HORIZON 2020

Artificial Molecular Machines

Rendicontazione

Informazioni relative al progetto

ArtMoMa

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Sito web del progetto

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Progetto chiuso

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Periodic Reporting for period 2 - ArtMoMa (Artificial Molecular Machines)

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Sintesi del contesto e degli obiettivi generali del progetto

Although complex biological machineries already exist in nature and are central to key cellular functions (such as replication, ATP (adenosine triphosphate) synthesis, transport, and motion), the recent progress made in the field of artificial molecular machines only represents the initial

fundamental stages of what could result from the miniaturization of machines. It is expected that such machines could be at the foundation of groundbreaking application in nanomedicine, nanorobotics, and smart materials. Before reaching such a societal impact, specific science should be developed and a number of challenges needs to be overcome in the understanding, implementation and application of molecular machines. Those challenges structured our endeavors in the ArtMoMa network.
Overall, during the ArtMoMa project, we have achieved a number of our initial objectives and reached new heights in the emerging field of artificial molecular machines, pushing its boundaries beyond the state-of-the-art. These findings are currently published in best international reviews and discussed in top level conferences. We have trained, often through collaborative works, a new generation of visionary researchers capable of conducting high risk, high gain research. We have engaged with leading companies in real-life applications of molecular machines and paved the way for the design of entirely new products and materials. ArtMoMa was the first action to structure this field of research at such level, and it is recognized among our peers as a remarkable initiative of excellence, and as a landmark for the future of this research domain.

Lavoro eseguito dall'inizio del progetto fino alla fine del periodo coperto dalla relazione e principali risultati finora ottenuti

The construction of the ArtMoMa project was organized around a number of challenges to face.
Challenge 1: Precisely controlling the functional mechanical tasks of molecular machines in environments submitted to Brownian motion.
As major achievements in this part of the project, we developed smart systems by designing new photoswitches with easy access, modular nature, and excellent fatigue resistance. By controlling molecular motion at nanoscale, we have also shown how to access organic superbases, 1013 times more efficient than their static counterparts. We have in addition synthesized molecular pumps that can emit a fluorescent signal as they work, and that can transport cargo from one precise location to a new one along a track. By coupling biological motors, we have also demonstrated cooperative effects in biomolecular transport systems (vesicles along microtubules), bringing new insights in the understanding of complex intracellular transport. The control over light-driven rotary motors by precise tuning of the placement of single carbon atom was also discovered, leading to easy modulation of their speed and directionality. In addition, novel technological tools were also developed, for instance by the creation of a new device capable of microscope free gliding speed determination of microtubules moved by motor proteins.

Challenge 2: Understanding and controlling the conversion of physical or chemical sources of energy in mechanical work in order to access a new class of systems functioning out of thermodynamic equilibrium.
The use of DNA strand displacement in out-of-equilibrium conditions by using natural GTP as a biochemical fuel led to the creation of a biomimetic motor. Other striking developments were made in the coupling of rotary motors with peptide-based of origami-based flagella as nanorobots to mimic propulsion of bacteria in a liquid environment. Other advances were made in coupling a motion generated by a molecular motor with the displacement of the thermodynamic equilibrium of a chemical

reaction, extending the possibilities to transduce various type of energies in one another. Light energy was also used to pump macrocycles on a thread, and the efficiency of these motors were improved by coupling the photochemical step with a pH stimulus. First integrations of molecular pumps in phospholipid by layers and compartments were also performed. The work at air-water interface also led to the counterintuitive demonstration that precise nanoscale motion of molecular motors can generate structural order, in the form of highly structured supramolecular polymers.

Challenge 3: Achieving the integration of large assemblies of molecular machines working in concert in materials in order to amplify their mechanical output on a macro scale and to open up the window for new applications towards smart, active materials such as artificial muscles.
An important applicative demonstration of ArtMoMa was to show how to destroy very stable -amyloid fibers (present in neurodegenerative diseases such as Alzheimer) using the rotation of light driven molecular motors at room temperature. We have also shown for the first time how a synthetic catalyst analogous to a biomolecular motor can perform work and transduce a chemical fuel into a macroscopic muscle-like contraction. Photoswitches were also applied in the field of molecular solar thermal energy storage, and they were also coupled to redox systems for orthogonal control of gel expansion and contraction. Finally, a real-life application consisted in developing a new platform using mechanical bonds to improve the efficiency and to lower the toxicity of plasticizers in industrial PVC.

Many fundamental and applicative results have been obtained, and most of them have been, are currently, or will be published in the best international journals, including generalist ones for the most important findings. Other aspects are currently in the process to be patented.

Progressi oltre lo stato dell’arte e potenziale impatto previsto (incluso l’impatto socioeconomico e le implicazioni sociali più ampie del progetto fino ad ora)

We have achieved a number of key scientific steps along our initial objectives, and important landmark results were obtained in the 3 main challenges we had to face. Beyond the direct report of these results to the scientific community, we have trained 15 young researchers to develop and achieve high level scientific projects. Along this journey, they have learned to think critically and to solve complex problems while respecting research integrity. They have learned on teamwork, and how to communicate their results to various audiences. We have also fostered new international collaborations between academic laboratories, and between academic researchers and industry, with an exploitation strategy which is now starting and which will be developed after the official end of the project. Therefore, we are confident that ArtMoMa will impact both the field of molecular machines and the career perspectives and employability of our ESRs, therefore strengthening European innovation capacity.

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