Habilitation document reviewing : Lucjan Kozielski

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This habilitation report is about the various properties of the piezoelectric transformers used as detector functionality (multifunctional). It presents the influence of the processing, the structure and the material properties on the sensitivity to magnetic field or light intensity.
The first chapter is about a wide state of art on the piezoelectric transformer. It successively introduces the piezoelectric property, their material compositions (mainly focus on PZT), numerous designs of piezo-transformers, their field of applications, and finally the modeling. This first part is very dense and a bit confusing by the transitions on many different aspects of the topic. For example, an analytic modeling of a disk piezo transformer is detailed, based on a cited reference. Nevertheless this part is not exploited subsequently. Such a part can be easily removed or synthetized for a better clarity.
Then, the requirements of high-power transformers in terms of design, technical limits, power supply and driving are discussed.

[In the chapter 1, there are some misprints: Eq 11 is wrong, Eq 14: error of sign on relation D, P41 is duplicated on p43]

The second chapter is more focused on the capability of piezo transformers used as sensors, distinctly for magnetic field, light intensity measurements and also as a magnetic energy harvester. It is a relatively brief introduction of such implementations and a state of art on electromagnetic coupling structures. Regarding the main subject of the overall report this chapter should have been more detailed compared to the previous one.

[the title of the chapter does not correspond to the chapter content because it is only relates the magnetic field sensor.]

The third chapter clearly enters in the heart of the matter. Every part is correctly introduced and discussed. It concerns the various methods for preparing the material and the critical steps for making the ceramic. The presented methods are the Mixed Oxide Method, the synthesis by sol-gel and a finally the pressure assisted sintering method. Properly speaking, this latter method does not occur at the same step of the making process but it constitutes an essential milestone for improving the material properties expected. Advantages and drawbacks of the different methods are discussed.

Part 4 concerns the preparation of several ceramic samples with different rates of Lanthanum. These PLZT ceramics have been selected for the study because of its remarkable photostrictive property. The Lanthanum quantity is identified as donor doping able to promote the light sensitivity in photoinduced and elastic phenomena.

[p61, Please change the sentence about the Villari effect which corresponds to the Converse magnetostrictive effect (and not a converse magnetoelectric effect)]
[p64 correct the title 3.1 Mixed oxides method]

MOM and pressure assisted sintering are the techniques used for making the ceramic samples. In order to evaluate the process, quality controls are done at several steps to check the reaction mechanism, the stoichiometry, the spatial structural properties or the phase stability depending on the sintering. Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) are the main tools for controlling the sample quality. The obtained crystalline structures, microstructure and chemical compositions are compliant and finally they valid the making process of PLZT ceramic by MOM and HUP methods. The piezoelectric properties of samples are analyzed after a step of poling and compared each other.
Then, in order to compare both synthesis process, two different material compositions have been realized by sol-gel technique, completed by HUP sintering. This technique is used because of its better transparency result and consequently expecting better sensitivity to the light illumination. The ceramic structure and composition is validated and finally the piezoelectric properties are evaluated in dark and illuminated conditions. In spite of the influence of light is measurable, it seems too weak for being exploited as light detector in such manner.
The second section of chapter 4 is about additional donor doping of Iron material in order to investigate the magnetic field sensitivity of such material. A small rate of the lanthanum is replaced by iron, leading to a PLFZT ceramic composition. Several samples are made with different iron rates. All samples are prepared by MoM and HUP sintering. PLZT 9/65/35 is selected for its piezoelectric capabilities measured previously. Comparisons clearly highlight the significant influence of iron doping on the electrical properties, especially visible by measurements of dielectric constant and loss in function of temperature. It demonstrates the crucial effect on the phase transition. Among the different samples, only one has shown a significant response when it is immerged in magnetic field.
To continue, the material synthesis of another PZT ceramic (with barium and few Calcium doping) is carried out in the purpose to be mechanically coupled to a magnetostrictive material (Terfenol-D). After controlling the material grain structure by AFM, the electrical characteristics are obtained by complex impedance analysis in function of temperature, leading to highlight the influence of temperature and Ca doping rate. Polarization capability, mechanical and piezoelectric properties are finally evaluated for every sample, leading to emphasize the complex contribution of Calcium in it. It demonstrates the eligibility of some of them, but essentially it valids the characterization method by local (PFM) and global methods.

[In spite of the chapter 5 is titled "piezo-transformer used as a light intensity transducer", it is actually about all multifunctionality depicted here. As seen several times above in the document, the title of the section does not match with the subsection contents.]

The first subsection of this chapter focuses on the light intensity sensor relying on the output voltage value in function of the light illumination. Investigations rely on the samples presented in chapter 4. These ceramics are finally polarized and electrode to become

piezoelectric transformers. Among the set of samples, one composition is appropriate to give a significant electrical quantity variation. It is interesting to note that this electric quantity variation is large enough to be observed, and so in spite of the very tiny variation of the mechanical and piezoelectric properties of the matter. This is made possible by the sensitivity increased by operating in the vicinity of the resonant frequency of the device.
Then, the second subsection of this chapter focuses on the transformer response made with PLFZT under magnetic field immersion.

[Half part of page 106 looks like introduction about piezoelectricity and it seems not to be in an appropriate page at almost the end of the report.
Subsection 5.2.3 only contents one sentence. Does it really require a specific subsection?
5.2.5 and 5.2.6 have the same title.
This chapter contains several misprints not itemized here]

PBZT ceramic layer mechanically associated to magnetostrictive material is qualified as H field sensor. The experimental electric response of such sensor is observed by the measurements of the output voltage amplitude and the voltage gain under the influence of the magnetic field. If the document clearly emphasizes the capability to be sensitive to the magnetic field, investigations of the different variations are not significantly deepened.
The final part of chapter 5 is dedicated to the possible use of piezo transformer as a magnetic energy harvester. It relies on the same association than the section above i.e. magnetostrictor associated to piezoelectric layer. Effective energy transmission has been observed with the device but not investigated (or presented) enough to qualify the capabilities.

[equation 53 is wrong and the denominator must be R^3]

Conclusion :
This report relies on multifunctional piezo-transformer, distinctly used as magnetic field sensor, light emission sensor or magnetic energy harvester. Its content is more about the demonstration of feasibility rather than properly speaking the development of efficient devices. Several methods for characterizing the material properties are presented and constitute a significant contribution in the manner to qualify such material.
Experimental investigations are also performed in the last chapter to demonstrate their capabilities to work like magnetic or light sensors. Contrary to the characterization of material properties, this part suffers at least not enough explanations about the testbench, or not enough interpretation of the observations.
Nevertheless, the overall work constitutes a significant contribution in knowledge on material making process (composition and preparation) for such purpose of multifunctional capabilities. Despite the fact that the report has many misprints and defect of the form, it demonstrates undoubtedly the large skills of the candidate. **Regarding all these comments, I recommend this thesis for the habilitation of Dr Lucjan Kozielski.**

François Pigache