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VOICE COIL

THE PERIODICAL FOR THE LOUDSPEAKER INDUSTRY

IN THIS ISSUE

Spotlight

Magnetic Materials for the Loudspeaker Industry

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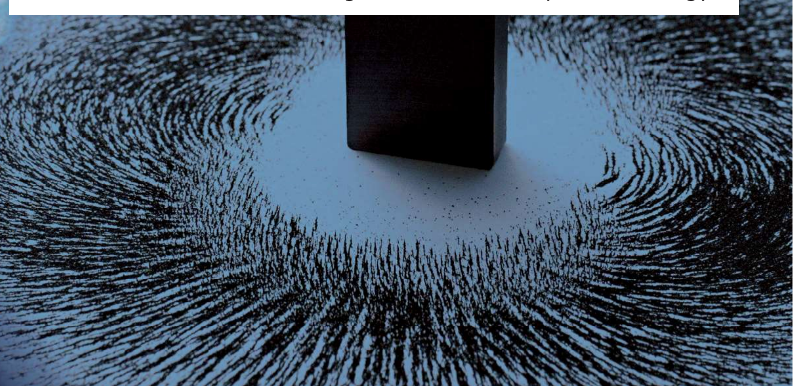
Materials science is a fascinating field, and often from the time an element is discovered, or an alloy invented to the time it can be produced in products, decades can pass. Magnets and magnetic return circuits are a good example, and we all know ferrite, alnico, and neodymium magnets, as well as low carbon steel for the magnetic return structure.

It is common knowledge that in the early 1980s Sumitomo Special Metals developed the magnet powder metallurgy process, and General Motors developed the magnet melt-spinning process, both of which enable the commercial production of the alloy NdFeB (neodymium, iron, boron).

In the following decades, corrosion resistance and higher magnetic density and temperature tolerance were significant refinements. Most of us have the impression that neodymium is the new kid on the block, yet it was discovered in 1885 by Karl Auer. The story began with the discovery of cerium, from which Carl Gustav Mosander extracted didymium in 1839 into the elements of neodymium and praseodymium. A century passed before Electro-Voice began shipping neodymium dynamics mics and its first neo-compression driver with JBL right behind them. So, let's take a survey of other materials relevant for loudspeaker magnets and magnetic structures that have quietly reached the market, or are about to, or are still in the unobtanium stealth mode.

Nitride Iron Magnets, "Clean Earth Magnets"

In previous *Voice Coil* articles, we introduced Niron magnets, the first new permanent magnet material for speakers in decades, Niron, is continuing its move toward commercialization. Niron Magnetics has developed technology



that enables permanent magnets to be fabricated from Iron Nitride, a powerful permanent magnet that does not utilize any rare earth elements. Iron Nitride promises several major advantages over rare earth magnets. Sustainability is another part of the story, with approximately 75% less CO_2 emissions over the lifecycle vs. neodymium. Unlike neodymium or cobalt, Iron Nitride is composed of commodity raw materials, readily available around the world. Insulated from geopolitical factors and globally manufacturable, Iron nitride-based Clean Earth Magnets stand to minimize the impact of tariffs and logistics on speaker manufacturers.

Niron Magnetics was born out of the labs of the University of Minnesota, with initial funding from a Department of Energy grant and later rounds of funding from Volvo and other big fish—more than $50 million in financing behind the company to date. Using a patented, scalable process, Niron Magnetics is developing the first mass-production process for iron nitride-based Clean Earth magnets. Samples of Niron's market-entry product were released to select strategic partners earlier this year. The company is active in entering into collaboration agreements with value-added partners looking to be ahead of the curve in commercializing this new technology.

Concurrent with its focus on development toward scaling, commercialization, and productization has been an expansion of its leadership team, including seasoned materials executive Jonathan Rowntree joining as Niron CEO and other key appointments on the product and manufacturing teams. The first magnet generation of Niron Magnetics is intended to break the compromise faced by speaker manufacturers today as a "gap magnet," representing a significant step up from ferrite's performance at a more stable cost than neodymium. The initial energy product of iron nitride magnets will be between that of ferrite magnets (which are below 5 MGOe) and neodymium magnets (ranging from about 30 MGOe to 50 MGOe). A disk of a Clean Earth magnet sample produced by Niron Magnetics is shown in **Photo 1**. This is the answer for speaker designers and manufacturers who have reluctantly downgraded from neodymium designs to ferrite designs.

Figure 1 shows the magnetic field distribution for a headphone driver equipped with a Clean Earth magnet. Cost and weight/size-sensitive applications stand to benefit significantly as well as markets that have long-term contracts, where volatile input material costs pose serious business risks. The other potential winners are designers for applications where temperatures are higher (either environmental temperatures or temperatures reached by hard-working speakers from concert sound to active noise-cancellation speakers in cars), who will benefit from iron nitride's intrinsically stable performance at high temperatures.

In 2025, Niron Magnetics plans to introduce Clean Earth Magnets that compete directly with neodymium magnets. **Figure 2** shows the magnetic field comparison for a headphone driver equipped with a Clean Earth magnet and one with a neodymium magnet. The headphone driver structure for the Clean Earth magnet was optimized by authors to get similar magnetic field distribution compared with the neodymium magnet headphone structure. Like neodymium displacing alnico in the 1980s, integrating new material into speaker designs favors companies committed to moving quickly on innovation. For the companies that are willing, iron nitride magnets promise a competitive edge—an answer to many of the intractable problems faced by speaker manufacturers today and providing new benefits to boot.

With powerful magnets (e.g., neodymium and Niron magnets), the limitations of the magnetic return circuit begin to get in the way. Soft iron alloy's superior material for magnetic return structures has been around for decades but not on most people's radar. Today, if you tear down a balanced armature earphone driver or Apple's headphones and earphones, you won't find a low carbon steel magnetic structure but rather a soft iron alloy that is thinner, lighter, and has higher magnetic flux capacity.

Iron has been used for more than a millennium for tools (and weapons), and by adding a bit of carbon, a steel alloy was created along with a disproportionate amount

Photo 1: This is a sample of Niron Magnetics' novel iron nitride-based Clean Earth Magnet (Image Source: Niron Magnetics)

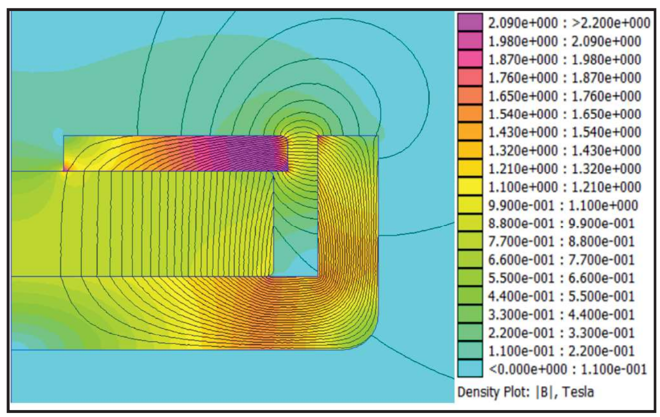


Figure 1: Magnetic flux distribution is shown in a headphone driver equipped with a Clean Earth Magnet.

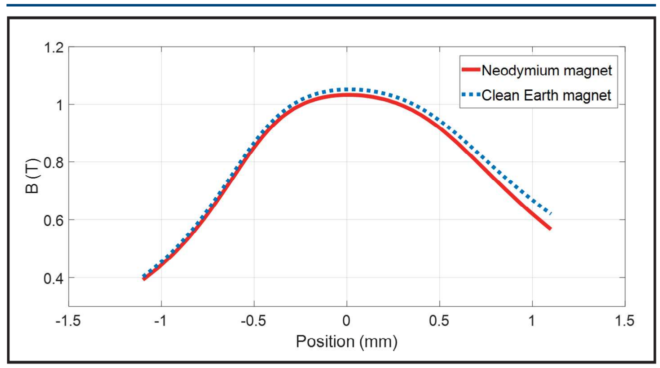


Figure 2: The magnetic flux density for a headphone driver with a Clean Earth Magnet is compared with a neodymium magnet.

of strength gained. But for carrying magnetic flux, only enough carbon is needed to enable practical forming techniques. It is low carbon (soft) steel (LCS) that is the default loudspeaker magnetic structure backplate and top plate material, typically cold-forged to shape. Steel 1010 alloy has 10% carbon, and most cold-forged steel back plates from Asia are 1008 (8%). While top plates can be 1004, they are expensive and hard to obtain in the US but readily available in Asia, although a bit soft to work with.

For almost a century there have been high-performance iron alloys used for mission-critical applications—and now with potent magnets such as iron nitride and neodymium, these iron alloys offer real performance benefits for magnetic structures from compression drivers to headphones and balanced armature earphones and hearing aid transducers. The material enables thinner microspeakers for smartphones, lighter and shallower auto sound speakers, lighter and smaller earphone and headphone drivers, compression drivers with higher Tesla voice coil gaps, and more. While not always cost-effective, most electro-dynamic transducers would benefit from ultra-low magnetic flux resistance soft metals.

A History Lesson

It all started with Permendur, invented in 1929 at Bell Telephone Labs, a cobalt iron soft ferromagnetic alloy with equal parts of cobalt and iron, notable for its high magnetic saturation—with a maximum saturation of 24 kilo Gauss (kG).

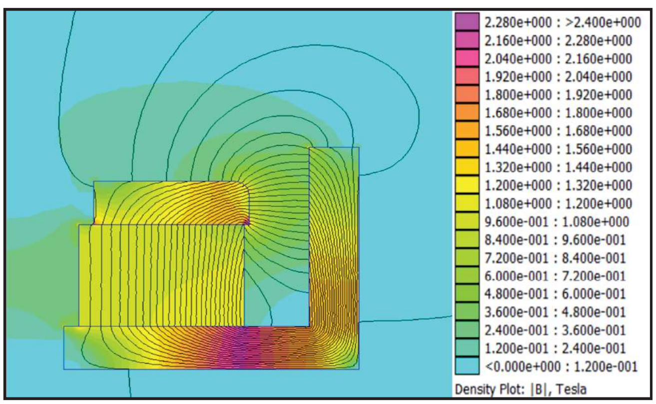


Figure 3: T Magnetic flux distribution in a neodymium earphone driver with pole pieces made of low carbon steel (LCS)

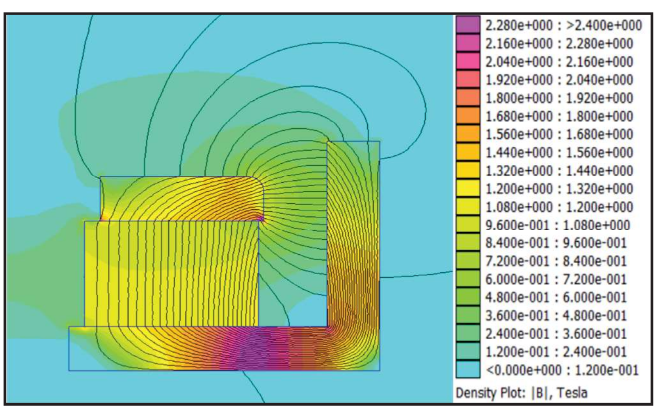


Figure 4: Magnetic flux distribution in a neodymium earphone driver with pole pieces made of Hiperco 50

Permendur presents a high permeability, low losses, and low coercivity. Utilizing Pemendur in the pole pieces of speakers, it's possible to reach beyond 20kG in small voice coil gaps. The advantage of high saturation in a magnetic circuit is that it can function at higher magnetic field strengths, so it is more compact and lighter for a given magnetic flux and power level. Supermendur, which some of us know as Carpenter Technology's "Hiperco 50," was invented in 1957 and has a similar composition to Permendur 49 but is grain oriented.

Hiperco 50 can be found in balanced armature earphones and hearing aid drivers. **Figure 3** and **Figure 4** show the magnetic field distributions for an earphone driver equipped with a neodymium magnet and with low carbon steel and Hiperco 50 pole pieces. **Figure 5** shows the magnetic field comparisons for an earphone driver equipped with different neodymium magnet grades and equipped with pole pieces made of low carbon steel and Hiperco 50. The earphones with Hiperco 50 pole pieces present a high magnetic field in the air gap region compared with the magnetic field produced by earphones with low carbon steel pole pieces. In general, one can see the magnetic benefit of the use of Hiperco 50 in small speakers.

In 2016, researchers from the Minnesota University of Minneapolis developed Minnealloy, a soft material that could be used for the return path or pole pieces of loudspeakers. Minnealloy is a compound of iron, nitrogen, and carbon that could reach a maximum magnetic saturation between 24.7kG and 28kG—which is higher than the magnetic saturation exhibited by the Hiperco material, which presents a maximum magnetic saturation of 24kG. This Minnealloy material and its simple chemical composition is independent of special rare-earth materials, such as cobalt. The Minnealloy material can be synthesized and produced in laboratories under certain temperatures and nitridation conditions, which facilitate the production of this magnetic material in high volumes.

The size and weight of loudspeakers could be significantly reduced by utilizing the Minnealloy material, helping to lessen the amount of magnet and magnetic material in loudspeakers to produce high flux densities in the air gaps. Horn loudspeakers with flux densities up to 30kG could be designed and manufactured using the Minnealloy material.

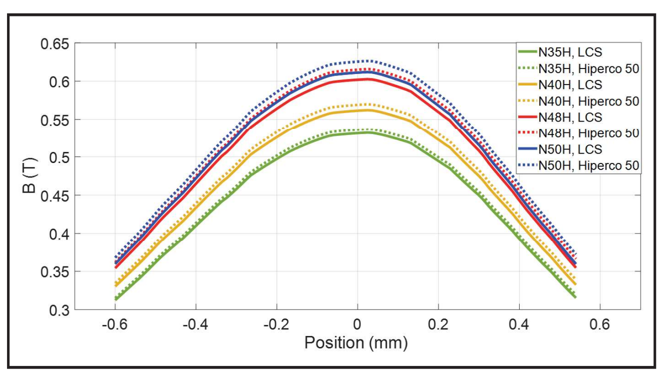


Figure 5: Magnetic flux density distributions for an earphone driver equipped with different neodymium magnet grades and with low carbon steel (LCS) and Hiperco 50 pole pieces

Unfortunately, the research on Minnealloy material ended some years ago and this magnetic material is no longer available in the market. A company called "Minnealloy Magnetics" was founded in 2016 to commercialize Minnealloy but was out of business sometime after its foundation.

Tetrataenite—"The Cosmic Magnet"

This section was inspired by an email from Vance Dickason, which read in part: "I don't recall you talking about this in the magnet articles, just that I don't remember hearing about Tetrataenite until one of the owners at Accuton made mention of it, and asked if I knew of any commercially available magnets made out of this stuff as yet."

Tetrataenite has only been found in meteorites, so this material is one better than rare earth—it is rare on earth. It is a combination of two base metals—nickel and iron—cooled over millions of years. That process creates a unique compound with a set of characteristics that make it ideal for use in high-end permanent magnets with properties comparable with neodymium.

The real issue is that this material cannot be easily synthesized in a laboratory. Small amounts of tetrataenite have been found in natural meteorites. However, scientists have analyzed tetrataenite samples from some meteorites collected in different regions of the world. A photo of tetrataenite crystals from a meteorite recollected in Nuevo Mercurio, Zacatecas, Mexico is shown in **Photo 2**.

Photo 2: These are tetrataenite crystals from a real meteorite recollected in Nuevo Mercurio, Zacatecas, Mexico (Image Source: Rob Lavinsky & irocks.com).

The magnetic properties of tetrataenite have shown interesting results, with tetrataenite presenting a maximum magnetic energy product of 42 MGOe, which is very similar to the magnetic energy product presented by actual neodymium magnets. The tetrataenite coercivity values are higher compared with the coercivity values for ferrite magnets but very competitive with the values of coercivity present in neodymium magnets. The magnetic properties presented by tetrataenite indicate that it could be an excellent candidate to replace neodymium magnets as a rare-earth-free magnet. In addition, tetrataenite offers excellent thermal stability at high temperatures and it doesn't require the addition of high dysprosium amounts (super costly) as in neodymium magnets.

Recently, new methods to synthesize and produce tetrataenite have been proposed and patented that depend on the presence of phosphorus to form the structure of tetrataenite in seconds, which naturally occurs during millions of years in meteorites. These methods could permit speeding up the production of tetrataenite for several applications, such as loudspeakers and other magnetic products or devices. Two teams of scientists—one at Northeastern University in Boston, MA; the other at the University of Cambridge in the UK—recently announced that they managed to manufacture, in a lab, synthetic tetrataenite. These new synthesized methods have been proposed by Prof. Yurii Ivanov and colleagues at Cambridge University and by Prof. Laura Lewis and colleagues at Northeastern University.

Tetrataenite with an adequate production process could replace neodymium magnets in loudspeakers (e.g., woofers, compression drivers, headphones, and earbuds) but their magnetic properties should be improved to compete with actual and commercial high-energy neodymium magnets. Tetrataenite remains "unobtanium" for the near future, as even getting an existing neodymium mine and ore separation facility and adding magnet fabrication lines can take a decade, it would be daunting to undertake the process to get a new magnetic material scaled up in production, so expect to read about this process becoming mainstream hopefully before you retire. ***VC***