

Advancements in new materials and fabrication technologies are an important part of the permanent battle for smaller, better integrated, faster, cheaper and more environmental friendly modern electronics. The proposed project is devoted to a topic which is crucial for Information and Communication Technologies (ICT), specifically for 5G and 6G telecommunication systems. The project goal is developing and broad characterization of new ceramic substrates based on borates, tungstates and phosphates, which are feasible in ultra-low temperature cofired ceramics (ULTCC) technology and suitable for applications at tremendously high, terahertz frequencies. Low cost, simplicity, design flexibility, miniaturization, possibility of integration of passive components in one multilayer module and reliability are well-known profits of LTCC technology. The ULTCC version of the LTCC technology entails further reduction of costs, energy consumption and environment pollution during processing due to lower temperature of heat treatment (below 660°C) and cofiring with cheap Ag and Al based conductive films. Inexpensive and abundant starting materials and a low weight are additional important benefits for ceramics containing elements with low atomic weights (such as boron, lithium) which are planned to be developed in the project.

For taking advantage of the giant potential application scope of THz radiation, including ultra-fast communication systems, military and security systems, safe medical imaging, nondestructive inspection, sensing in harsh conditions (rain, dust, fog), and novel optoelectronic devices, it is necessary to develop new materials and gather the information about their dielectric properties at broadband terahertz frequencies.

The project will be focused on the investigation of the relationship between the composition, structure and processing parameters of the developed materials and the desired properties of the fabricated ULTCC substrates – ultra-low sintering temperature, low and temperature stable dielectric permittivity and low dielectric loss. Low dielectric permittivity is beneficial for reducing signal propagation delay, crosstalk between signal lines and electronic device size, low dielectric loss decreases power consumption and improves frequency selectivity, while low temperature coefficient of dielectric permittivity enables avoiding the influence of temperature fluctuations on operating frequency. Several additives will be applied to decrease the sintering temperature and to adjust the temperature coefficient of dielectric permittivity to the value close to zero.

ULTCC substrates will be fabricated in several steps including solid state synthesis of materials, preparation of slurry for tape casting, tape casting, laser cutting, screen printing of internal conductors and filling of vias connecting electrically the layers in the multilayer ULTCC structure, stacking of green sheets, isostatic lamination and cofiring of ceramic tapes with metallic electrodes.

It is planned to perform broad studies of composition, thermal, dielectric and mechanical properties of the fabricated substrates using various methods. Optimal synthesis and sintering conditions and behavior during heating up to 900°C will be established for undoped and doped materials based on differential thermal analysis, thermogravimetric measurements and observations in a heating microscope. X-ray diffraction method will be used to investigate the phase composition and crystal structure of the developed materials, while their electronic structure will be modeled by the density functional theory (DFT). The composition and microstructure of the ceramics including porosity, size of grains, presence of crystalline and amorphous phases, distribution of additives will be studied using scanning electron microscopy and energy dispersive spectroscopy. Optimization of the quality of green tapes will be attained by controlling the kind and proportions of organic components of the slurries, viscosity and conditions of slurry mixing and casting.

The dielectric properties in the broad terahertz range of 0.1-3.5 THz will be investigated by time domain spectroscopy (TDS) as a function of frequency and temperature. These studies which are crucial for the realization of the project goals will be a novelty on an international scale. For selected substrates, some additional dielectric, thermal and mechanical measurements will be carried out, comprising dielectric characterization in the GHz range, thermal expansion coefficient, thermal conductivity, roughness, flexural strength and hardness.