Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information

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PhD information

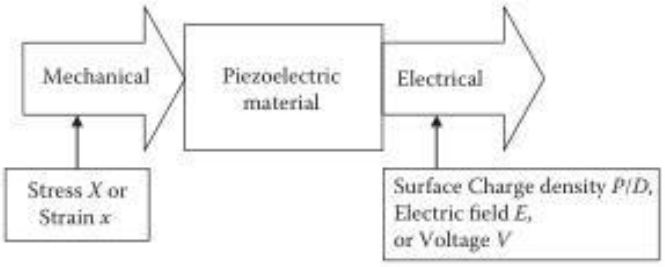
Title	Innovative doping of piezoelectric ceramics
Main topics regards to CSC list (3 topics at maximum)	High performance ceramics materials

	Information, storage and sensors materials Environmental behavior and failure materials
Required skills in science and engineering	Applicant possess good background and interest in piezoelectric ceramics materials, Materials science, mechanical engineering, numerical modelling

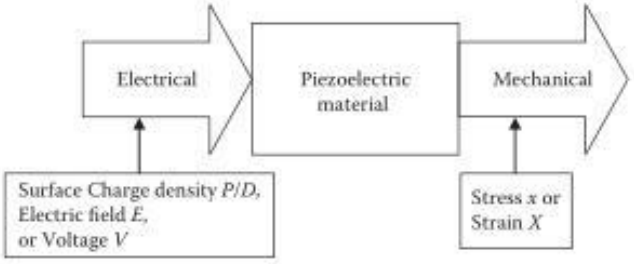
Subject description (two pages maximum)

Piezoelectric materials are classified as being functional ceramic. In the sensors, they allow the conversion of stress, pressures and accelerations in electric signals (direct piezoelectric effect) and in transmitters and sound and ultrasound actuators, they convert the electric voltages in vibrations or strains (indirect piezoelectric effect) – Figure 1. The piezoelectric ceramic materials are classified on one hand according to their chemical composition and on the other hand according to their conditions of application:

- Materials for transmitters of power (ultrasound applications)
- Materials for sensors (transmitters and ultrasound receivers)
- Materials for actuators (positioning of precision or system of injection)
- Materials for special applications (biomedical applications for example)



(a)



(b)

Figure 1: (a) Direct piezoelectric effect: Input is mechanical and output is electrical- (b) Indirect Piezoelectric effect: Input is electrical and output is mechanical [1].

Barium Titanate ($BaTiO_3$) is widely used in the electronic industry because of its ferroelectric properties finding extensive applications as dielectric material in piezoelectric actuator, multilayer ceramic capacitors, embedded capacitance as positive temperature coefficient of resistivity sensors and also used in printed circuit boards. $BaTiO_3$ is an inorganic compound it has perovskite structure and it has ferroelectric properties. Ferroelectric ceramics have wide range of applications in the electronic industry because it has high dielectric permittivity. Barium Zirconate Titanate (BZT) is an important species of the family of $BaTiO_3$. Its potential applications are such as DRAM for memory application, tunable microwave devices, piezoelectric transducers, and electrical energy storage units. $BaZr_xTi_{1-x}O_3$ (BZT) ceramics are interesting materials for being used as dielectrics in commercial capacitor applications. They present high voltage resistance, high dielectric constant, and composition-dependent Curie temperature (T_C). It has been reported that $BaZr_xTi_{1-x}O_3$ exhibits better temperature stability than $Ba_{1-x}Sr_xTiO_3$ in paraelectric state [2-4].

A common way to improve the material performance is by impurity-doping in BZT electro-ceramics. In the same time, Niobates such as (M = K, Na, Mn…)NbO_3 are among the most promising present lead free compositions to substitute lead based Piezoelectrics. Further it is also imperative to study single crystal behavior of BT based ceramics produced via solid-state single crystal growth (SSCG) method [2]. Since the piezoelectric ceramics are anisotropic, it is important to test them with different modes (longitudinal mode – d_{33} mode, transversal mode - mode d_{31} or d_{32} and shear mode – mode d_{15}) [5,6]. The objectives are to determine the electromechanical coupling coefficient (k_{em}) and the mechanical loss factor (Q_m). Different points have to be carried out for these objectives:

1. Preparation by a special sintering process and characterization of BZT and (M)NbO_3 (XRD, SEM, EDX, Raman). Different doping elements will be tested. Use of Thermocalc™ software for the prediction of the different phases.
2. Electrochemical and mechanical characterization (indentation, scratch test, wear test, corrosion test, four bending test with acoustic emission, fatigue, aging, impendance-metry)
3. Coupling thermo-electro-mechanical behavior. Well known PZTceramic will take into account as reference.

Expected results:

- A comprehensive investigation of several compositions of BT based ferroelectric ceramics and the establishment of mechanical properties of ceramics.

References

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2. M. A. Rafiq, M. N. Rafiq, and K. V. Saravanan, "Dielectric and impedance spectroscopic studies of lead-free barium-calcium-zirconium-titanium oxide ceramics," *Ceramics International,* vol. 41, pp. 11436-11444, 2015..
3. K. M. Sangwan, N. Ahlawat, S. Rani, S. Rani, and R. Kundu, "Influence of Mn doping on electrical conductivity of lead free BaZrTiO3 perovskite ceramic," *Ceramics International,* 2018.
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5. Christopher R. Bowen, Vitaly Yu. Topolov, Hyunsun Alicia Kim, Modern Piezoelectric Energy-Harvesting Materials, Springer, Springer Series in Materials Science 238, 2016
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