



# Tech Bulletin

This electronic Tech Bulletin is produced by:

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**Tech Bulletins** are technical newsletters from Metal Powder Products Company, and are published and e-mailed approximately 4-5 times per year. In each issue, we address specific technical issues, answer technical questions, and communicate useful information about processes, services, new equipment, and the ever-expanding capabilities of Metal Powder Products Company. This **Tech Bulletin** is devoted to an overview of MPP's expertise in PM Soft Magnetics.

## Soft Magnetics in Powder Metallurgy

Over the past few years, our Technical Bulletins have covered a number of areas in which Metal Powder Products possesses considerable expertise. The processing of soft magnetic PM materials is yet another of these areas. MPP's Vice President of Technology, Dr. Chaman Lall, is an internationally recognized expert in the field, having authored several papers on the subject, including the book *Soft Magnetism: Fundamentals for Powder Metallurgy and Metal Injection Molding*.

## Some Magnetism Basics

Magnetism as a subject has two distinctly separate fields. One is soft (or temporary) magnetism and the second is hard (or permanent) magnetism. The soft magnetic materials respond easily to the smallest external magnetic field, while hard magnetic materials resist the influences of even the largest external fields. At the microstructural level, the magnetic response of a material is determined by the size, shape and alignment of magnetic domains, plus the ability with which they can be altered by external magnetic fields. Each magnetic domain can be regarded as a magnet, fully aligned and magnetized in a given direction. In an "unmagnetized" part, the magnetic domains are orientated in all directions, but they cancel the effect of each other so that the external observer senses no magnetism. As an external magnetic field is applied to the part, the magnetic domains that are aligned with the external field start to grow and upset the balance. Increasing the external magnetic field causes orientation and growth of those magnetic domains in the direction of that field. When all the domains are aligned in one direction, that part is said to be saturated or fully magnetized. The important point is that the ease of magnetic domain wall motion and domain rotation determines if the material is soft magnetic or hard magnetic.

While both types of products can be made by the powder metallurgy technology, the goals or objectives of the processing method are entirely opposite. For soft magnetic parts the goal is to make the microstructure as clean as possible, while the aim for hard magnetic parts is to make the microstructure as "dirty" as possible, with as many hindrances as possible to inhibit magnetic domain wall motion.

## Soft Magnetics at MPP

The most common soft magnetic PM materials used by MPP are, in order of decreasing coercive field (width of a magnetic hysteresis curve): pure Fe, Fe-0.45% P, Fe-3% Si, and Fe-50% Ni. In addition, 410L and 434L plus similar grades of stainless are also good candidates for soft magnetic applications where corrosion resistance is needed. Examples of these are anti-lock brake systems (ABS) such as "sensor" or "tone" wheels. These are often located at the vehicle wheels and are exposed to water, dirt and salt from the road. Other soft magnetic materials covered by a protective coating compete in these types of applications.

In order to enhance the soft magnetic properties of these PM materials, MPP keeps contamination to a minimum in both the powder preparation and molding stages, as well as during sintering. We take special care to minimize pickup of carbon, oxygen, and/or nitrogen, as even minor amounts of these interstitial elements can decrease the coercive field of a given material. They form precipitates that "pin" the magnetic domain wall motion and, therefore, soft magnetic response. In a similar way, deformation damage in the form of dislocations at the microstructural level will also inhibit domain wall movement. A component that is subjected to a secondary operation such as machining or grinding should be magnetically annealed for optimum properties.

Higher temperatures during sintering and the use of pure hydrogen for oxide reduction will improve soft magnetic performance. The absence of nitrogen eliminates the deleterious effects of the element, while the higher diffusion rates increase density, dissolve precipitates, and promote recrystallization and grain growth. In the case of silicon steel and phosphorus steel, the increased densification occurs with the aid of transient liquid phases.

## Applications for Soft Magnetics

As mentioned above, a typical application for soft magnetics would be the sensors in anti-lock braking systems. Other applications include:

- Computer equipment
- Welding transformers
- Fuel injection systems
- Motor speed controls
- Current transformers
- Instrumentation (including Hall effect sensors)
- Electrical distribution transformers
- Medical equipment
- Telecommunications equipment
- Lighting and plasma displays

## To Read More About Soft Magnetics

If you would like to learn more about the science of soft magnetics in PM, you might want to read Dr. Lall's book *Soft Magnetism: Fundamentals for Powder Metallurgy and Metal Injection Molding*. This 160-page, softcover book introduces the subject of soft magnetism to engineers, technologists, and technical sales personnel who have responsibility for components processed by powder metallurgy (PM) and metal injection molding (MIM). Subjects covered include fundamentals of magnetism, fundamentals of powder metallurgy and metal injection molding, soft magnetic properties of selected alloys, and examples of soft magnetic devices. To order a copy, please call 800-783-2420.

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**MPP uses its experience with PM soft magnetics in the production of these automotive sensor parts.**



**Soft magnetic solenoid plungers**