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# Miniaturized Coplanar Waveguide for Nanostructured Magnetostrictive Multilayer Characterization <sup>†</sup>

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**Abstract:** A miniaturized coplanar waveguide (CPW) on a Y-cut LiNbO<sub>3</sub> substrate operating in Radio Frequency region (RF) is proposed for studying of magnetostrictive multi-layered structure. The structure is composed of a 14 × [TbCo<sub>2</sub> (3.7 nm)/FeCo (4 nm)] nanostructured multi-layer. Using microtechnology process, the miniaturized CPW has been designed with a 50 μm wide signal line in the frequency range from 6 MHz to 6 GHz. Electromagnetic simulations based on <sup>®</sup>Ansys/HFSS demonstrate insertion losses less than 2 dB and show that the magnetic field is more confined in the nanostructured multi-layer placed on top of the micro-sized CPW. By using Vectorial Network Analyzer (VNA) the Ferromagnetic Resonance (FMR) is investigated from the reflection (S<sub>ii</sub>) or transmission (S<sub>ij</sub>) coefficients of scattering parameters. An inversion model is finally used to extract the complex permeability spectrum of the thin-film in a large frequency range.

**Keywords:** nanostructured thin film; magnetostrictive thin film; RF characterization

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## 1. Introduction

Recent works in our study area demonstrate the great interest of multilayered piezoelectric-piezomagnetic composites in the development of Surface Acoustic Waves (SAW) sensors. It was shown that in magnetoelastic films exhibiting in-plane uniaxial anisotropy, a high susceptibility to the external driving field can be obtained in the vicinity of a field-induced Spin Reorientation Transition (SRT) [1,2]. Their large magnetoelectric coefficient, compared to one of the single-phase materials, will allow the development of sensitive sensors. Nevertheless, a reliable and authentic value of the permeability is very important for such applications. FMR based on a VNA and CPW has become a common experimental tool for studying magnetic films [3]. However, the necessity for an accurate and localized characterization of these materials in terms of electric and magnetic properties is still needed.

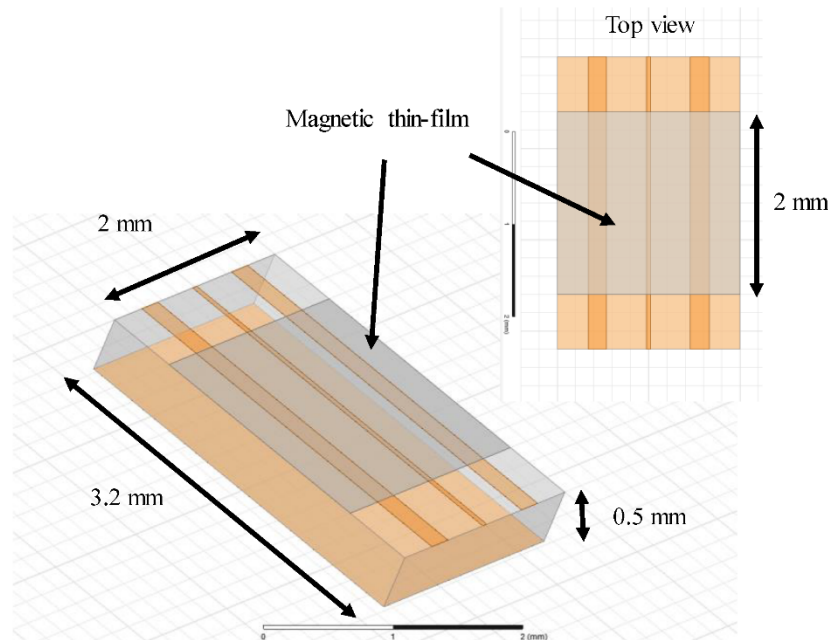
For this reason, we present here a method that is based on a miniaturized CPW on a Y-cut LiNbO<sub>3</sub> enabling here broadband measurement of RF scattering parameters. The set-up description is given in Section 2. Preliminary results are presented in Section 3.

## 2. Set-Up Description

The miniaturized coplanar line topology is designed for frequencies up to 6 GHz on a 500 μm thick Y-cut LiNbO<sub>3</sub> substrate in order to investigate a nanostructured magnetostrictive thin film.

The coplanar line technology consists of three gold metal lines deposited on the substrate. The dimensions are a 50µm wide signal line and a 435µm gap as shown in Figure 1.

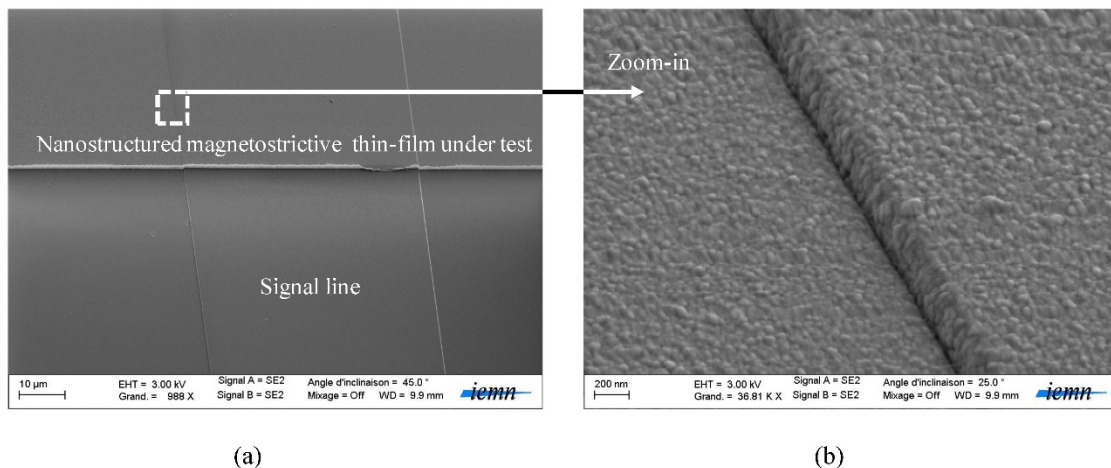
From an electromagnetic point of view, the miniaturized waveguide is adopted to confine the fields in the magnetic-film.



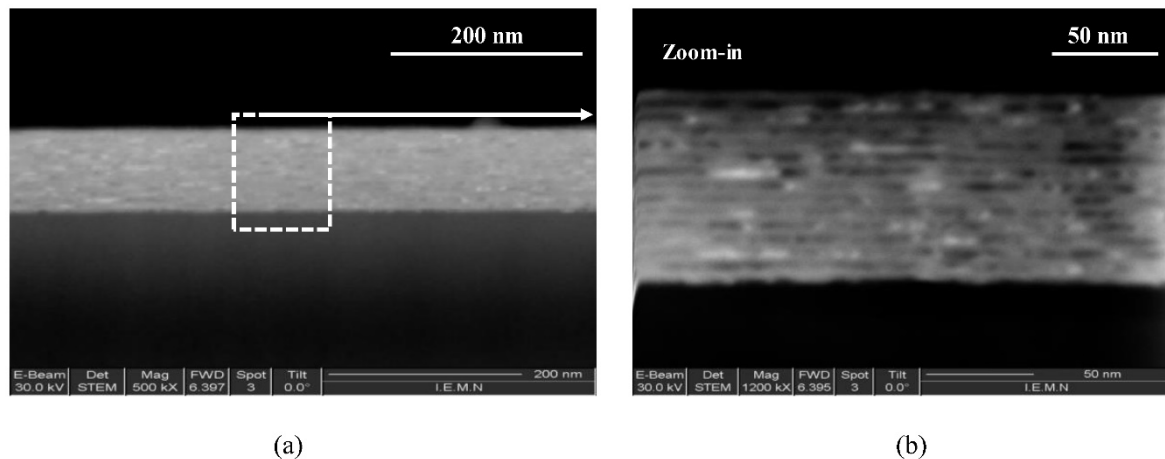
**Figure 1.** Schematic representation of the miniaturized CPW showing the location of the 107 nm thick  $14 \times [\text{TbCo}_2 (3.7 \text{ nm})/\text{FeCo} (4 \text{ nm})]$  nanostructured multi-layer under test. The inset is a top view.

A 2 mm wide and 107 nm thick  $14 \times [\text{TbCo}_2 (3.7 \text{ nm})/\text{FeCo} (4 \text{ nm})]$  thin film is deposited by RF-Sputtering on the miniaturized CPW. A magnetic easy axis (EA) is obtained in the magnetic layer by applying a magnetic field during deposition [4]. A thin layer of photoresist insulates the film from the CPW.

The fabrication of the miniaturized test structure is based on standard microtechnological processes. Scanning Electron Microscope (SEM) images of the fabricated structure are given in Figure 2. The pictures show that the nanostructured thin-film was successfully deposited by RF-Sputtering with the CPW line underneath. As an illustration, cross-sectional transmission electron microscopy (TEM) images of the nanostructured uni-axial multi-layer structure deposited on a silicium wafer are given in Figure 3.



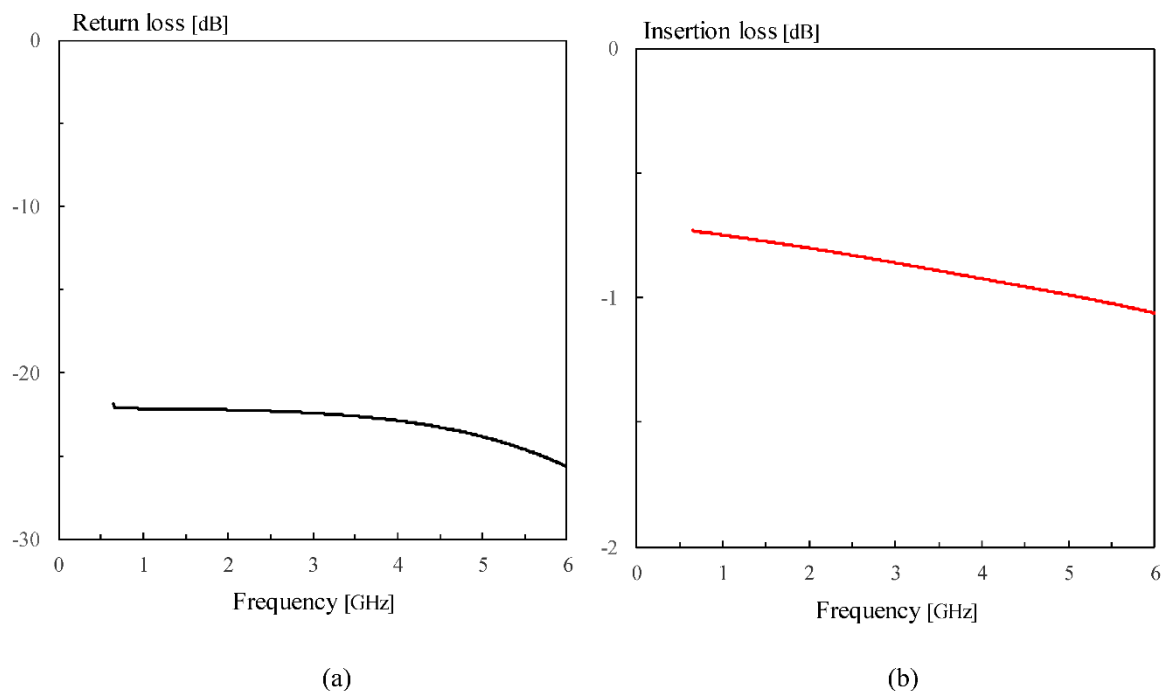
**Figure 2.** (a) SEM, image of the  $14 \times [\text{TbCo}_2 (3.7 \text{ nm})/\text{FeCo} (4 \text{ nm})]$  deposited on a CPW. (b) Zoom-in on the nanostructured multi-layer thin-film.



**Figure 3.** (a) TEM,cross-section image of the of a 14 × [TbCo<sub>2</sub> (3.7 nm)/FeCo (4 nm)] nanostructured multi-layer. (b) A zoom-in.

### 3. RF Simulation

Electromagnetic simulations based on <sup>®</sup>Ansys/HFSS allow to extract S-parameters. In Figure 4, we present the simulation of the reflection coefficient and the transmission coefficient in free-space conditions up to 6 GHz. We can note that the return loss is better than -20 dB. Also, the results demonstrate insertion losses less than 2 dB over the frequency range. These preliminary results are hopeful up to 6 GHz.



**Figure 4.** S-parameters recorded in the frequency range from 60 MHz to 6 GHz. (<sup>®</sup>Ansys/HFSS—S11–S21).

### 4. Conclusions

In order to investigate nanostructured magnetostrictive multilayers, a miniaturized coplanar waveguide based on the interaction of a magnetic thin-film with electromagnetic waves at gigahertz frequencies was developed. The structure was designed using Electromagnetic simulations based on (<sup>®</sup>Ansys/HFSS). Preliminary results have been given and demonstrate insertion losses less than 2 dB over the frequency range. Also, SEM images show the success of the realization in clean room.

In the future works, the magnetization of the nanostructured TbCo<sub>2</sub>/FeCo thin film will be measured with a Vibrating Sampling Magnetometer (VSM). Also, by using Vectorial Network Analyzer the experimental Ferromagnetic Resonance spectra will be extracted for different external magnetic fields. Finally, from the scattering parameters the effective impedance arising from the sample magnetic response (i.e., permeability) of the sample will be determined.

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**Conflicts of Interest:**

The authors declare no conflicts of interest.

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