New Magnetic Ferrite Materials for Innovative RFID Concepts

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RFID Applications (acronym for Radio-Frequency IDentification) consist the most up-to-date identification technique using high frequency radiation on a "tag-antenna" communication setup. With significant advantages compared to the conventional barcode utilities that include greater reading distances without a requirement for a direct line of sight, very high read rates (>40 tags/sec), reusability and most importantly, a read-write capability and communication, RFID systems are already introduced in most supply chain automations, asset tracking, access control, equipment/personnel tracking, animal/pet tracking and various medical applications [1].

The communication efficiency between the tag and the antenna can be significantly improved when the tag (usually a copper coil pattern) is supported on a background of a ferromagnetic material. Due to the development of a magnetic field around the copper coil, which is parallel to the surface of the identified item, an elimination of signal distortion is accomplished and signal enhancement is achieved.

In the present work a new ceramic magnetic material was developed in order to improve the RFID data transfer for the 900 MHz operation frequency, in terms of reading distance and a possible miniaturization of the ferrite antenna. A hexagonal Y-type ferrite material was specially designed to meet the magnetic requirements of high initial permeability, low magnetic losses at the operation frequency and a resonance frequency above 2 GHz. An increase of the reading distance by a factor of 2 was detected on the prototype RFID setup with the ferrite backing the tag in near-field measurements.

Experimental

The Y-type hexagonal ferrites of the molecular formula $Ba_2 (Co_x Cu_y Zn_z) Fe_{12} O_{22}$, where x+ y+ z=2 were prepared by the solid state reaction method. The raw materials were wet mixed and the mixed powder was prefired at 1050-1150^{0}C in air for several hours. The obtained Y-type hexagonal phase was checked by X-Ray Diffraction and the powder was subsequently milled for 3 hours. A PVA binder was added to the dried powder by roll granulation and ferrite toroids and cylinders were uniaxially pressed to form compacts of a green density of 3.30 g/cm^3. Sintering cycles between 1100-1400^{0}C were applied and the electromagnetic properties of the sintered specimens were measured up to 3 GHz, using a spectrum analyzer and an impedance analyzer. Thin disc-shaped slices with a thickness of 0.5-1 mm were cut from the sintered cylindrical specimens by a microtome.

Application testing

The experimental setup used for the evaluation of the ferrite slices in terms of reading distance enhancement is schematically described in Fig. I. A loop antenna (1) is connected through a special module (2) (Skyetek M9) and an interface (3) to the USB port of the computer (4) carrying the appropriate software (Skyetek, Skyware 4). The tag (5) (type IN26, RSI ID technologies) is placed on a sliding surface opposite to the antenna. As long as the tag is identified by the antenna, a signal appears on the computer screen. Upon increasing the distance between the tag and the antenna at a certain moment the tag is no longer readable. This is defined as the maximum reading distance (MRD). Once MRD is registered for the tag alone, the experiment is repeated with the tag supported on a thin (0.5-1mm) slice of ferrite material (6). The new MRD is also registered and any difference with the reference is recorded.

Results-Discussion

In Fig.II the initial permeability (μ_i, measured at 20 kHz), the quality factor (Q_{900}, measured at 900 MHz) and the MRD enhancement are shown for samples S1-S6. The MRD enhancement is defined as given in Eq. I:

$$MRD = \frac{(MRD_{with\ \ ferrite} - MRD_{without\ \ ferrite})}{MRD_{without\ \ ferrite}} x100 \qquad (1)$$

It is found that as the Co content is increased (S1-S6), the initial permeability decreases, while the quality factor increases. This is due to the highly anisotropic character of Co, which leads to a shift of the resonance frequency to higher levels [2]. As a consequence, the quality factor increases, as it depends strongly on the onset of the ferromagnetic resonance and the imaginary part of the permeability. This behavior of the permeability is a well known phenomenon described by Snoek's law [3] and its modifications for polycrystalline systems [4,5] and also holds for other ferrite materials, like those of the cubic spinel structure. The mentioned trends also follow the gradual decrease of the Zn content, in accordance to previous studies [6]. Comparing samples S4-S5-S6, a gradual permeability drop is detected, caused by insufficient densification due to the absence of Cu, which is known to act as a sintering aid in ferrite systems [7].

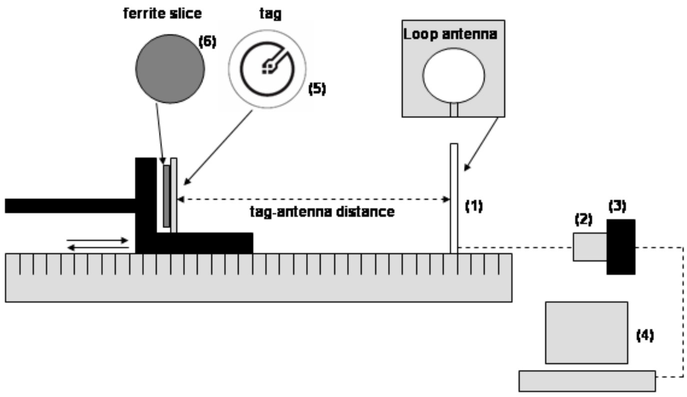

Fig.I. Experimental setup for the RFID measurements

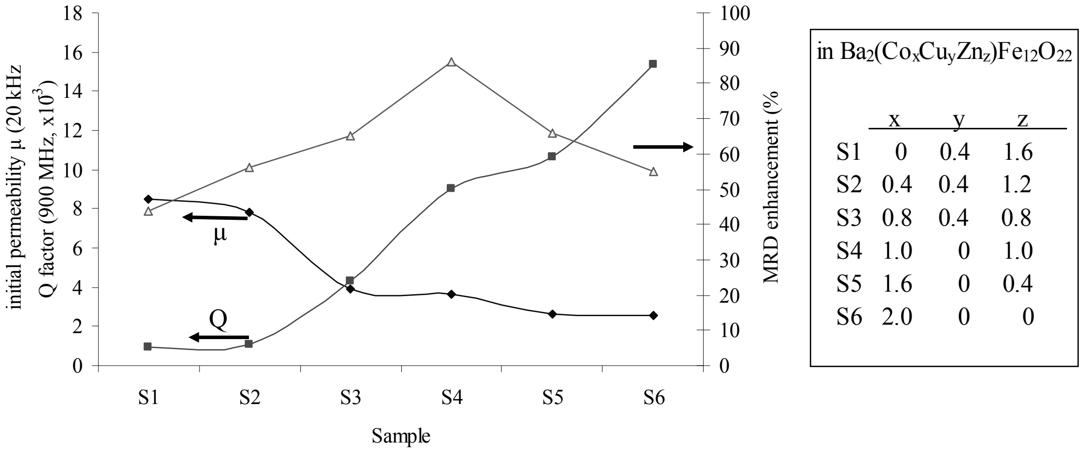

Fig.II. Initial magnetic permeability, quality factor and MRD enhancement for samples S1-S6

It is found that there is an optimal set of conditions required to achieve the greatest MRD enhancement, which indicates that a certain density is required to give an adequate average permeability-high quality factor set. A maximum MRD enhancement of 86% is achieved with sample S4. Under the chosen experimental conditions (e.g. antenna, tag type etc.) the typical net reading distance (without the ferrite support) of 10mm increases to 18.5±0.3 mm when the tag is supported on the S4 ferrite slice.

Finally, the strong dependence of the quality factor on the morphological characteristics of the polycrystalline microstructure, such as potent insufficient densification, secondary recrystallization phenomena and second phase inclusions is also evident on the evaluation of the MRD modifications under the same ferrite chemistry.

Conclusions

It can be concluded that for an effective increase of the reading distance in 900 MHz RFID applications, hexagonal Y-type ferrite slice supports can be effectively used with a minimum permeability of approximately 3 and a high quality factor at the operation frequency.

Future investigation towards the direction of component design aspects, which also play a crucial role in the final system performance and on the manufacturing cost, is in progress.

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