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Properties of MnZn ferrites prepared by powder injection molding technology

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ABSTRACT

In this work, manganese zinc ferrite components were manufactured by powder injection molding—PIM technology. A fine powder consisting of $Mn_{1-x}Zn_xFe_2O_4$ with small addition of hematite α-Fe_2O_3 as used in mass ferrite production was mixed with an organic binder (Solvent System) to form ferrite feedstock for powder injection molding—PIM technology. Excess of Fe_2O_3 was present in the starting powder in order to suppress conversion of Fe^{3+} to Fe^{2+} ions which would lower the permeability. The ferrite feedstock was injected in a mold with a cavity shaped like a small cylinder with a hole on the main axis. Injection molded samples were then solvent and thermally debinded and sintered in different atmospheres: air, argon and nitrogen. The starting powder, injected green samples and sintered samples were characterized using X-ray diffractometry, scanning electron microscopy, thermogravimetry, differential thermal analysis as well as by magnetic measurements. Rietveld refinement of measured X-ray patterns was done to detect possible phase transformations of Fe_2O_3 to other iron oxides through reduction by binder residues (carbon) at elevated temperatures during thermal debinding and sintering. Finally, the magnetic properties were measured by hysteresis graph and mutually compared for the injected samples that were sintered in air, argon and nitrogen. The obtained magnetic characteristics where found to be comparable with commercial samples prepared by traditional sintering technology.

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1. Introduction

Manganese zinc ferrite $Mn_{1-x}Zn_xFe_2O_4$ is a magnetically soft material suitable for use as magnetic cores in the low frequency range (typically 1 kHz to 1 MHz). Today soft ferrites are used as cores such as RM (rectangular modular), P (pot) cores, E-cores, ER, ELP, EFD (flat cores), U and UR cores. These cores are used as transformers for power supply in AC/DC and DC/DC converters and cores for spooled chip inductors in TV sets, computers, telecommunication, automation and car electronics, ships, trains and planes, i.e. virtually everywhere in the modern electronic equipment. Manganese zinc ferrite $Mn_{1-x}Zn_xFe_2O_4$ has the same spinel configuration as magnetite Fe_3O_4 or $FeO{\cdot}Fe_2O_3$ (isomorphous to $MgAl_2O_4$, Bragg mineral Spinel). Although $MnO{\cdot}Fe_2O_3$ has higher magnetization at room temperature than $ZnO{\cdot}Fe_2O_3$ or $FeO{\cdot}Fe_2O_3$, a complex configuration representing a solid solution of spinels (Mn, Zn, Fe)$\cdot Fe_2O_4$ [1,2], is the most useful type for a variety of applications. As shown in Fig. 1 magnetic permeability is a function of the $MnO/ZnO/Fe_2O_3$ composition ratio [2]. Variation of the Mn/Zn/Fe ratio in MnZn ferrites gives a wide range of initial relative permeability values from 10^3 to 10^4, lower losses and increased thermal stability of magnetic properties [3,4].

For soft ferrite magnetic core production, a well known technique of uniaxial powder pressing with 1% polyvinyl alcohol (PVA) and sintering for defined temperature/time profiles and with defined partial pressures of nitrogen and oxygen is used [5]. However, recently a number of alternative preparation routes have been applied for the production of ferrite powder, such as co-precipitation, wet methods employing aqueous solutions and various gel techniques.

Powder injection molding (PIM) is an extremely flexible manufacturing technology that enables the production of generally small components to highly complex geometrical shapes from different materials (ceramics and metals). Nowadays both soft and hard magnetic materials are used in the production of numerous components. Some complex magnetic parts have already been made using PIM technology. This technology is very suitable for hard magnetic materials and its application enables easier production of complex cores than the classical technique [6–11].

The power losses in ferrite cores can be lowered by increasing the permeability of the material. There were two main motivations for PIM investigations of MnZn ferrites: higher core shape complexity in RM and EFD cores and better permeability, e.g. lower power losses. In this work PIM technology was employed for reaching the

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