The objective of the project is development of the composition and processing procedure for a group of new ceramic materials which due to low dielectric permittivity, low dielectric loss and low firing temperature, will be useful for obtaining the innovative substrates for electronic circuits operating at very high frequencies. The LTCC/ULTCC (Low/Ultra Low Temperature Cofired Ceramics) method is a modern, although inexpensive technology that enables advances in miniaturization and integration scale of advanced substrates and packages by combining many functional electronic components in one multilayer module. In this technology, green (not fired) ceramic tapes obtained by tape casting are stacked, laminated and cofired with screen printed conductive films, typically below 960°C being the melting point of Ag (for LTCC) or below 660°C being the melting point of Al (for ULTCC).

The project is focused on development of a methodology for obtaining a group of new materials and green ceramic tapes based on these materials destined for multilayer LTCC/ULTCC microwave substrates. It is planned to investigate the correlation between the dielectric properties, starting compositions and parameters of the process that determine the phase composition and microstructure of the substrates. This will be achieved basing on the results of various characterization techniques. Using thermogravimetry (TG) and differential thermal analysis (DTA), enabling tracking of the changes in mass and temperature of a sample during heating in a wide range of temperatures, it will be possible to identify the effects associated with the burnout of organic components of a green tape, as well as the glass crystallization temperature and melting points of the investigated materials. Research carried out by a heating microscope, in which the changes in size and shape of a sample are observed during heating up to high temperatures (1000-1450ºC), will be helpful to determine the optimal firing profile. Critical for obtaining of compact substrates without deformations is gathering the knowledge of optimal ranges of firing temperatures, and the proper selection of melting and softening temperatures, wettability and reactivity of the applied sintering aids. It is planned to characterize the phase composition and crystal structure by X-ray diffractometry and Fourrier Transform Infrared Spectroscopy (FTIR), and elemental composition and microstructure (porosity, grain size, crystalline phases fraction, additives distribution) using Energy Dispersive Spectroscopy (EDS) and scanning electron microscopy. The crucial measurements in the project will be those of dielectric properties of the developed materials in a very wide frequency range. In the lower range of frequencies (Hz-MHz) these investigations will be carried out by impedance spectroscopy (measuring the response of a sample to a small alternating electrical signal) and for high frequencies (GHz and THz) by transmission method (by measuring the transmission and reflection coefficients of the incident electromagnetic wave). For the highest THz frequencies, TDS (time domain spectroscopy) method will be used, where laser pulses cause excitation of the electromagnetic wave. Possibilities of safe medical imaging, nondestructive inspection of electronic devices and sensing in dusty or foggy atmospheres are great advantages of THz technology.

Dynamic development of telecommunication is aimed at greater miniaturization, higher degree of integration and higher operating frequencies. Modern wireless and cable communication systems are using very high frequency signals of the order of gigahertz (10^9 Hz) and terahertz (10^{12} Hz) (corresponding to microwaves and millimeter waves). A broad application scope of these systems includes: mobile telephony, computer networks, radar and navigation systems. However, the huge advances in miniaturization created by the development of semiconductor integrated circuits, is often impeded by the lack of suitable dielectric materials for substrates and packages. Distortion and delay of signals in the conducting layers and in the housing of a system may limit the allowable maximum operating frequency. Thus, crucial for transmission of signals at high speed is to use materials which exhibit low dielectric permittivity and low dielectric loss. Low dielectric permittivity of the substrate enables miniaturization by decreasing the distance between signal lines, reduction of parasitic capacitances and crosstalk between lines, and minimizing signal distortion and delay. Furthermore, a low dissipation factor, characterizing the loss of energy dissipated in the dielectric in the form of heat, contributes to the reduction of energy consumption, miniaturization and frequency selectivity improvement. Close to zero temperature coefficient of resonant frequency reduces the influence of temperature fluctuations and ensures frequency stabilization.

A significant reduction in the cost of multilayer substrates can be achieved through planned in the project lowering of the sintering temperature (below 960°C/660°C for LTCC/ULTCC). This will enable using of cheap silver or aluminum based pastes for conductive layers. The planned simultaneous achievement of all the above mentioned desired properties of the substrate materials by development of innovative compositions and the use of LTCC/ULTCC technology is a big challenge, not so far undertaken in the country. The project scope meets the urgent current needs of the rapidly growing field of microwave and millimeter wave electronics. The planned extension of the scope of dielectric measurements of the developed materials to the terahertz range is a novelty on an international scale. Environmental friendly aspect of the project should be highlighted which is related to energy saving during low temperature sintering of ULTCC substrates and due to lack of toxicity and low temperature burnout of new organic components of the slurries planned to be used for tape casting.