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IC-plasma sprayed Nd-Fe-B-coatings for applications in electrodynamic microactor systems

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1. Introduction

Magnetic actors are dominating common drive technologies. The trend in this field is clearly going to a miniaturization of functional parts and therewith an increasing of the packing and energy density. In microactoric systems, the existence and formation of a magnetic field as an essential requirement of the functionality, is connected to a three dimensional microstructure. Hence, especially applications in this growing field are demanding coatings with a thickness of 20 µm to 1.000 µm with a high energy density. In contrast to well known applications of permanent magnetic layers, i.e. data storage with a coating thickness of some nanometers only, the preparation of thick magnetic coatings is a technical challenge. Because of having the highest known energy density, rare earth materials are often used as basic materials for such coating systems.

Commonly used technologies, like sputtering, screen-printing or embedding of powders in polymers are limited in producing coatings with the demanded thickness, magnetical/mechanical parameters and process effectivity. On the other hand, thermal plasma spraying is well known as an effective way to get thick coatings. But corresponding studies for plasma sprayed magnetic coatings are rare because of significant thermal and/or chemical induced transformations of the powders during plasma spraying. This leads to the effect that the magnetic properties of the as-sprayed coatings are far away from the initial powders.

A previous research project, performed by the Department of Plasma and Surface Technology has demonstrated the possibility of spraying thick magnetic Nd-Fe-B-coatings with considerably better properties, compared with DC-sprayed samples by using an inductively coupled thermal high frequency plasma (ICP).

This can be explained by the fundamental different plasma characteristics and out coming of this the different conditions of powder heating in the IC-plasma and the deformation/cooling down of the molten particles on the substrate surface.

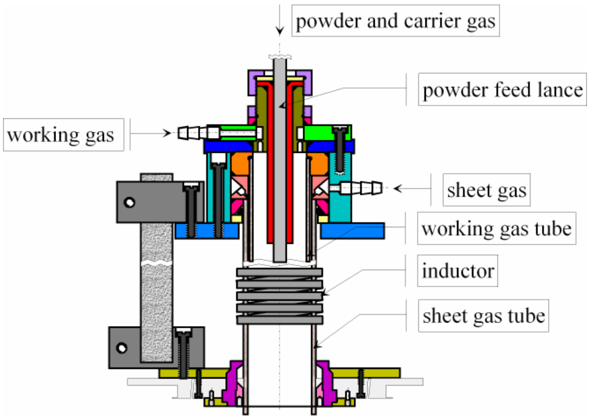
2. State of the art

NdFeB-magnets with relatively simple geometries are well known as compact sinter bodies[1]. Another possibility for producing such magnets is the embedding of powder in a polymeric matrix, but here the magnetic properties are reduced due to the decreasing density of the magnetic material in the magnet [2].

For using permanent magnets in actoric systems this compact structures are not usable, coatings of a thickness between 50 µm and 1.000 µm on complex 3-d-geometries are demanded [3]. Plasma spraying of such coatings may be an effective way for its manufacturing but up to date only a few studies about plasma spraying of NdFeB-coatings using a DC-Plasma torch were published [4-7]. The main reason for this seems to be the strong chemical transformation of the material after the Impact on the substrate surface and during the process of cooling down. This is connected to a drastical decrease of the magnetic properties compared with the initial powder.

3. Experimental Setup

An ICP plasmatron, developed at the TU-Ilmenau, serves as plasma source (picture 01). This plasmatron consists of a system of concentrically tubes, placed centered in an induction coil. The principle of plasma generation is nearly similar to the well known induction heating of metals but because of the plasma gas properties at the ambient plasma temperatures the depth of permeation is much higher here compared with copper at room temperature [8]. Plasma generation occurs in a quartz glass tube in the area of the induction coil. It is covered by a sheet gas flow.

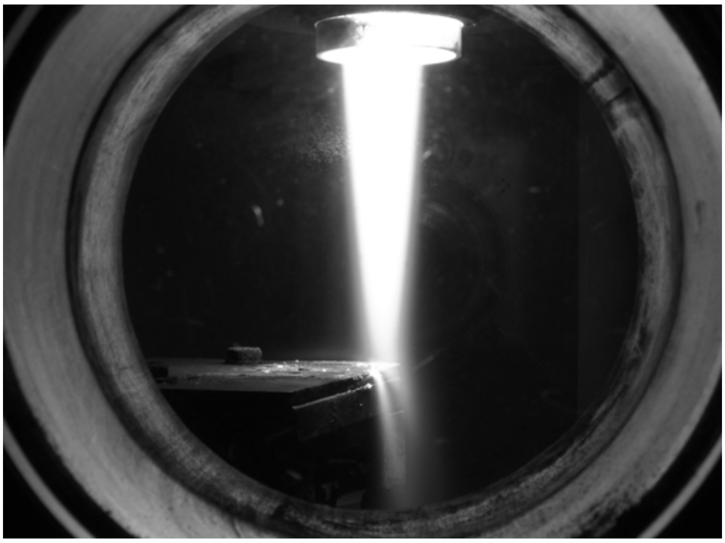


Picture 01: schematic of the ICP generator

The sheet gas (mixture of Argon and Nitrogen) , with a radial component, and the tangential working gas flow (Argon), which are separately fed by concentrically arranged sheet gas and working gas tubes into the plasmatron, stabilize the plasma. The relative speed of the working gas flow is lower than that of the surrounding sheet gas flow. Because of the laminar flow of the sheath gas it forms an inert cover around the plasma that decreases the infiltration of the surrounding atmosphere into the plasma caused by convection drastically.

For exact powder injection a powder feeder lance, which is axially arranged to the working gas tube, extends into the plasma core. Thereby at a Power of 20 kW a ring-shaped discharging zone with temperatures > 10.000K will be established [9].

Hence, all system components (inductor, sheet- and working gas tube, powder feeder lance) must be water-cooled. The resulting plasma jet expands in a vessel with an adjustable pressure between 600 mbar and 220 mbar and is shown in picture 02 (p = 220mbar).



Picture 02: resulting plasma torch by 220mbar [10]

The source powder material for the coating, MQP-S 9-8 made by MAGNEQUENCH company is an NdFeB spherical powder with a grain size spectrum from + 63 µm - 45 µm which contains the hard-magnetic $Nd_2 Fe_{14}$ B-phase.

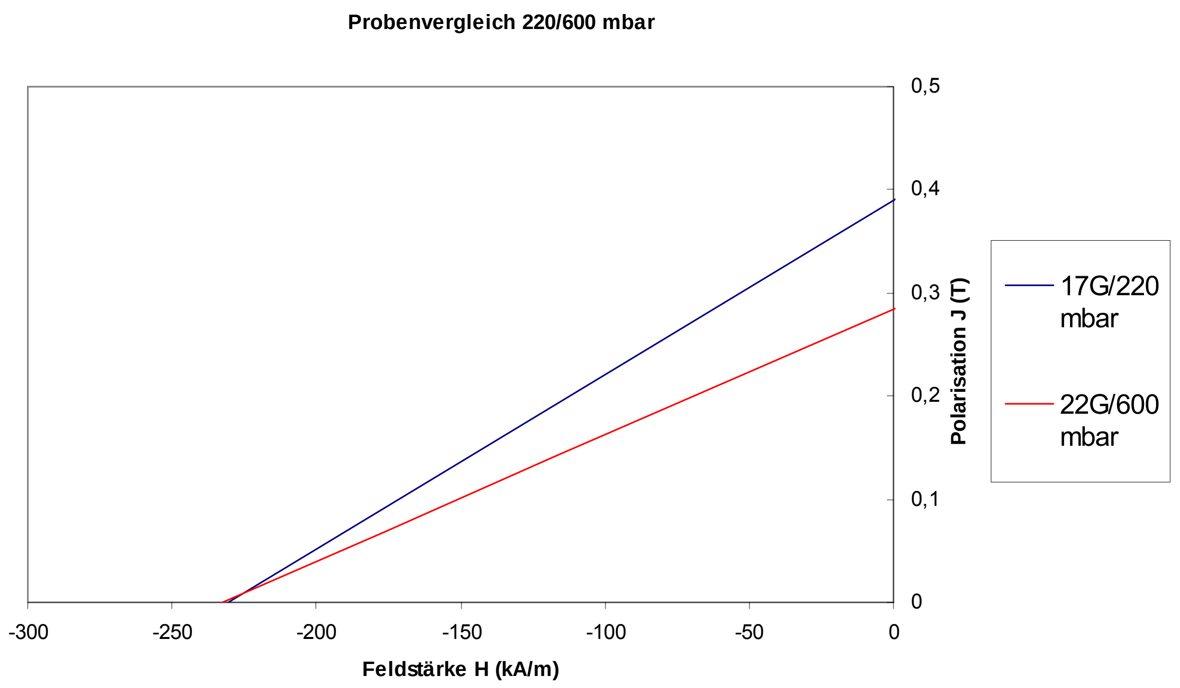
Table 03: magnetic values of MQP-S 9-8

Property	Value
Remanence induction	680 - 720 mT
Coercivity	640 - 760 mT
Energy product	67 - 77 kJ/m^3
Density	7,37 g/cm^3
Curie – temperature	≈ 300°C

4. Results

The samples were magnetized with an impulse magnetizer. Only this way the necessary saturation inductions can be reached. Coated samples were placed in an iron ring and the magnetic flow was measured. The principle of this measurement is the changing of the magnetic flow with and without the sample. It has to be mentioned, that this principle is not comparable with the one of the initial powder, so the results are not directly comparable to the known values of the powder too.

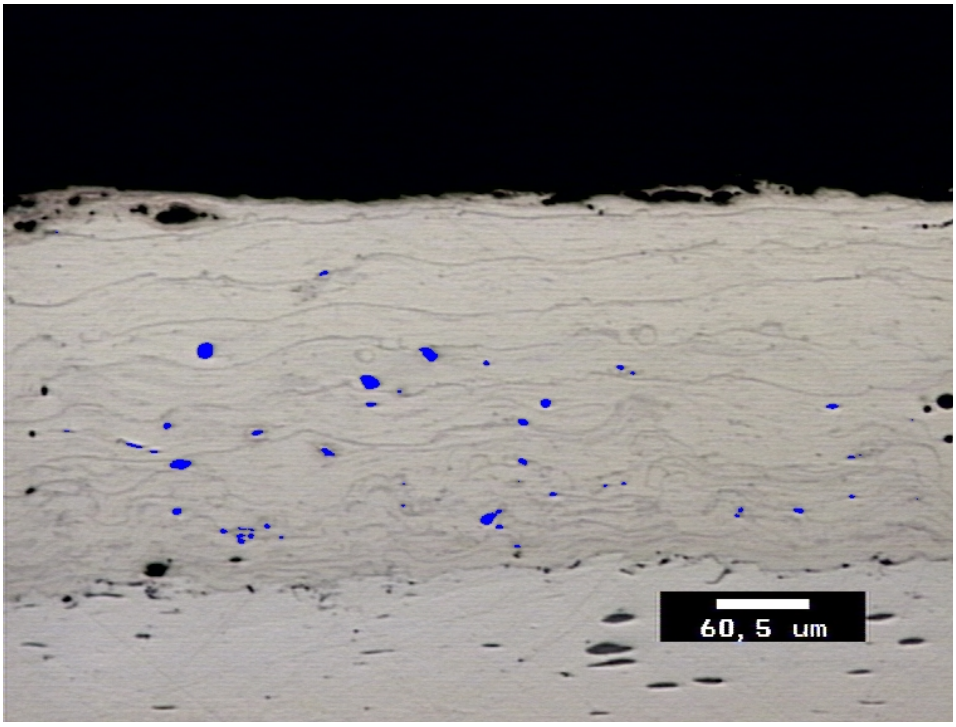
Picture 03 shows the results of the measurements of the magnetic properties for two variuos chamber preassures. One can see differences in the magnetic properties, caused by changed plasma and surrounding atmosphere properties, respectively.



Picture 03: magnetic properties of two samples, sprayed with various chamber pressures [10]

The decreasing of the chamber pressure leads to a increasing of the plasma length and velocity. This is combined with changed conditions of powder heating and melting and with a higher kinetic energy of te molten particles at the moment of impact. Coevaly the deformation will change. This and the decreasing amount of possible reactions with the surrounding atmosphere seems th be the reason for the better results at 220 mbar. But on the other hand this effect can be used for spraying magnetic coatings with adjustable magnetic properties.

The changed sperayING conditions can also be found at the cross sections of the samples. An example is shown in Picture 04. We found a lower porosity at 220 mbar compares with 600 mbar due to the better conditions of heating and melting (incresing of the dwell time of the particles in the plasma).



Picture 04: Cross section of a sample, sprayed at 220 mbar [10]

5. Summary

The developed manufacturing of IC-plasma sprayed layers with approximately reproducible magnetic and mechanical qualities can be the basis for later applications in technology. With the ICP coatings with explicit better properties compared with the published DCP-coatings can be produced. Further investigations are necessary to ensure the reproducibility and the influence of the chamber pressure on the properties of the coatings.

The main advantage of the ICP sprayed magnetic layers is the high energy density combined with a good mechanical stability. The TU-Ilmenau is currently working on the further examination and a commercial exploitation of this coating procedure.

References:

[1] P. l´Heritier et al.,
C. R. Acad. Sci. 299 (1984) 284 ff.

[2] Sumitomo Special Metals – Company publications
www.ssmc.co.jp, March 2006

[3] E. Kallenbach et al.
Proc. Mechatronics 98, Skövde 465 ff.

[4] J. J. Wyslocki:
J. Mat. Sci. 27(1992), 3777ff.

[5] R. A. Overfeld et al:
Appl. Phys. Letters 49(1986), 1799ff.

[6] F.-W. Bach et al:
Proc. of the UTSC´99, Düsseldorf 1999

[7] SBIR: Small Business Innovation reseach Project
#53, Project #55; www. Sbir.er.doe.gov

[8] G. Nutsch: Habilitationsschrift
TU Ilmenau 1995

[9] B. Dzur: Dissertationsschrift
TU Ilmenau, 2002

[10] G. Thomas: Studienarbeit
TU Ilmenau, FG POT, 2006

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