Coating of NdFeB to Improve Corrosion Resistance and Retaining Magnetic Susceptibility

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Abstract: NdFeB is a rare earth magnet which is one of the strongest permanent magnets. NdFeB has low corrosion resistance due to which its applications are limited at both low and hig temperatures. The core objective is to enhance the corrosion resistance through application of inorganic coating such that it can be used at various temperature ranges. First of all EDS of NdFeB was done to check for its composition. After which potentiodynamic testing was carried out to find out the corrosion potential of our sample by GAMRY Instruments. AlN coating on NdFeB by using PVD technique in order to achieve minimum thickness so that it can also sustain magnetic properties along with better corrosion resistance. PVD will impart minimum thickness of coating resulting in better magnetic properties as compared to CVD or other coating techniques. AlN coating will not peel of under some loading conditions and will maintain the protection in each and every environment because coating is less adherent with hydrogen so attack of hydrogen on grain boundaries rich in Nd will not occur. Corrosion resistance of NdFeB is improved to about tenfold and hardness is also achieved because AlN has more hardness than conventional aluminum.

Key Words: NdFeB, GAMRY, EDS Hysteresis loop, Corrosion Resistance

I. Introduction

Neodymium magnets are strongest and widely used permanent magnets but these magnets are vulnerable to oxidation/corrosion than samarium-cobalt and other permanent magnets. Corrosion can cause unprotected magnets to spall off a surface layer, or to crumble into a powder. Gold, nickel, zinc and tin plating are widely used coatings for the protection of these magnets; such coating can provide corrosion protection. NdFeB has inherently low corrosion resistance which limits it application at both room temperature and at High Temperature. The core objective is to enhance the corrosion resistance through the corrosion resistance of AlN coated NdFeB using PVD will increase to tenfold the conventional Nickel Coating with no loss in magnetic flux density. Three things are important in preventing corrosion of Nd-Fe-B magnets. We can prevent it by controlling the chemistry of the grain boundary in the magnet or by preparing the surface for coating and applying the coating correctly. Coatings can improve the corrosion resistance.

The present work aims at depositing the AlN coating on NdFeB using PVD techniques to impede the corrosion resistance. Comparison of Ni coated magnets using PVD is also done with the presented work i.e. Ni coating by PVD is also done. The properties of AlN coating system are done with Ni coating system. From PVD less thick coating can be obtained as compared to CVD. PVD gives about 2-5microns of thickness whereas from CVD 5-10microns thick coating will be obtained.

II. Experimental:

A. Materials:

Sintered NdFeB magnets which are our sample material can be commercially produced by powder metallurgical route. The neo magnets had the hydrostatic density of 7.58 g/cm3, while their theoretical density is 7.60 g/cm3. The chemical composition of the magnets (Table 1), was determined through SEM, Boron has low atomic number and have low transition energies so that cannot be detected by available EDX analyzer.

Table 1 Chemical composition of sintered NdFeB permanent magnets

Elements	B	Nd	Fe	Pr
w/wt.%	1.26 ±0.15	32.90 ±0.33	Balance	9.3
x/at.%	8.0	15.0	75.0	2.0

B. Specimen preparation:

C shaped neo magnets were grinded and polished metallographically. Further magnets were cleaned electrochemically using sulphuric acid, nitric acid and distilled water. To reveal the micro-structure the specimens were etched in 1% HF solution.

C. Coating using PVD:

The coating for our sample is AlN using PVD technique. Selection criteria for coating are;

- High temperature resistance
- Magnetic properties
- Stability of coatings

PVD processes are carried out under vacuum conditions. The process involved four steps:

- Evaporation
- Transportation
- Reaction
- Deposition

D. Evaporation

During this stage, a target, consisting of the material to be deposited is bombarded by a high energy source such as a beam of electrons or ions. This dislodges atoms from the surface of the target, 'vaporizing' them.

E. Transport

This process simply consists of the movement of 'vaporized' atoms from the target to the substrate to be coated and will generally be a straight line affair.

F. Reaction

In some cases coatings will consist of metal oxides, nitrides, carbides and other such materials. In these cases, the target will consist of the metal. The atoms of metal will then react with the appropriate gas during the transport stage. For the above examples, the reactive gases may be oxygen, nitrogen and methane.

In instances where the coating consists of the target material alone, this step would not be part of the process.

G. Deposition

This is the process of coating build up on the substrate surface.

Depending on the actual process, some reactions between target materials and the reactive gases may also take place at the substrate surface simultaneously with the deposition process.

III. Characterization:

Characterization for coated samples using SEM, EDS, GAMRY and for magnetization testing hysteresis test was used to obtain hysteresis loop. Samples are prepared metallurgically by grinding and polishing. Electrochemically cleaning of samples using solution of sulphuric acid, nitric acid and distilled water is done.

Samples are tested under SEM for their microstructure and EDS to determine their composition.

Spectrum processing:

Peak possibly omitted: 0.271 keV

Processing option: All elements analyzed (Normalized)

Number of iterations = 3

Element	Weight%	Atomic%
Al K	2.38	6.06
Fe K	62.97	77.37
Pr L	7.12	3.96
Nd L	26.52	11.62
N k	1.01	1.33
Totals	100.00	

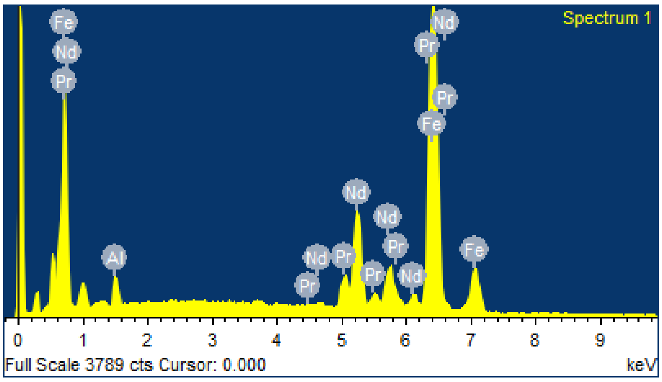

Figure 1: EDS analysis of coated sample

Boron has low atomic number and have low transition energies so that cannot be detected by available EDX analyzer.

Whereas SEM micrograph of surface coating can be seen in figure below, surface image or reflection can be seen only because of coating.

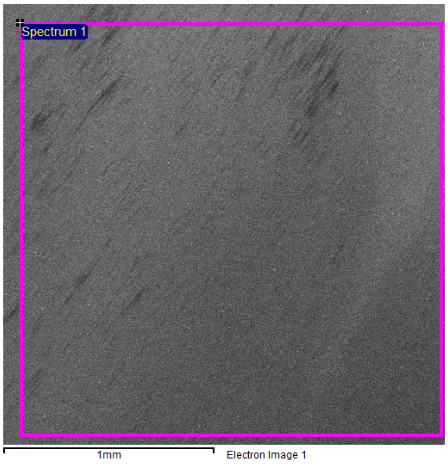

Figure 2: SEM image of AlN coating surface

For measurement of corrosion potential, GAMRY test was done. Corrosion potential values of uncoated magnets were

Ecorr = 507mV

Icorr = 437mA
Corrosion Rate = 199.7×10^4mpy
Chi Squared = 437mA
Beta A = 1.942V/decade
Beta C = 1.4155V/decade

Whereas for AlN coated magnets corrosion potential value was found to be good than uncoated an Nickel coated magnet;

Corrosion Rate =465mpy

This also proved that we were successful in improving the corrosion resistance of our samples.

Magnetometer and hysteresis loop were used to determine the magnetization of coated magnets and it was found that coating does not involved in reducing any sort of magnetic susceptibility of magnets. Obtained results deduced that there was no inferiority in magnetic properties of the magnet as compared to original properties of the magnet. So approximately similar magnetism like permanent magnet was achieved using AlN coating by PVD process.

IV. Results and discussion:

AlN coating retains magnetic properties at various temperatures. It is more stable than conventional Nickel and TiN coatings at higher temperatures. Good adherence with matrix and are hard (harder than carbide, 3X hard chrome).The corrosion resistance is increase to much extent with no loss in magnetic flux density. AlN coating will not peel of under some loading conditions and will maintain the protection in each and every environment because coating is less adherent with hydrogen so attack of hydrogen on grain boundaries rich in Nd will not occur. Also we will be able to make the magnets with Nd rich phase which will increase the magnetization. AlN coating thus not only retaine the magnetic properties but it also resulted in improving the corrosion resistance of the magnet. So coating selection will effect in the increase of magnetic flux density as well as the improved corrosion resistance at low and at elevated temperature with large amount of stresses because convention coating do not work well under the dynamic condition of loading and temperatures but AlN can sustain loading and can work well at higher temperatures.

V. Conclusions:

Researches and work has been done on NdFeB magnets to protect them from corrosion but to protect their magnetic properties and give them corrosion resistance at various temperatures we applied AlN coatings by PVD. PVD will give less thickness as compared to CVD due to which magnetic susceptibility is retained by our samples. Corrosion resistance of magnet is also improved to much extent without altering magnetic properties of the samples. So objective of our work was achieved to much extent. AlN can also provide sufficient hardness because it has better hardness than conventional coatings and can sustain loads.

VI. References:

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