Transparent conducting oxides (TCOs) have revolutionized the way we live by enabling wide touch-screen adoption in electronic devices that started around a decade ago. Smartphones, tablets, new types of laptops and intelligent displays are everywhere and make the user interaction more seamless and entertaining. Usually, transparent materials, such as glass or plastics, do not conduct electrical current. There are only several carefully engineered or discovered examples of such materials that do conduct electricity, mostly when some additional elements have been added to them, in a way not changing their internal structure significantly, but changing their electrical properties. Also, organic materials have been recently developed for applications in transparent conducting electrodes. It is however not the only application of TCO materials - they can be used also to form contact structures in semiconductor devices - for optoelectronics (light emitting diodes, laser diodes) due to their transparency as well as for microelectronics (diodes, transistors) due to their high chemical stability.

The possible known TCOs are few and the dominating one is indium tin oxide, a highly conducting material that contains indium, a rare element with limited supply. Its use is dominating the smart-electronics market, however its mining and processing is highly unsustainable. There is therefore a need to find other materials, that would match the performance of indium tin oxide, however which would also be sustainable.

This project is part of this effort, and its goal is to explore a possible family for TCO materials, namely ones where metallic grains are embedded in amorphous silicon dioxide matrix, akin to raisins in a dough. The general chemical name for them would be M-Si-O with M - metal, Si - silicon and O - oxygen. The initial studies showed that examples of such materials are not only transparent to a significant degree, but also conduct electricity. This research aims to discover more than the currently known three such materials, try to generate knowledge on the means of their formation and on the way they conduct electricity. We plan to perform theoretical calculations enabling us to screen the most promising metals to form these structures and subsequently, we will perform experiments aiming to fabricate the M-Si-O materials with selected transition metals to understand the formation mechanism of the raisin-in-dough structure (Fig. 1). We will study carefully their nanostructure, optical properties and electrical transport properties and will join the results of these studies with numerical modelling to understand the way these non-standard TCOs conduct electricity and how it is different than the mechanism observed for the standard materials. We will also test the new materials in semiconductor contact structures to determine their application potential for microelectronics and optoelectronics.

The realization of this project will result in the development of new types of TCOs, a blueprint for their optimization and a description of current conduction in nonhomogeneous materials, that can prove useful in other similar nonhomogeneous systems.

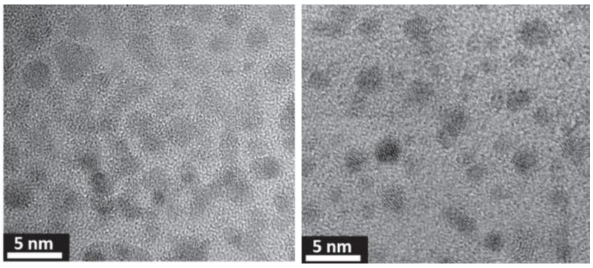

Fig. 1. Transmission electron microscopy images of the microstructures of two Ru-Si-O films with different Ru grain sizes and at the same time, different electrical conductivities (higher conductivity is observed for the film with more grains, on the left hand side).