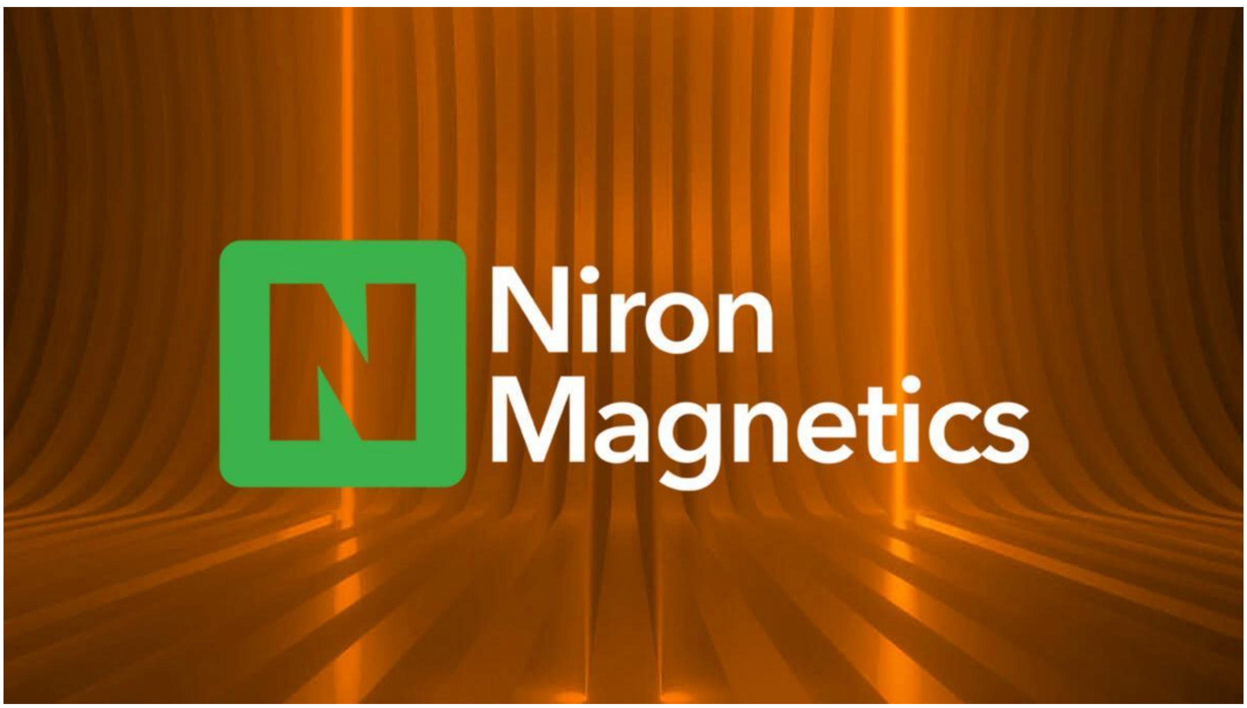
Guest Editorial

Mike Klasco and
Salvador Magdaleno-Adame

Clean Earth Magnet Technology
Iron Nitride - The Biggest News in Magnets in 40 Years

The Niron story starts in 2002 at the Electrical and Computer Engineering Department at the University of Minnesota. Dr. Jian-Ping Wang, a leading physicist and material scientist in the field of magnetics, and his small army of Ph.D. students began untangling the mysteries of this material. After eight years of fundamental research with the collaboration of research scientists at four US Department of Energy (DoE) national research facilities (Oak Ridge, Argonne, Brookhaven, and Los Alamos), the team was awarded a project to develop a permanent magnet based on Iron Nitride, which offers the best characteristics of neodymium without the supply chain drama, at a price point between ferrite and neodymium (neo).

Spun off from the University of Minnesota in 2014, Niron Magnetics now operates in a dedicated industrial lab facility and has been funded with $34 million to date. Combining breakthroughs in nanomaterials with mature metallurgical methods, they are leading the commercialization of Iron Nitride.



Niron Magnetics is the company developing the world's first high-performance Iron Nitride permanent magnets, free of rare earths. Niron's technology delivers magnets that are less expensive, more sustainable, globally available, and made from abundant input materials not subject to supply constraints or price instability.

As the name suggests, Iron Nitride is composed of common elements - iron and nitrogen. Manufacturing a magnet using these common elements unlocks a whole host of benefits: magnets that are less expensive, more sustainable, globally available, and not subject to supply constraints or price instability. As a bonus, Iron Nitride has inherent temperature stability that ensures performance doesn't falter at speaker operating temps where neo falls off or requires expensive dopants.

Two New Magnet Options for Speaker Designers
Existing speaker magnet design choices are highly polarized. The Niron magnet family fills a set of market gaps and resolves the material trade-off that has long existed between ferrite and neo. Niron's product roadmap climbs the ladder of performance.

The first commercially available is a bonded Iron Nitride. Dubbed the "Generation 1 Clean Earth Magnet" for its environmental sustainability, it seeks to break the compromise between ferrite and NdFeB magnets. Its price-performance positioning will give designers the option to upgrade from ferrite in applications where size, weight, and performance matter, but neo is too pricey and volatile or (alternatively) substitute neo in applications where price-performance, environmental sustainability, and temperature stability matter in addition to absolute size and weight.

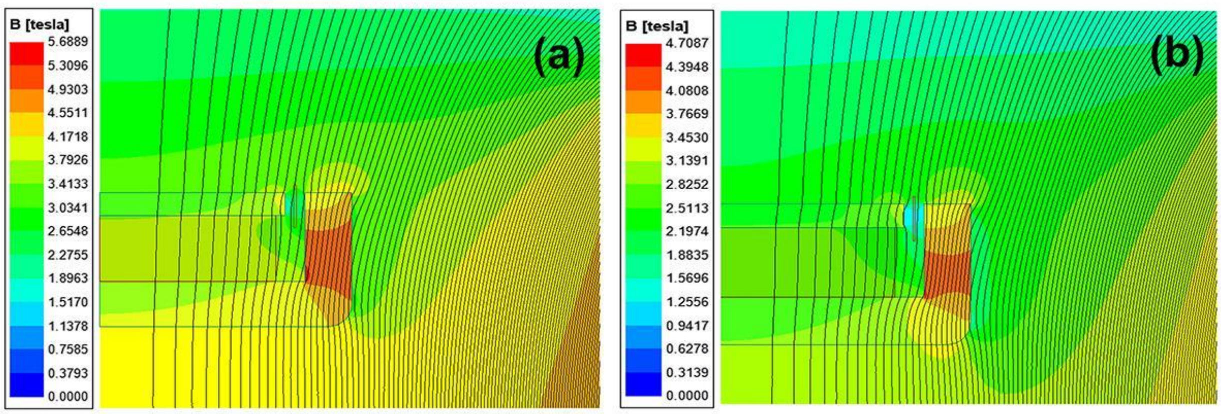


Figure 1. Magnetic field distribution produced during the in-situ magnetization process of a 40mm headphone driver: a) sintered neodymium magnet, b) Niron Generation 2 magnet.

The advantage is likely most compelling in applications where cost and size/weight pressure converge, where speakers need to maintain performance at higher operating temperatures, where long-term purchasing agreements make price volatility a serious risk, and where there is a consumer-facing sustainability branding opportunity.

Car sound comes to mind as a potential sweet spot. The company's second product, the "Generation 2 Clean Earth Magnet," looks to compete with neodymium based on absolute performance. Targeted for 2023, it follows neo's path to higher residual flux density, with superior temperature tolerance.

Superior high-temperature performance makes Niron especially competitive against high-temperature grades of neo, primarily because of the cost of the dopant dysprosium. Dysprosium Oxide is part of the neo recipe to avoid real-time performance loss and partial demagnetization — and this tweak additive costs 4× the price of neo! Iron Nitride's material structure offers superior temperature performance without the expensive additives. Iron Nitride has a low reversible temperature coefficient, which means that it holds its magnetic properties at high operating temperatures slightly better than ferrite and significantly better than neo.

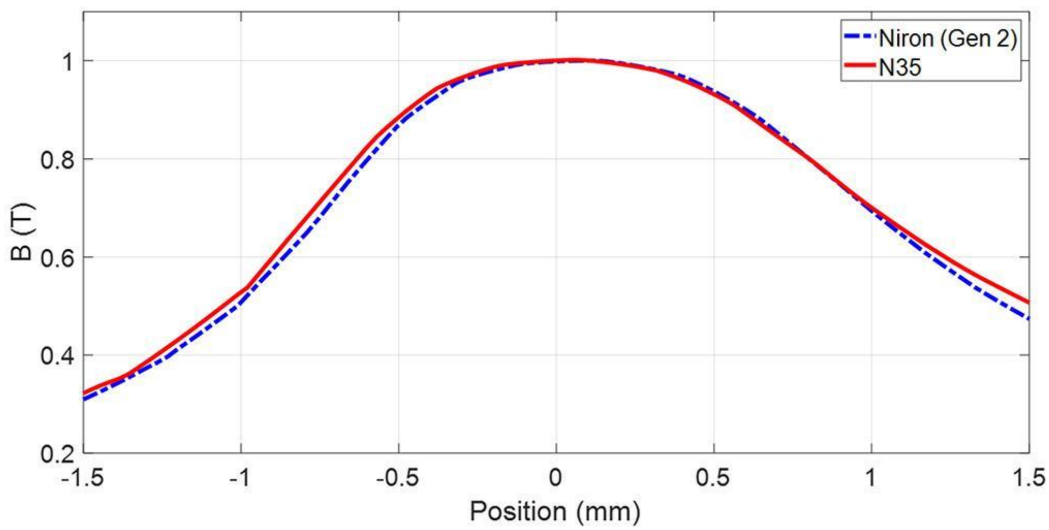


Figure 2. Magnetic field distribution in the air gap region of the magnetic headphone driver structure equipped with neodymium and Niron's Generation 2 magnet.

Environmentally Sustainable
Compared to neodymium, Iron Nitride avoids significant environmental damage across water contamination, radioactive waste, and acidic by products from mining and processing steps that are required for neo. As companies and consumers take steps to mitigate climate change, Iron Nitride generates ~70% less C02 emissions over its lifecycle vs. comparable grades of neodymium. This is assuming non-recycled inputs. At present, Niron is refining the process by which it can use recycled steel as a source of iron to further improve the material's sustainability. Niron is branding both Generation 1 and Generation 2 of its Iron Nitride magnets as "Clean Earth Magnets" — the data suggests they'll live up to the name.

Easy to Magnetize - Even in Assembled Magnetic Structures
While the speaker industry enjoyed being able to magnetize magnetic structures with ferrite magnets, the challenge in the magnetization process of neodymium magnets was a rude awakening with huge and expensive magnetizing machines and fixtures. The fix was buying pre-charged (or pre-magnetized) neo slugs and bruised fingers. The in-situ magnetization of magnetic assemblies with Niron magnets will be possible utilizing the current magnetization technology (magnetizing machines and magnetizing fixtures), while pre-charged will be more common for Niron's Generation 2 magnets.

The magnetization process of Niron's Generation 1 magnets is easy and fast. The magnetization and saturation characteristics of the Generation 1 magnets permit magnetizing loudspeaker assemblies employing short cycle times, potentially increasing the production of loudspeakers as woofers and subwoofers.

Finally, the magnetization and saturation characteristics of the Generation 2 magnets permit magnet assemblies to be magnetized utilizing less energy compared with the energy utilized to magnetize neodymium magnet assemblies. Figure 1 shows the magnetic field produced during the in-situ magnetization process of a 40mm headphone driver with a sintered neodymium magnet (a) and with a Niron Generation 2 magnet (b). Both headphone drivers are magnetized and saturated utilizing the same magnetizing equipment. The headphone driver with the sintered neodymium magnet requires more magnetizing current or more energy compared with the headphone driver with the Niron Generation 2 magnet.
As such, it may offer the benefit of an increased lifetime for magnetizing fixtures utilized in the magnetization process and permit reduction of the cycle time required to increase the production of loudspeakers.

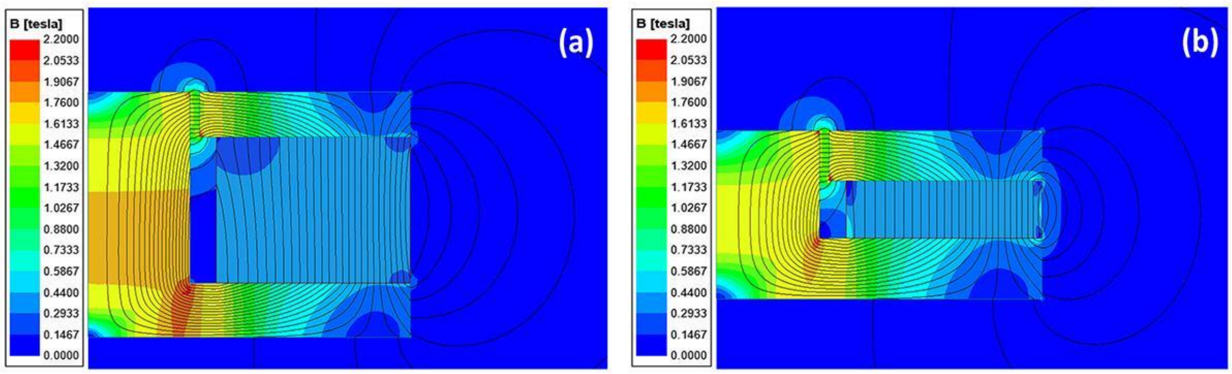


Figure 3. Magnetic field distribution in the magnetic woofer structure: a) ferrite, b) Niron Generation 1

Commercial Production for Niron
What does commercial production look like for Niron? What, if any, challenges must be overcome? Niron is not yet churning out Iron Nitride magnets from the assembly line, but commercialization has always been the focus. The manufacturing methods Niron is employing in the lab today are all validated as being highly scalable, existing at the thousand-ton scale today in service of similar materials for other industries. Now under construction is Niron's pilot production facility to produce samples of the Generation 1 magnet.

Niron Magnetics has also begun working closely with a selection of leading speaker design and manufacturing companies, doing the design work to optimize existing speakers for the integration of iron nitride Clean Earth Magnets and to secure a competitive edge.

How does Iron Nitride perform in a speaker? The authors of this article recently worked with Niron Magnetics to complete preliminary magnetic studies using finite element simulations of the Niron magnet material in a variety of form factors and adjusting design parameters to optimize the magnetic return structures and extract maximum magnetic performance.

Several loudspeaker topologies have been studied and initial optimization work conducted, among them the magnetic structures of headphone drivers where Niron's Generation 2 magnets have been studied and compared with sintered neodymium magnets.

Initial findings suggest that Generation 2 magnets offer a more distinct advantage for loudspeakers where higher magnetic gap strengths (1 Tesla+) are targeted. Magnetic headphone structures with a sintered neodymium magnet and with a Niron Generation 2 magnet were optimized to produce 1T in a 1mm air gap. From Figure 2, you can see that both headphone drivers produce the same flux density in the air gap region with a maximum value of flux density of 1T. The magnetic headphone structure with the Niron Generation 2 magnet presented 10% less magnet weight compared to the neodymium version.

In addition, some woofer magnetic structures with ferrite and Niron's Generation 1 magnet were analyzed. A commercial 4" woofer with an air gap of 1.2 mm was analyzed and optimized to produce a flux density of 1.3T in the air gap. Figure 3 shows the magnetic field distribution in the magnetic woofer structures equipped with a ferrite magnet (a) and with a Niron Generation 1 magnet (b).

Figure 4 shows the size comparison between the ferrite woofer and the Niron Generation 1 woofer. The Niron Generation 1 woofer presented approximately two-thirds less magnet volume and weight versus the ferrite woofer. For ferrite applications where weight or footprint is constrained - auto sound, soundbars, smart speakers to touring sound speaker arrays - this could be a game-changer.

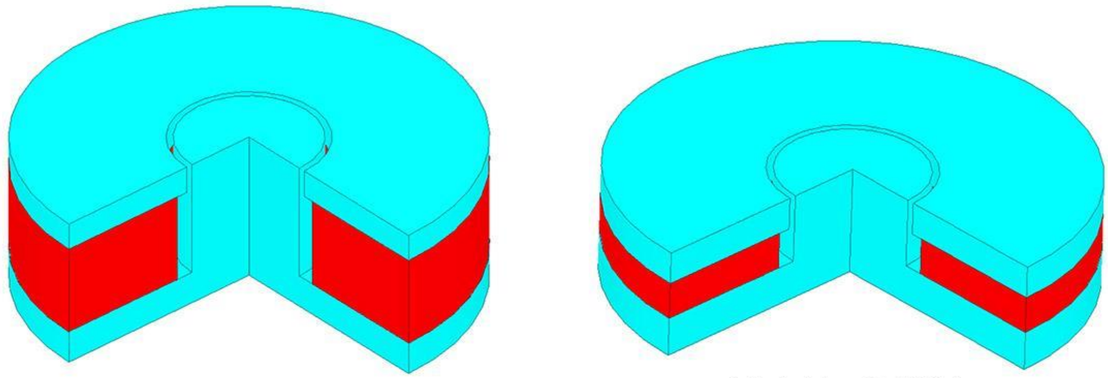


Figure 4. Size comparison of magnetic woofer structures: a) ferrite, b) Niron Generation 1.

Conclusion
As neodymium costs continue to go up, geopolitical tensions rise, and competition for limited supply is made fiercer by the continued electrification of transport, there are limited magnetic options for speaker companies. The choice for designers has been downgrading to ferrite, or raising prices and risking sales volume, or simply eating the cost.

As when ferrite displaced AlNiCo in the 1970s, and neodymium at least sharing the stage with ferrite today, integrating new material into speaker designs requires work. But the reward is sweet. For the companies that are willing to take the opportunity, Iron Nitride promises an answer to many of the intractable problems faced by speaker manufactures today, and a few new benefits to boot.

Niron Magnetics is now working with strategic partners who can closely collaborate with Niron to design Clean Earth Magnets into suitable applications. In return, these partners get priority access to this groundbreaking material and a leg up on competitors. To learn more you can **email Tom Grainger**, Niron's Director of Strategy and Business Development, who oversees design partnerships.

Read also the full *audioXpress* **Market Update - Speaker Technology** published in January 2022 for a complete overview of latest technologies for speaker applications.

Niron Magnetics | **www.nironmagnetics.com**