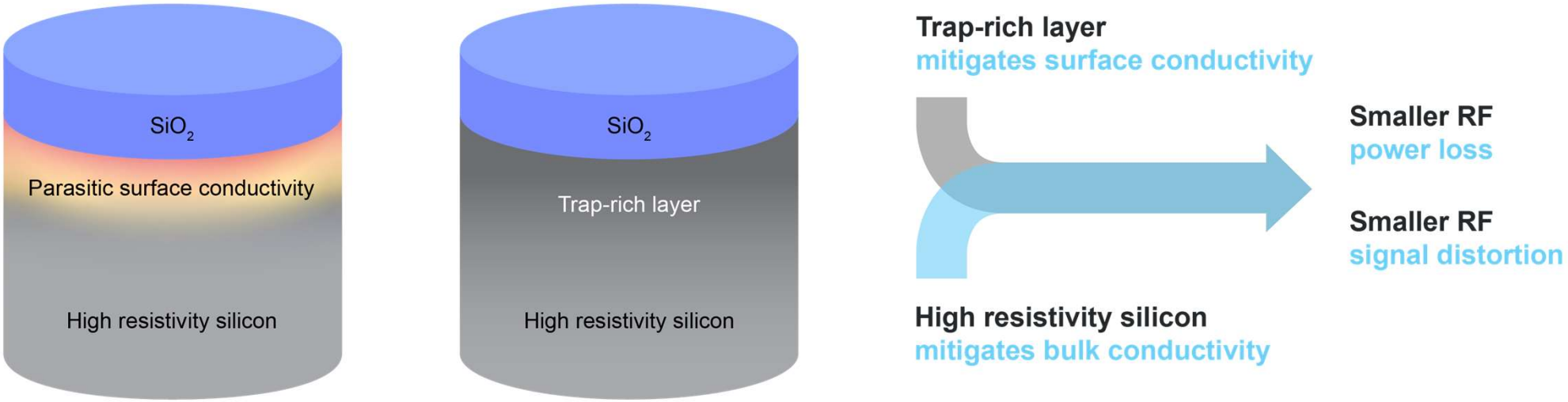
Substrate losses including those from Si substrate impact Qp



L. Gao et al., 2021, doi: 10.1109/IUS52206.2021.9593816

Mitigating substrate-induced losses

Engineered High Resistivity wafers' dual properties enable superior linearity



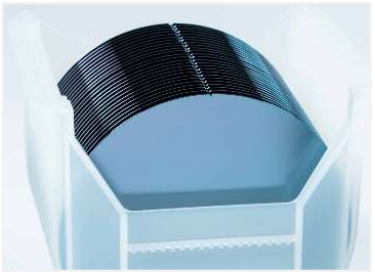
RFSi® wafer family in 150-200 mm – High Resistivity for RF device needs

High Resistivity wafers

> Up to >7 kOhm-cm resistivity without trap-rich layer, low loss **RF IPD** or **Integrated RFFE / RFIC** substrate

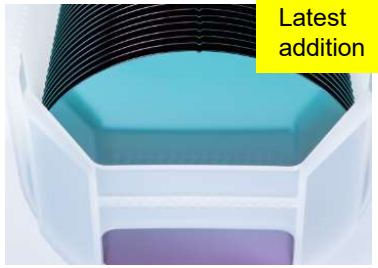
Engineered High Resistivity wafers

> Up to >7 kOhm-cm resistivity with added trap-rich layer, extremely low loss subtrate for **RF filter devices**



UF-RFSi® wafers

> Engineered low loss substrate with Up to >7 kOhm-cm resistivity, trap-rich layer and Ultra Flat properties for e.g. **Thin Film SAW**



Latest addition

Engineered Ultra High Resistivity wafers

> Over 10 kOhm-cm resistivity and added trap-rich layer, close to zero-loss substrate for **RF filter devices**

High Resistivity SOI

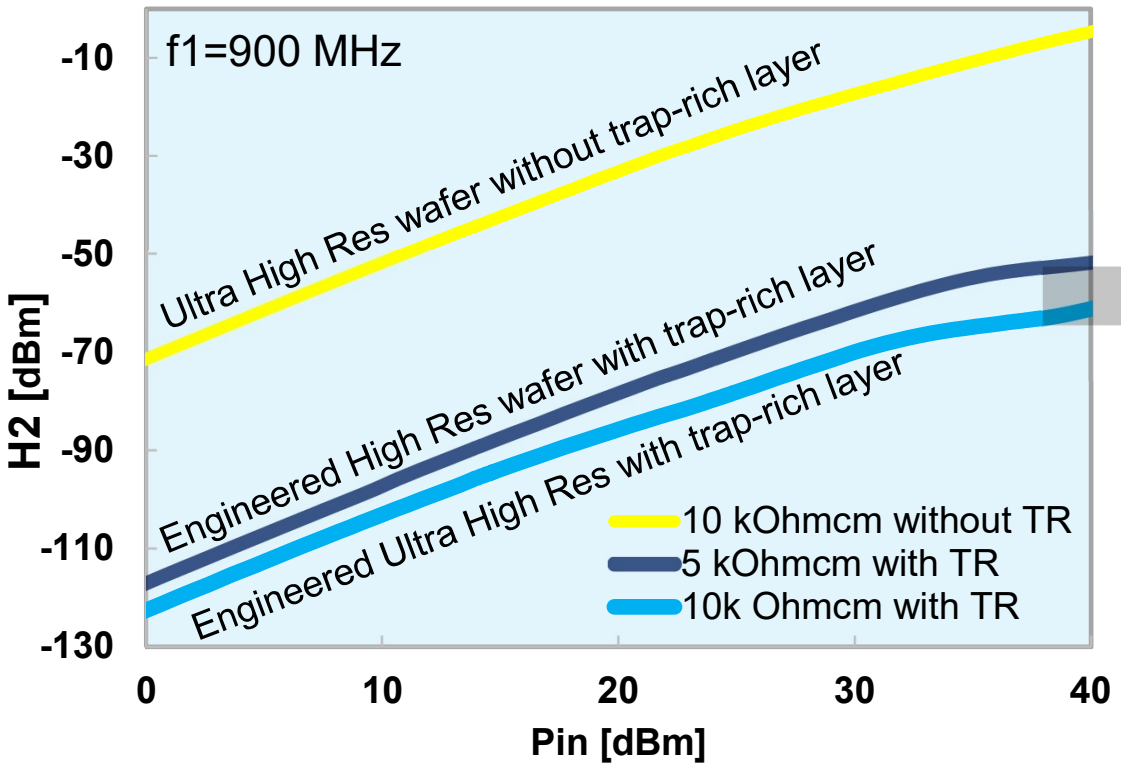
> Bonded - BSOI or suspended C-SOI® low loss structures per Customer design, e.g. **BAW** resonator

RF GaN Substrate wafers

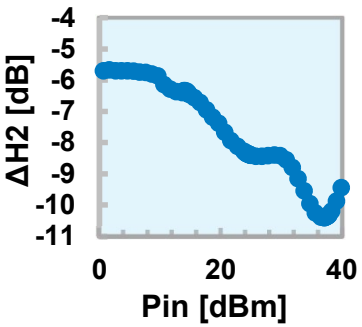
> Typically extra thick <111> MCz wafers **GaN-on-Si RF Power device** substrate with advanced stress management

Exceptional RF linearity improvement with Okmetic Engineered Ultra High Resistivity wafers

Second harmonic levels using different Si wafers



Improvement in H2

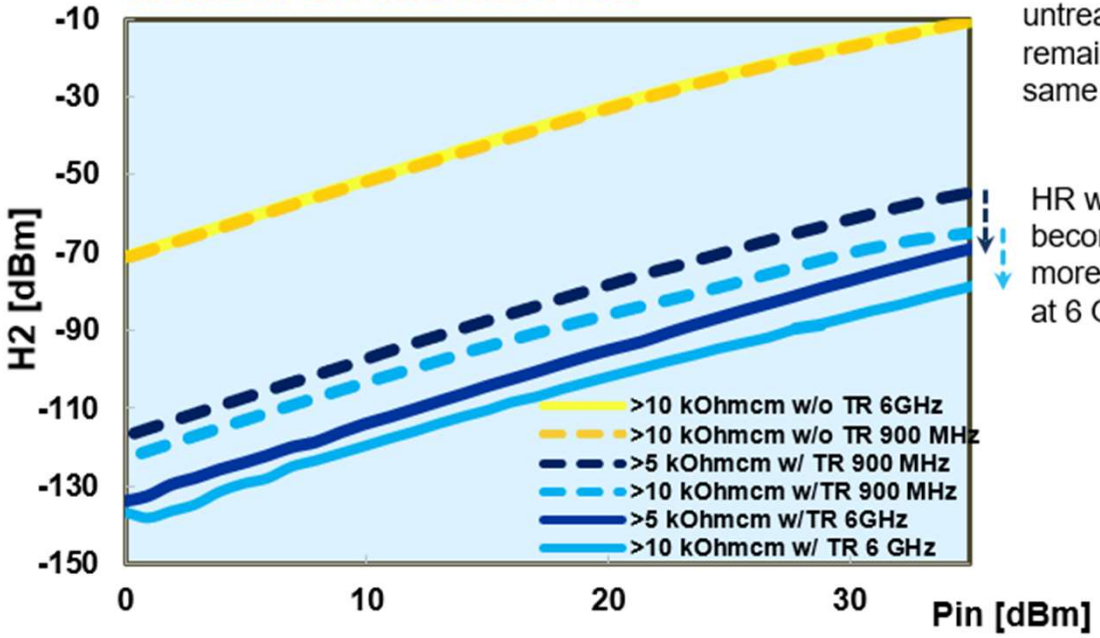


- Using 10 kOhmcm crystal with TR layer as opposed to 5 kOhmcm, **even 10 dB further improvement** in linearity can be achieved especially at high powers.

Measurements by **Incize.** 2 mm length 50 Ω CPW test structures.

New bands and higher frequencies benefitting from improved linearity and losses

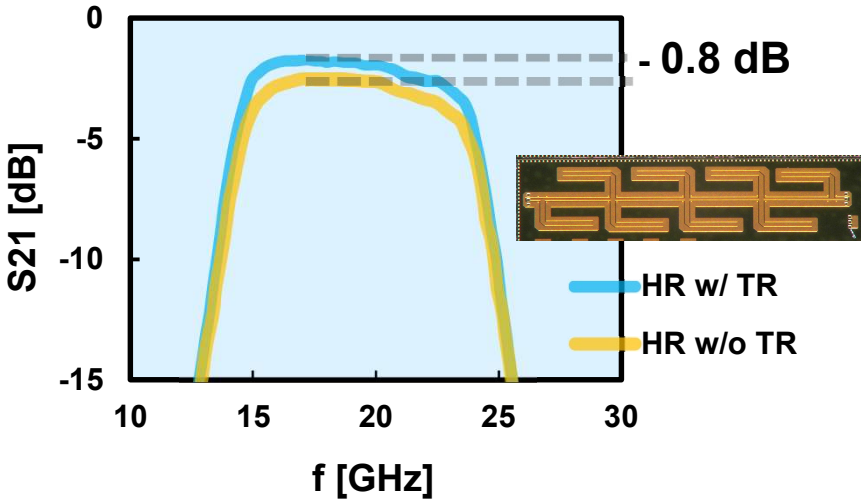
Second harmonic levels using different Si wafers at 900 MHz and 6 GHz



H2 output of HR wafer with untreated PSC remains the same

HR w/ TR becomes more linear at 6 GHz

Lower insertion losses for 20 GHz IPD-based BPFs



20 GHz shunt stub filters fabricated with IPD technology by **VTT** as test structures for 6G development. Small-signal measurement.

Measurements by **Incize.** 2 mm length 50 Ω CPW test structures.

Key takeaways

- Linearity targets for RF devices are becoming more ambitious due to the evolution of wider bands, higher frequencies, carrier aggregation and new power standards

- Advanced silicon wafers bring substantial benefits in technical performance and achieving new goals

Thank you

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