Passive microwave devices: modelling and test

People involved: A. Gensbittel, A. Dégardin, A. Kreisler

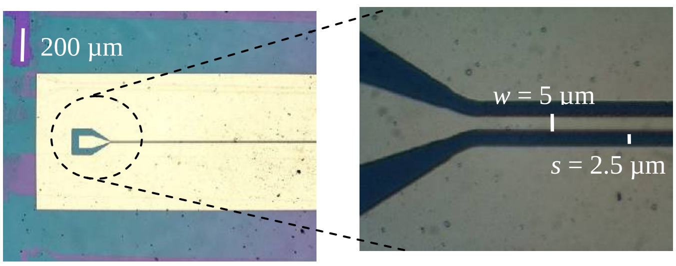
Project description:

In the past few years, the use of ferroelectric (FE) materials has been widely investigated to develop electrically tunable microwave devices. Thin FE films, among which $SrTiO_3$ and $Ba_xSr_{1-x}TiO_3$ are the most widely studied, provide the possibility of tuning due to the electric field dependence of their dielectric properties.
First, we used $SrBi_2Nb_2O_9$ (SBN), an original material for such applications. Then, we studied $SrTiO_3$ (STO) thin films deposed by MOCVD, an unconventional deposition method for this material. For the first time to our knowledge, competitive results in terms of tunability have been obtained with $SrTiO_3$ films produced by MOCVD while $SrTiO_3$ was until now and mostly deposited by sputtering. The dielectric properties of ferroelectric films were also obtained from models and compared with literature, marking significant progress for both materials.

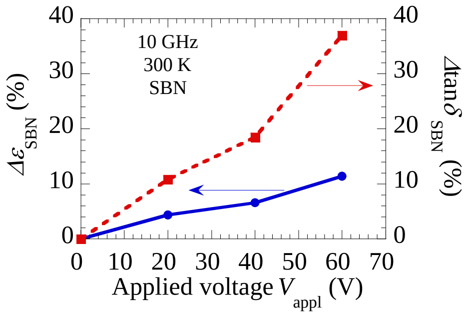
Microwave devices such as transmission lines and interdigital capacitors are patterned on bilayers gold / ferroelectric thin films in a clean room (CTU of the IEF in Orsay, Paris 11). These devices are characterized at the IEF in Orsay between 45 MHz to 40 GHz and between 60 and 300 K (Collaboration with Prof. Crozat).
SBN thin films were deposited by laser ablation at LCSIM in Rennes (Pr. M. Guilloux-Viry). STO thin films were deposited by MOCVD at LMGP in Grenoble (F. Weiss).

$SrBi_2Nb_2O_9$ thin films:

The FE material $SrBi_2Nb_2O_9$ exhibits an electrical polarization parallel to the *ab* plane, a convenient feature for electrical control using coplanar waveguides (CPW). Its dielectric properties (dielectric permittivity and loss tangent) were up to now studied at low frequency (up to 1 GHz). We previously showed the frequency tunability of a CPW resonator at 10 GHz. Then, we studied Au/SBN CPW transmission lines in the microwave frequency range up to 40 GHz. Phase shift and figure of merit values obtained show the feasibility of tuning microwave components made with SBN thin films.
Theoretical models were used to extract the dielectric characteristics of the SBN films. Relative variations of the dielectric permittivity and the loss tangent at 10 GHz for an applied field of 24 V / m at 300 K are respectively 11 and 37%.



Photos with microscope of a Au/SBN/MgO transmission line of 5 µm width.

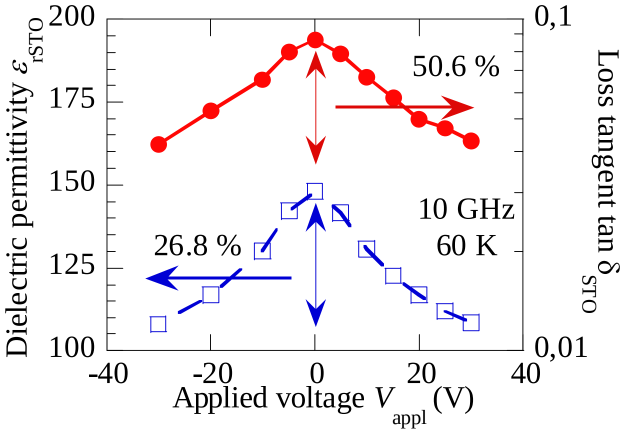


Evolution as a function of applied bias, of relative variations of the dielectric permittivity (blue) and of the loss tangent (red) for a 500 nm thick SBN film at 10 GHz and 300 K

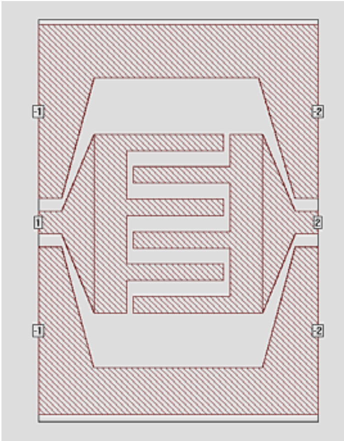
$SrTiO_3$ thin films:

Concerning $SrTiO_3$ thin films deposited by MOCVD, the best variations are observed at 60 K: this material presents largest dispersions of his dielectric characteristics with applied bias at low temperatures. $SrTiO_3$ (STO) thin films associated with high temperature superconducting (HTSC) materials is a good compromise to realize electronically tunable devices combining controllable dielectric properties of ferroelectric films with low loss microwave conductivity in HTSC. STO, which exhibits a perovskite structure, is suitable for epitaxial growth of YBaCuO films

Relative variations of the dielectric permittivity and the loss tangent at 10 GHz for an applied field of 8.6 V / m at 60 K are respectively 27 and 51%. This is the first time to our knowledge that competitive results in terms of tunability have been obtained with $SrTiO_3$ films produced by MOCVD while in the literature $SrTiO_3$ is mainly deposited by sputtering.



Evolution as a function of applied bias, of dielectric permittivity (blue) and of the loss tangent (red) for a 250 nm thick $SrTiO_3$ film at 10 GHz and 60 K. The relative variation is given in percent.



Schematics of an interdigital capacitor simulated by Sonnet®

Modeling of varactors: Electromagnetic simulations of interdigital capacitor (IDC) geometries are performed using Sonnet® software. We use a de-embedding method to extract, from the simulations, the capacitance of the IDC alone. We have been able to obtain a relative variation of capacity of 10% over the frequency range 1 to 10 GHz using the dielectric characteristics of $SrTiO_3$ films deposited by MOCVD described above.

For more details see :

A. Gensbittel, A. F. Dégardin, F. Weiss, A. J. Kreisler, “Tunable coplanar waveguide microwave devices on MOCVD-$SrTiO_3$ thin films”, *Ferroelectrics*, 362:48–54, 2008

A. Gensbittel, A. F. Dégardin, M. Guilloux-Viry, A. J. Kreisler, “In-plane tunability of coplanar microwave devices by $SrBi_2Nb_2O_9$ ferroelectric thin films”, *Ferroelectrics*, 362:41–47, 2008

A. Gensbittel, A.F. Dégardin and A.J. Kreisler « MOCVD-$SrTiO_3$ Thin Film Microwave Coplanar Tunable Devices: Modelling of Varactors », 8th European Conference on Applied Superconductivity (EUCAS 2007), Brussels (September 2007), présentation poster N° S2-0138, Journal of Physics, conference series: http://www.iop.org/EJ/toc/1742-6596/97/1, paper #012083.