Ecole doctorale SMAER

Sciences **M**écaniques, **A**coustique, **E**lectronique, **R**obotique

Thesis subject 2018

Laboratory: **Group of Electrical Engineering - Paris (GeePs)** – UMR CNRS 8507 – CentraleSupélec

University: **Sorbonne Université**

Title of the thesis: **Innovative uncooled semiconductor detectors for fast terahertz imaging**

Thesis supervisor: **Annick Dégardin**, Pr Sorbonne Université

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Collaborations within the thesis: **Pr M. Tonouchi (Osaka University, Japan)**

This subject can be published on the doctoral school's web site: **YES**

Thesis's summary (abstract):

Low power terahertz waves are fully harmless electromagnetic waves in the frequency range from 500 to 5000 GHz (= 5 THz). These waves can penetrate dielectric or non-conducting materials like plastics, ceramics, paper, wood, fabric, etc. By contrast, metallic or conducting surfaces are reflecting those waves. THz imaging is therefore a promising technique in the civil security field to detect suspect objects concealed underneath clothing, for instance. In addition to the popular civil security issues, applications also encompass environment and health domains.

We are developing pyroelectric detectors made from semiconducting Y-Ba-Cu-O (hereafter YBCO) oxide materials. These semiconductor oxides can be prepared at room temperature in the form of thin films and can be integrated with already processed CMOS electronic readout technologies. Near infrared (IR) tests (at 0.850 µm wavelength) of detectors made from these films show impressive performance in terms of response time (2-3 µs) as compared to commercial pyroelectric detectors (0.1-100 ms). The final objective of the thesis, which will be extensively experimental, is to develop these detectors for longer wavelengths: THz waves (60-300 µm or f = 1-5 THz). The main points that will be dealt with in the thesis work will include:

a) Physical properties of semiconducting YBCO materials: Optimization of the interface between the contact metal film and the YBCO film will be first considered, with respect to the microstructure of the film and its DC electrical characteristics. Various metals will be investigated. UV photoelectron spectroscopy will be used to extract work function of metals and electron affinity of the semiconducting YBCO material. THz wave interaction with YBCO material will be studied by THz time domain pulsed spectroscopy (collaboration with Prof. Tonouchi, Osaka University) in order to understand carrier dynamics in YBCO and so optimize the design of the future YBCO pixel.

b) Design of antennas, device technology and validation: Each pixel will be connected to a planar micro-antenna to favour coupling between the pixel and incident radiation. Planar antennas for the medium IR range and THz waves will be designed with the help of dedicated simulations. As small 2D arrays of 2×2 pixels, then 8×8 pixels will be developed, thermal crosstalk between the pixels as well as electromagnetic crosstalk between the antennas of the array will be simulated. Large scale models of designed antennas will be fabricated and tested in anechoic chamber, and experimental results will be compared to simulation results. Technological process of small arrays will be performed using clean-room facilities. Preliminary operational tests in the THz range using quantum cascade lasers will be conducted in parallel to optimise various pixel parameters: sensitivity, noise level, bandwidth, crosstalk...

c) THz imaging system. As a final step, a THz imaging system will be designed, implemented and tested: it will include the scene illumination with a THz source and the scanning of the scene with a small pixel array.

Required education and skills: Master of Science degree or equivalent degree in Electronics, Photonics or Applied Physics. **Excellent academic results are required.**