Sodium nitrate passivation as a novel insulation technology for soft magnetic composites

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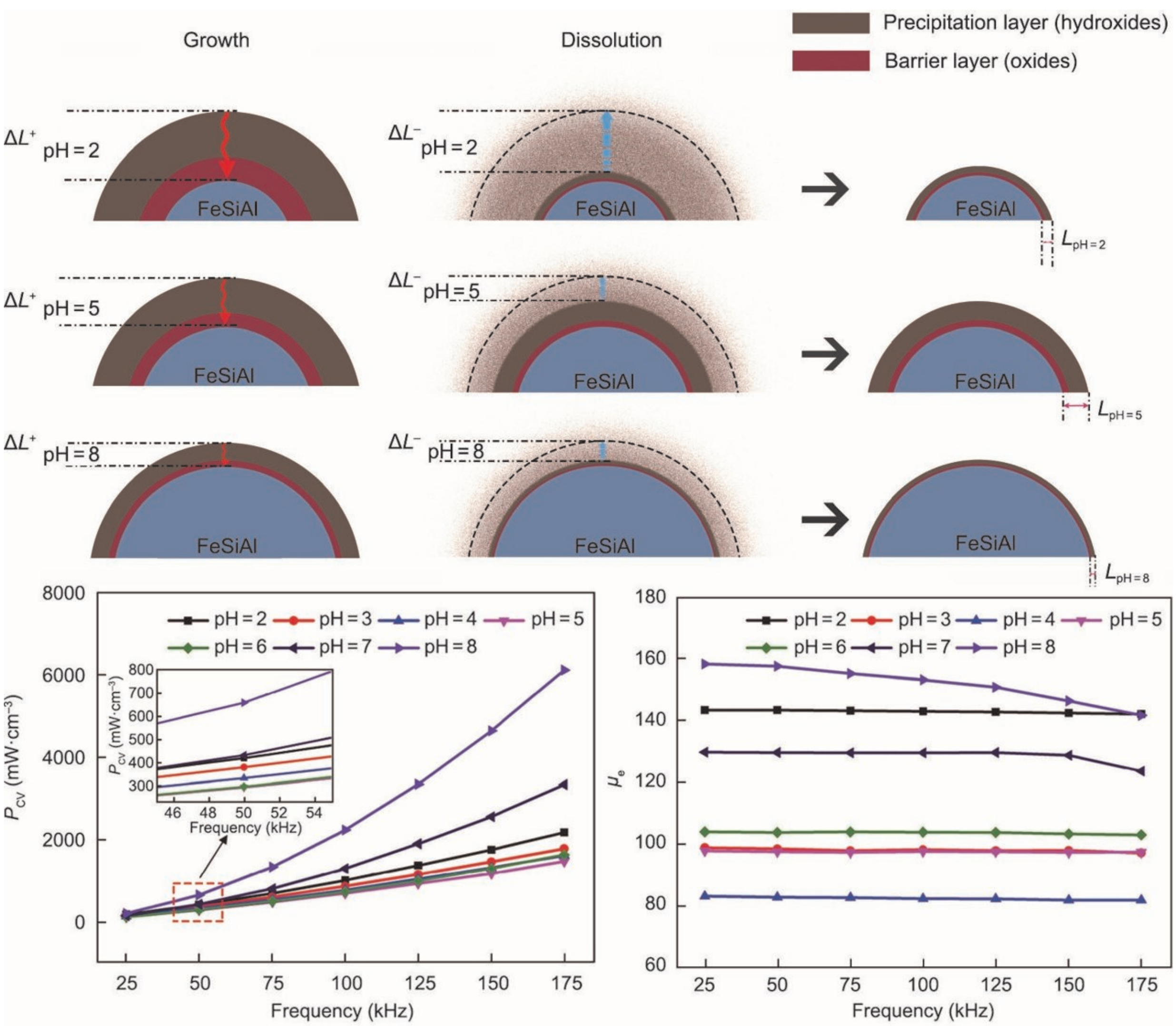

The insulation coating exhibits bi-layered structure containing an oxide barrier and a hydroxide precipitation layer. The growth and the dissolution rate of the coating vary with the pH value of the $NaNO_3$ passivation solution, resulting in different coating thickness, which is correlated to the magnetic performance of the corresponding soft magnetic composites. Credit: Prof. Mi Yan

Soft magnetic composites, which are fabricated based on metallic magnetic powders via insulation coating, binding, compaction, and annealing, serve as the key fundamental material in various fields including energy, transportation, aerospace, and national defense. Due to the low-electrical-resistivity nature of the soft magnetic alloys, it is challenging to control the eddy current loss, which has become a bottle-neck problem for high-frequency applications.

For scientific research and industrial production, phosphorization technology is usually used to generate insulation coatings. However, the resultant phosphate coating tends to decompose above 600 C and lose the insulation effect at elevated temperatures. It is of great significance to develop new insulation technology to form coating layers with strong adhesion, together with satisfactory thermal stability and electrical resistivity for high-frequency applications of soft magnetic composites.

Recently, *Engineering* published research work on sodium nitrate passivation as a novel insulation technology for soft magnetic composites developed by Prof. Mi Yan and Dr. Chen Wu's team.

In this work, Prof. Yan and Dr. Wu's team has proposed sodium nitrate passivation as a novel insulation technology for soft magnetic composites. Evolutions of the coating under different pH conditions have been revealed based on systematic compositional and microstructural investigations, with the growth mechanisms of the coatings unveiled through kinetic and thermodynamic analyses.

The study shows that the insulation coating obtained using an acidic $NaNO_3$ passivation solution with pH = 2 consists of Fe_2O_3, SiO_2, Al_2O_3, and AlO(OH). Large growth rate of the coating layer resulted due to the strong oxidation capability of NO_3^- under acidic conditions, while the dissolution rate of the passivation layer is also high because of the large H^+ concentration, giving rise to small thickness of the passive layer at pH = 2.

With an increased pH of 5, the Fe_2O_3 converts into Fe_3O_4 with weakened oxidation capability of NO_3^-. Despite the slightly decreased growth rate of the passivation layer, the reduction of H^+ concentration also greatly inhibits its dissolution, resulting in a maximum thickness of the insulation coating for significantly enhanced electrical resistivity and optimum alternating current (AC) magnetic performance ($\mu_e = 97.2$, $P_{cv} = 296.4$ mW/cm^3 under 50 kHz and 100 mT).

Further raising the pH to 8 significantly weakens the oxidability of the NO_3^-, resulting in only Al_2O_3, AlO(OH), and SiO_2 in the passivation layer with slow growth and significantly reduced thickness. In addition, corrosion occurs in some regions of the magnetic powder surface, leading to deteriorated performance.

The $NaNO_3$ passivation technology developed in this work is not only extendable to other magnetic alloy systems but also lays a solid foundation for the development of novel and advanced insulation coatings that use oxidizing agents such as nitrite, superoxide, and permanganate.

More information: Mi Yan et al, Sodium Nitrate Passivation as a Novel Insulation Technology for Soft Magnetic Composites, *Engineering* (2022). DOI: 10.1016/j.eng.2022.01.016

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