

# Magnetism and Stainless steel

**UGITECH**

Providing special steel solutions



Ugitech offers you in-depth know-how  
and a wide range of stainless steels for electrotechnical applications:

- Austenitic grades for guaranteed non-magnetic parts
- Ferritic grades for soft and resistive cores
- Martensitic grades for mechanical loads
- Duplex for high corrosion resistance requirements

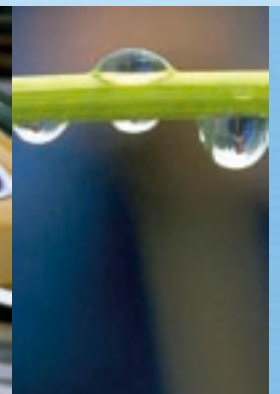
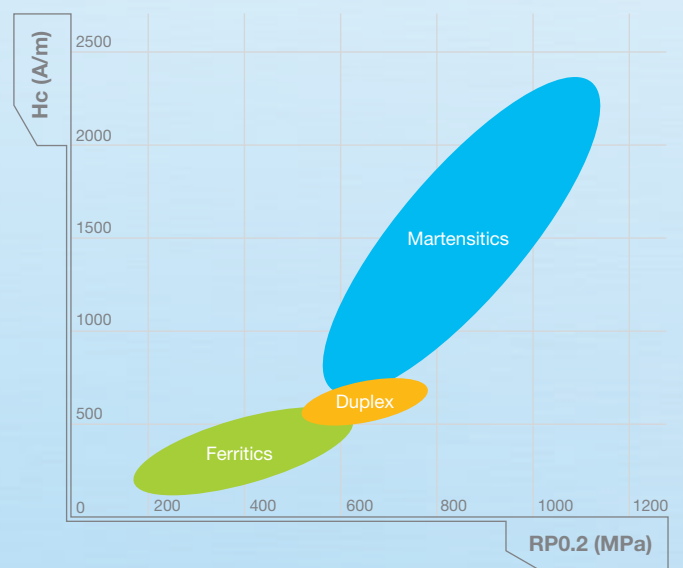
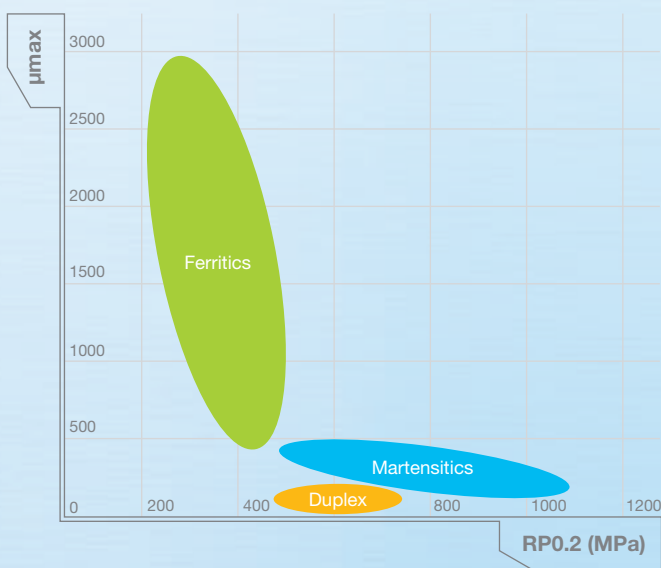
## A complete package:

Round and hexagonal bars,  
Special profiles and diameters on request.  
Metallurgical conditions and finishes:

- drawn,
- drawn and ground,
- drawn, magnetically annealed and ground (ferritic grades)

To produce ferromagnetic materials, Ugitech uses all available recognized magnetic measurement techniques: permeameters (IEN 60604-4/ ASTM A341/A341M), coercimeters (IEN 60604-7), gaussmeters and sigmimeters.

Maximum relative permeability / coercitive force in relation to elastic limit



# For non-magnetism:

## UGITECH austenitics

Many applications require stable non-magnetism. In such cases, austenitic grades are the best choice, due to their:

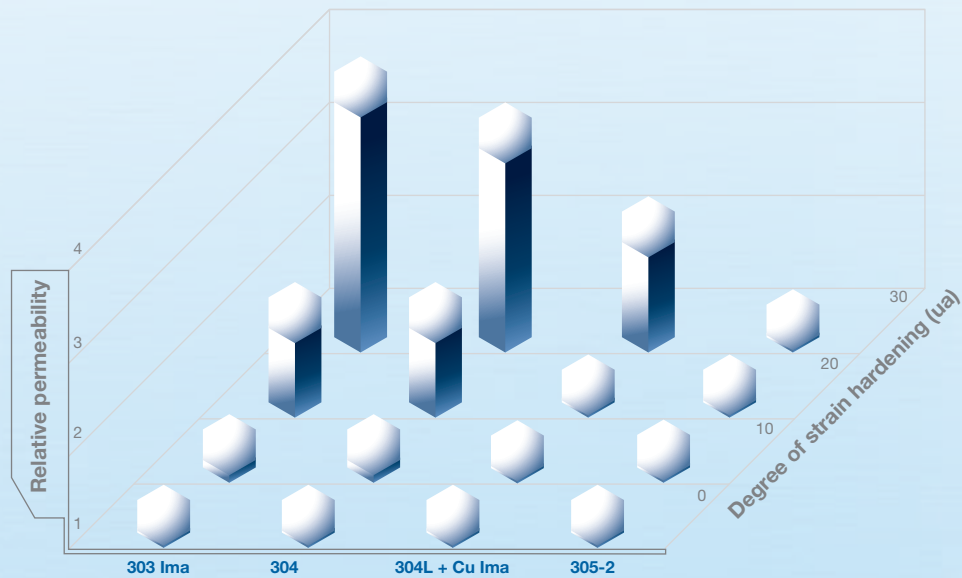
- anti-corrosion and mechanical properties
- very low permeability values

### Care needed in choosing and using

The choice of an inappropriate austenitic grade can generate a fractional martensitic phase during cold transformation, leading to a degree of ferromagnetism.

For this purpose, Ugitech offers grades that are relatively transparent immune to this phenomenon.

Examples of the change in the relative permeability of wires in relation to the grade and the different levels of strain hardening.



Grades	rate of work hardening			
	0	10	20	30
<b>305-2</b>	1.004	1.004	1.004	1.005
<b>304L + Cu lma</b>	1.005	1.005	1.012	1.082
<b>304</b>	1.012	1.046	1.626	3.09
<b>303 lma</b>	1.003	1.05	1.62	3.42

# For magnetism:

## UGITECH's ferritic grades

Ugitech offers a range of grades designed specifically for magnetic applications



### Ugiperm 12FM:

- Ferritic stainless steel with 12% chromium, with or without sulfur.
  - The stainless steel benchmark in terms of magnetic performance: excellent maximum permeability and low coercitive force.
  - Adequate corrosion resistance in gasoline environments.
  - High saturation flux density and electrical resistivity.
- Particularly suited to demanding short-response time applications: electro-injection, electrovalves, magnetic sensors, magnetic brakes.

### UGI 4105Si:

- Resulfurized stainless steel with 17% chromium and 1.5% silicon corresponding to alloy 2 of the ASTM A838/838M standard.
  - Trade-off between corrosion resistance/desire magnetism.
  - 2 levels of magnetism for annealed bars depending on customer requirements.
- Most widely used grade for automotive injection and electrovalves.

### IMRE:

- Resulfurized stainless steel with 18% chromium, 1.5% silicon and 1.5% molybdenum.
  - Excellent corrosion resistance in aqueous media and particularly in chlorinated media.
  - Level of magnetism close to that of UGI 4105Si.
- Widely used for electrovalves.

### UGIPERM 17:

- Stainless steel with 17% chromium and a low sulfur content.
  - Magnetic performance close to that of UGI 4105Si, with a lower electrical resistivity but higher mechanical properties.
- Used for automotive applications.

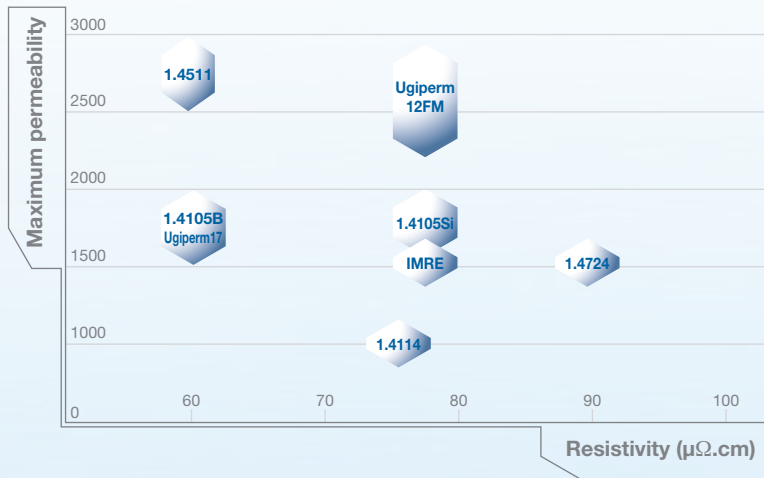
### UGI 4511:

- Stainless steel stabilized with niobium, with a low sulfur content for improved weldability
  - The 17% chromium content enables use in more aggressive environments.
  - Magnetic performance close to that of Ugiperm 12FM.
  - The best compromise between corrosion resistance/magnetism.
- Used for automotive applications – electrovalves.



Example: positioning according to maximum permeability/ electrical resistivity.

Diagram of maximum relative permeability of some ferritic grades in relation to their electrical resistivity.



### General properties of the grades suitable for magnetic applications.

	IMRE	UGI 4105Si	Ugiperm 12FM	Ugiperm 17	UGI 4511
Saturation of magnetization (T)	1.60	1.60	1.70	1.65	1.67
Coercitive force* (A/m)	150 to 200	130 to 200	100 to 125	150 to 200	100 to 150
Maximum permeability	1100 to 2000	1200 to 2200	2000 to 3000	1000 to 2000	2000 to 3000
Remanent field* (T)	0.25 to 0.8	0.5 to 0.9	0.5 to 0.7	0.5 to 1	0.5 to 1
Resistivity (μΩ.cm)	76	77	78	60	60
Appropriate media	Fuels, moderately chlorinated aqueous environments. Example: beverage machines	Fuels, moderately aggressive and slightly chlorinated aqueous environments	Fuels, moderately aggressive and slightly chlorinated aqueous environments	Fuels, moderately aggressive and slightly chlorinated aqueous environments	Fuels, moderately aggressive and chlorinated aqueous environments (resistance in weldable zones)
Machinability	improved	improved	Improved or standard	standard	standard

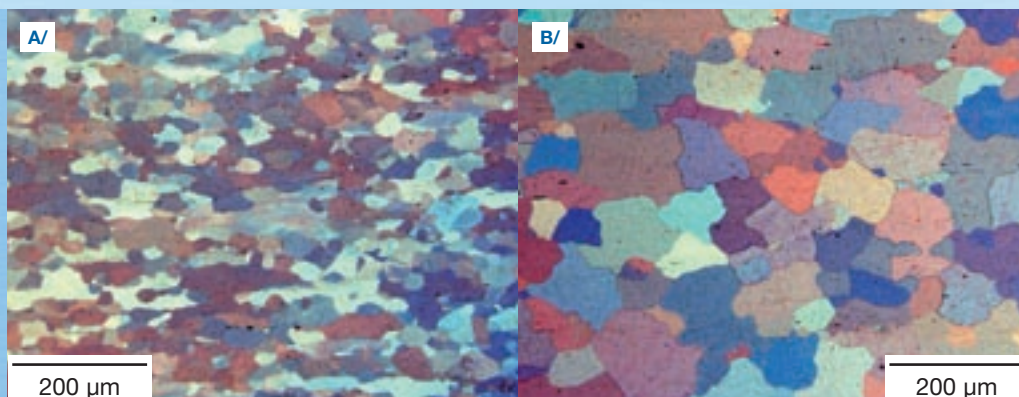
\* measurement after magnetic saturation of the material

To achieve a soft ferromagnetic state, magnetic annealing of either the bars or of the machined parts will be necessary. Depending on the grade and the level of magnetism required, the heat treatment conditions must be individually adapted to obtain the optimum metallurgical structure.

Ugitech can adapt the metallurgical properties of the grade to meet the requirements of your application.

Below, the microstructure of the same grade treated in 2 different ways but showing different magnetic performances.

This example illustrates the effect of grain size on the coercitive force.



Electron microscope showing 1.4511, both untreated and treated with magnetic annealing. Influence on coercitive force.

A/ Untreated - Hc = 350 A/m  
B/ Treated - Hc = 140 A/m

## The martensitic solution

The martensitic grades enable you to achieve good magnetic performance with high mechanical properties. In comparison to the ferritic grades, these grades are more difficult to magnetize and de-magnetize. They are also recommended for permanent magnetic parts.

### General properties of some UGITECH martensitic stainless steel grades.

	UGI 4005	UGI 4313	UGI 4418	UGI 4542
Saturation of magnetization (T)*	1.75	1.6	1.3 to 1.5	1.3 to 1.5
Coercitive force* (A/m)	850 to 1000	1200 to 1500	1650 to 2600	1800 to 3400
Maximum permeability*	180 to 380	200 to 300	100 to 200	50 to 200
Remanent field* (T)	0.9 to 1.2	0.7	0.5 to 0.7	0.4 to 0.7
Resistivity ( $\mu\Omega$ .cm)	57	60	80	70 to 80
Mech. properties (Mpa)*	R <sub>p0.2</sub> : 570-700 R <sub>m</sub> : 730-830	R <sub>p0.2</sub> : 800 R <sub>m</sub> : 1000	R <sub>p0.2</sub> : 930 R <sub>m</sub> : 1020	R <sub>p0.2</sub> : 800 to 1200 R <sub>m</sub> : 800 to 1300

\* depending on the heat treatment

## An intermediate solution: the UGIPLEX range

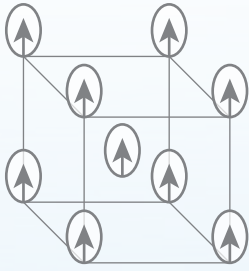
The Duplex grades are suitable for applications in highly corrosive environments.

The presence of a non-magnetic austenitic phase reduces the saturation flux density as well as the values of  $\mu$  and Hc in comparison with the ferritics.

### General properties of some UGIPLEX grades

	UGI 4362	UGI 4462	UGI 4507
Saturation magnetization density (T)	0.55	0.55	0.50
Coercitive force* (A/m)	600	700	750
Maximum permeability	50	40	30
Remanent field (T)	0.05	0.04	0.03
Resistivity ( $\mu\Omega$ .cm)	80	80	85
Appropriate medium	Identical to those for UGI 4404 (AISI 316)	"Middle of the range" Duplex for the chemical and petrochemical industries, paper mills and desalination	"Top of the range" Duplex for demanding applications in the chemical and petroleum industries, paper mills, desalination and pollution control

\*measurement after magnetic saturation



## How does it work?

The electrons present in a material give that material its specific magnetic properties when it reacts to the application of an external magnetic field (solenoid, magnet).

### The values used

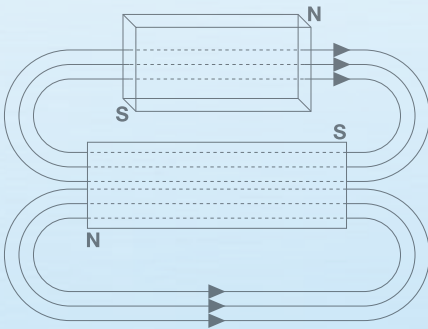
This reaction is measured using the induction,  $B$ , (air + material) or the magnetic polarization,  $J$ , corresponding to the material.

To assess the effect induced by the material, it is normally compared with that generated by the vacuum  $B_0$  when both are subjected to the same field  $H$ .

- in the material:  $B(H) = \mu(H) \cdot H$  - in the vacuum:  $B_0 = \mu_0 \cdot H$

The material is gauged using its relative magnetic permeability  $\mu_r$  corresponding to  $\mu/\mu_0$

### Several possibilities for Ugitech stainless steels



Based on the value of their relative permeability, two families can be defined

- The paramagnetics\* ( $\mu_r \geq 1$ ) that are crossed through by the field  $H$  with very little change. They are used for parts that must remain "transparent" with respect to a field applied. Austenitic stainless steels are part of this family. To ensure that they remain paramagnetic whatever the machining or heat treatment conditions, a very stable austenite is necessary.

\*also called non-magnetics

- The ferromagnetics ( $\mu_r \gg 1$ ) include ferritic, martensitic and duplex stainless steels. The polarization of the metal tends to align with the external field, and then channel it and reinforce it. They can be used as field amplifiers (magnetic cores) and/or field channelizers (magnetic lining).

### Is electrical resistivity important?

Stainless steels are particularly suited to this application, due to the significant presence of alloying elements.

When a ferromagnetic part is subjected to a variable field, Eddy current parasites are generated. To obtain a rapid response from the application, magnetic performances alone are not enough. To counter this phenomenon, materials with high electrical resistivity are used.

Experience has shown that it can be just as important to consider resistivity as it is to consider the traditional magnetic values.

#### Typical electrical resistivities for materials measured at 25 °C.

Material	Behavior	Resistivity ( $\mu\Omega \cdot \text{cm}$ )
Austenitic stainless steel type AISI 304, 316	Paramagnetic	72 to 74
Electrical steel	Ferromagnetic	13
Steel with 2.5% silicon		40
Martensitic stainless steel UGI 4005		57
Ferritic stainless steel UGI 4016L, UGI 4511		60
Ferritic stainless steel UGI 4105Si, IMRE, Ugiperme 12FM		76 to 78



# UGITECH production plants

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