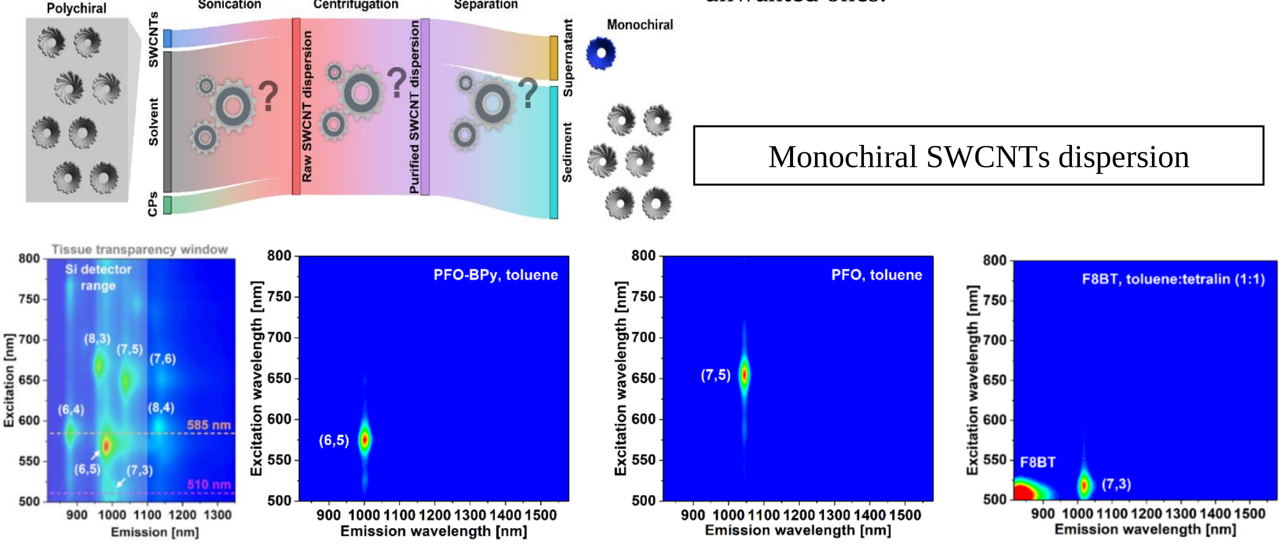
Fishing for rare species in the lake of nanotechnology: how conjugated polymers help isolate unique chiralities of carbon nanotubes

Imagine you are a fisherman on a vast lake teeming with many different fish species. Your goal is to catch one particular species which is exceptionally valuable and hard to breed under industrial conditions. This species represents single-walled carbon nanotubes (SWCNTs) with a specific, desired “chirality.” Unfortunately, just as certain fish can’t be easily bred, SWCNTs are difficult to selectively synthesize in large quantities. Each fish species has its favorite bait, but many share similar tastes. As a result, selectively catching your target species in an open lake becomes a significant challenge.

In our project, we develop “baits” for these fish i.e. special conjugated polymers capable of selectively capturing certain SWCNT chiralities. The polymer’s structure determines which “species” you can catch. The polymer chain length (our bait size) influences whether you’ll catch large, medium, or small fish. The choice of monomers acts like favored delicacies for a given species, while side chains serve as “ballasts” that can alter the bait’s behavior in the water (e.g., affecting how easily it dissolves or at what depth it floats). The polymer’s end groups are like seasonings making the bait more enticing to the chosen species or discouraging unwanted ones.



Sometimes, it’s impossible to find a single perfect bait for a particular fish species because many species share similar preferences. In that case, we need to “cross” different baits, much like in genetics, to produce new bait types. Doing this blindly would be costly and time-consuming. That’s where theoretical methods come in: they allow us to predict which baits will be favored by the “nano-fish” (the desired SWCNT chiralities), reducing trial and error approach. Sonication of polymers (exposure to ultrasound) gradually “shrinks” the baits, adjusting them to the chosen species’ preferences. Improving microwave-assisted polycondensation (the fundamental technique we use to create these baits) enables us to quickly produce new variants (polymers with different structures and potentially better properties). Furthermore, we aim to miniaturize the “lakes”, i.e., the conjugated polymer extraction (CPE) process, so we can test many different baits simultaneously in small, controlled environments.

Our goal is not only to create ideal baits but also to understand why certain combinations of composition and structure allow us to catch a given SWCNT species. This knowledge will let us design new polymers more purposefully, saving time and money. If we succeed, we’ll enable the selective isolation of rare SWCNT chiralities that can be used in the next generation of advanced electronic, photonic, medical, or photovoltaic devices. For instance, monochiral SWCNTs may allow for deeper tissue imaging in medicine, detection of disease biomarkers, developing quantum spin qubits, faster optical data transmission, or more precise sensors. Advancing these materials will foster progress in healthcare, electronics miniaturization, quantum and environmental technologies, and cutting-edge communication systems. Just as a perfectly matched bait lets a fisherman proudly display a prized catch, our approach will help unlock the widely appreciated potential of carbon nanotubes.