Microwaves&RF

# Inside Track with Klaus Werner, Executive Director, RF Energy Alliance

Interview by CHRIS DEMARTINO, Technology Editor

Dr. Klaus Werner is the owner of kw tec b.v., a company active in the fields of metrology, automation, and consultancy. Currently, he focuses on RF energy market development as the RF Energy Alliance executive director. Werner previously served as solid-state RF energy markets business development manager at NXP Semiconductors. He studied physics at the RWTH Aachen University, Germany, and holds a Ph.D. in semiconductor device technology from Delft University of Technology, Netherlands. Werner started his professional career as a process engineer at Philips Semiconductors. Prior to his assignment in the RF power device business, he performed in several engineering and operational management roles.

**First, can you tell us a little about the RF Energy Alliance?**

The RF Energy Alliance (RFEA) is a non-profit technical association comprised of companies dedicated to presenting solid-state RF energy's true potential as a clean, highly efficient, and controllable heat and power source. Members envision a fast-growing, innovative marketplace built around this sustainable technology, contributing to advances and paradigm shifts across many applications.

The RFEA is defining and standardizing several RF energy building blocks, their software and hardware interfaces, and their integration with power supplies and cooling systems. As such, the blocks will be "complete" and ready for use by application engineers. Ideally, this ease of use will give rise to the evolution of identified applications (i.e., microwave ovens) as well as the development of completely new applications (i.e., RF lighting, medical ablation devices, and RF plasma ignitions in automobiles).

By standardizing solid-state RF energy system components, modules, and application interfaces, the RFEA will:

- Reduce system cost
- Minimize design complexity
- Ease application integration
- Speed market adoption and enable growth
- Enhance user experiences

**CD: How do you see LDMOS and gallium-nitride (GaN) technology coexisting in terms of solid-state RF energy applications?**

KW: Currently, LDMOS is clearly the dominating technology for high-power RF applications. Based on silicon (Si), it enjoys the large economy of scale available in large wafer fabs and, hence, allows the "niche" LDMOS technology to benefit from high-volume processing cost. From a semiconductor standpoint (silicon), the material parameters are far less attractive than those of GaN. The latter, being a high-bandgap, direct III/V semiconductor, offers increased efficiency, higher temperature operation, much higher breakdown voltages (ruggedness), and higher carrier mobilities, which makes this material the ideal semiconductor for high-power, high-frequency (RF energy) applications. Unfortunately, GaN at this point cannot be produced at a scale that would allow comparable cost levels as those of LDMOS.

To make a long story short, the above mentioned performance/cost differences will also determine the use of the materials in applications. The moment the application demands the best available efficiency or bandwidth, GaN will be the obvious choice. If it requires cost-effectiveness at decent performance, Si LDMOS will win.

This "separation" will stay unchanged until GaN can be processed at Si cost—recent advances in that respect (GaN-on-Si technology) may prove disruptive in the coming years, and could enable a whole new host of compact, efficient amplifiers driving new RF energy applications.

**How can cooking appliances utilize solid-state RF energy? And what benefits can be achieved by using solid-state RF technology instead of traditional magnetrons in microwave ovens?**

For cooking applications, such as the microwave oven, solid-state RF energy holds many advantages over traditional magnetrons. These benefits include:

- Exceptional control and feedback of RF signal frequency, phase, power, and energy levels
- Real-time adaptation to changing load conditions
- Higher energy efficiency and lower voltage
- Smaller form factor
- An "all-semiconductor" electronics footprint with associated integration possibilities and design flexibility

The traditional magnetron-based microwave creates hot spots and cold spots in the food, which is counterproductive and lowers the overall quality. The brick-shaped 3D standing wave patterns in the cavity of the traditional microwave causes these temperature differences, and is the reason a turntable must sweep the food through the RF field. Even with the turntable, residual temperature differences caused by the inhomogeneous fields are one of the reasons food instructions say "leave to stand for one minute after cooking."

With solid-state RF energy sources, the frequency can be shifted to move nodes and anti-nodes around the cavity, while the power can also be modulated quickly and with ease. Collectively, the technology's attributes yield an unprecedented process control range, even energy distribution, and rapid adjustment to changing load conditions. By using solid-state RF energy in microwaves, the overall quality and taste of the food we cook will improve.

**Why has it taken so long to utilize solid-state RF technology in microwave ovens?**

Solid-state RF energy for cooking applications is gaining industry momentum and a variety of solutions have recently hit the market.[1,2,3] However, challenges still remain for adoption in high-volume markets. The reasons often tie back to engineering complexity and system cost.

Solid-state RF energy system design requires engineering knowledge, which is not generally available due to RF (power) engineers being occupied with "linearized amplifier" systems for data-transmission purposes or concerned with magnetron sources for heating applications. There is a general lack of design knowledge with respect to applying solid-state RF generation to additional, less-focused-upon RF energy systems.

When it comes to conceiving an RF energy system, a system architect must cover the "usual suspects" like power supplies, thermals, digital interfaces, microcontrollers, and firmware, as well as the intricacies around RF signal generation, amplification, and "injection" into the applicator.

Additionally, solid-state RF energy applications are still quite expensive due to the current volume supply base. The RFEA's efforts to develop specifications and roadmaps for solid-state RF energy will combat those obstacles—and we believe it will make solid-state RF mainstream. For example, the "RF Power Amplifier (PA) Roadmap: Residential Appliances" outlines multiple PA module scopes that feasibly reduce the system cost to be competitive with current magnetron-based solutions in the near future.

**Do you expect magnetron-based microwave ovens to eventually be altogether replaced by solid-state ones?**

Yes. Albeit that this will still be a couple of years out. The industry is actually moving ahead of the above mentioned roadmap; the implementation of the technology in consumer goods is just a year or two out. A lot of current investment goes into the integration of the new technology into appliances. But again, before the entire microwave oven market is converted, it will take couple of years—the magnetron is just too powerful and cheap to be that easily replaced.

**What does solid-state RF energy mean for the industrial market?**

The technology offers a number of advantages. First of all, the semiconductors are very reliable, can sweep frequency and power easily, and can be pulsed. The magnetron, on the other hand, is extremely powerful as a single source—the solid-state PAs need to be combined in relatively complex mechanical structures to achieve the same amount of output power as a single magnetron.

This may sound like a real disadvantage, and this may really be the case for some applications. But, overall, the smaller power chunks of the amplifiers also offers the opportunity to re-partition large industrial systems into smaller, independently controllable units, which then offer better process control and probably higher yields. Current industrial users still need to rethink their design flow to appreciate the benefits that a more granular, agile technology can bring to their systems.

**Lastly, what other markets are being targeted?**

Beyond residential cooking appliances, the RFEA is also targeting applications such as professional cooking appliances, industrial lighting, industrial heating, automotive ignition, plasma creation, and medical devices for imaging and treatment (MRI, ablation, hyperthermia, skin rejuvenation, etc.).


REFERENCES

1. http://www.popularmechanics.com/technology/infrastructure/a21030/solid-state-microwaves/
2. http://www.ampleon.com/news/news-articles/ampleon-and-midea-collaboration-results-in-world-s-first-solid-state-oven.html
3. https://www.macom.com/about/news-and-events/press-release-archive/row-col1/news--event-archive/macom-achieves-breakthrough-for