Individual carbon nanotubes (CNTs) could be seen by a chemist's eye as elongated macromolecules full of unsaturation centres. Both for the general scientific community as well as the whole human-kind CNTs as relatively novel carbon allotrope are characterised by a unique combination of superb physicochemical and biological properties. For example, they exhibit 'zero-loss' electroconductivity, excellent thermal conductivity, extraordinary mechanical strength and tailorable optical properties – from blackness through rainbow to transparency – this is just to mention the few most important ones. Their 're-discovery' in 1991 by Sumio Iijima (they have been with the human kind at least since antiquity) initiated an avalanche of the interdisciplinary research. And since 1991 CNTs has been promising to realize numerous applications by a 'properties-by-design' approach in a range of disciplines from electronics to medicine to high-performance composites. Nevertheless, only a rather small fraction of the promises has been fulfilled in the every-day or scaled-up implementations and many more are still awaiting their time to come due to the disadvantageous interface phenomena.

One of the most challenging problems of transfer the extraordinary properties of CNTs from nano- to micro- to eventually macro-scale is control over their surface chemistry. On the one hand, 'individualization' of CNTs (that is their uniform dispersion) – as key components of 'added-value' in complex systems such as solutions or hybrid materials – plays a vital role. This is particularly true in the manufacture of CNT-based composites of enhanced mechanical, thermal and/or electrical properties where low extremely low concentrations of CNTs would be required. Also, 'debundling' of CNT agglomerates is crucial in biomedical applications like targeted drug or gene delivery systems, theranostics, etc. where the complex vehicles must freely travel to destination places in the body. On the other hand, assembling of CNTs into desired forms and geometries of superior electrical, thermal and mechanical properties would require 'infinitely'-long CNTs. This feature would be achievable e.g. by CNTs cross-linking (called here in the project title 'networking' as opposite to 'individualization'). Both of these aspects could be met in the organic chemistry inspired surface functionalization of CNTs. Here it should be emphasized that, differently from low-molecular weight aromatic compounds, CNTs exist in a variation of differently 'twisted' versions (called 'chiralities') which regulate their metallic and semi-conducting properties as well as their chemical reactivity). CNTs differ in a number of wall imperfections (making CNT 'less metallic'), length-to-diameter ratios, number of walls, curvature, etc. One might say that CNTs – as the substance – differ as snowflakes… There are indeed no two identical CNTs and, paraphrasing perhaps the famous Richard Feynman's sentence, 'there is a plenty of room at the bottom…' for questioning the chemistry of CNTs. The attempts to conquer the promised land explored since nearly two decades – although still not fully known – are a subject of the intensive global research on the chemistry of CNTs and other carbon allotropes.

In this project – and importantly for electrical and thermal properties – chemical modifications of CNTs enabling individualization of nanotubes and, in parallel, the maintenance of their original skeleton would constitute the most powerful tool from the application point-of-view. As inspired by organic chemistry methods, we intend to extend the scope of possible chemical modifications of CNTs involving recovery of their original skeleton by subsequent thermal post-treatment. And so, after the first stages of addition of the pre-designed, numerous external reagents and their tethering to CNT walls, so-modified CNTs will possibly change into a state in which they will maintain their original character enabling delocalization of electrons as it takes place in metals. Afterwards, the modified CNTs will be incorporated to e.g. electroconductive textile coatings and thermally conductive nanofluids to check if the hypothesis was correct. Importantly, we will test if we are able to interconnect CNTs in order to make three-dimensional electrically and thermally conductive networks. If successful, the project will open tool-boxes with ways to prepare novel 21st-century lightweight and multi-functional materials exhibiting enhanced electrical and thermal conductivity.