Directed self-assembly of soft matter nanostructures on inorganic surfaces

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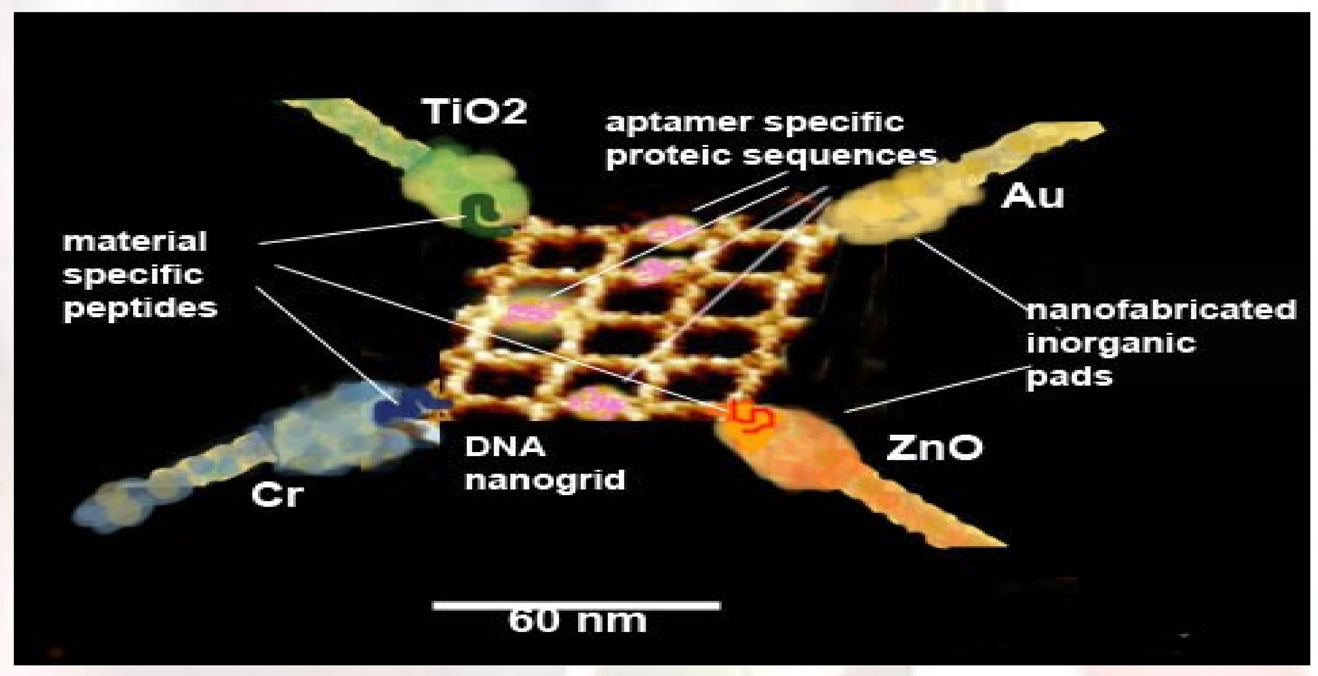
INTRODUCTION

WorkPackage 1 of the META project is aimed at the demonstration of a “DNA motherboards” concept, exploiting the self-assembling properties of biological macromolecules and advanced lithographic techniques to create a biomimetic interface for the creation of functional hybrid device architectures.

The concept shown in fig 1, is based on demonstrations that properly designed DNA sequences will self-assemble into ordered nanoscale architectures; these, in turn, will spontaneously facilitate the assembly of “plug-in” protein-based components on designated sites. Further self-assembling processes based on material selective peptides will be explored to direct specific motherboards onto designated locations of the chip.

Proof-of-concept demonstration of DNA motherboard assembly requires the following;

1) Assembly of the simplest DNA motherboards;
2) Fabrication of suitable anchoring pads on the surface
3) Assembly of the DNA-motherboard onto the anchoring pads
4) Assembly of the “plug-in” protein components onto the DNA-motherboard



.Fig 1: schematic of the “DNA motherboard” concept..

Attempts relating to 1), 2) and 3) are reported in this poster.

RESULTS

1) DNA square and ladder-like nano-architectures have been selfassembled from different oligonucleotide sequences; they have been characterized by AFM, randomly adsorbed on a mica surface and dried. Residues from the buffer salts in solution are largely present, in spite of repeated rinses in high purity water. Together with a large amount of incompletely assembled nanostructures. Optimization of the full assemblage rate is being investigated

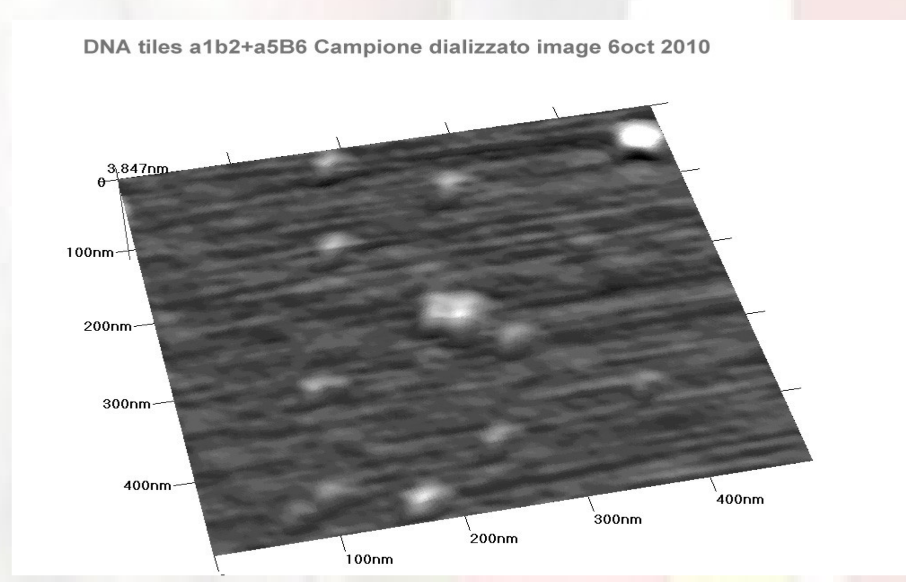


Fig 2: A single DNA nanosquare made of four cross shaped DNA “tiles”. The side of the square is 20 nm. Topographic AFM image

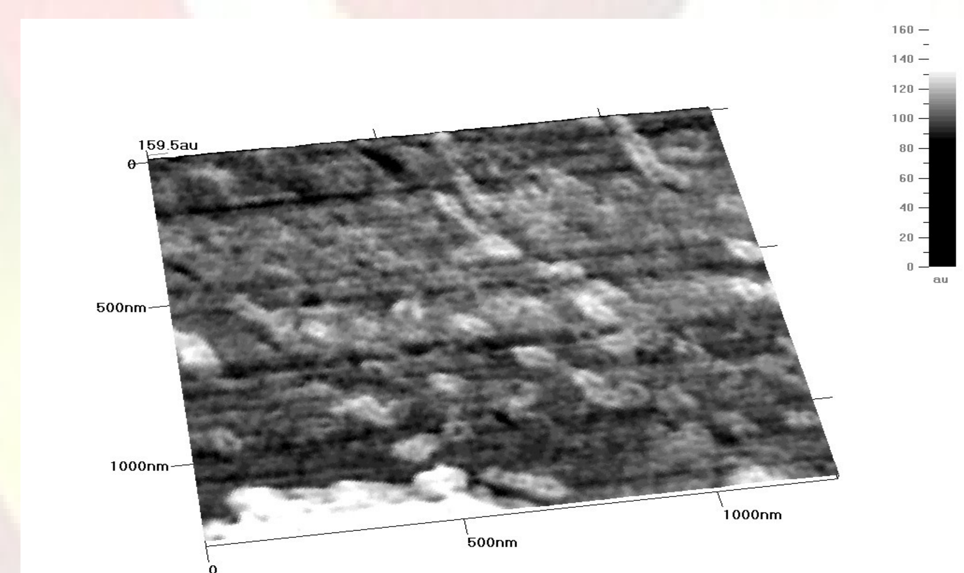


Fig 3: DNA ladder structures made of three nanosquares are observed in this phase contrast AFM image, together with incompletely assembled structures..

2) Gold spots in the sub-10 nm range have been fabricated by electron beam lithography with uniform spacing. Gold spots are of the order of 6 nm in diameter, with 105 nm free space, made to immobilize 115 nm long double stranded DNA endowed with thiol groups at both ends. The following figures and plots show outstanding precision and repeatability.

Fig 4: SEM imaging of a pattern of 10 nm gold spots arranged in groups of 4 with 115 nm center to center spacing

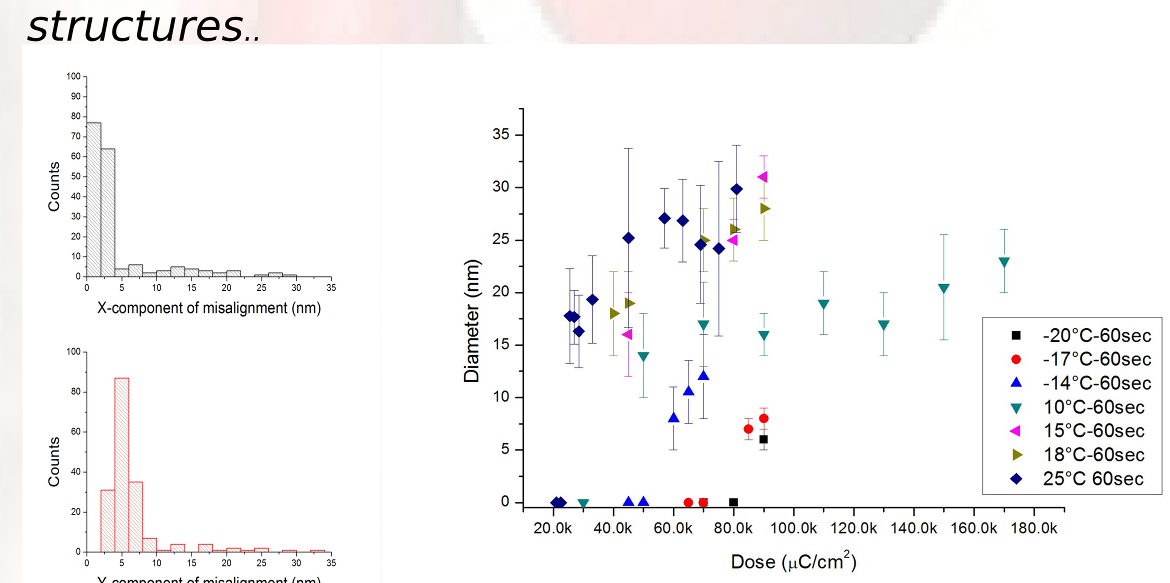


Fig. 5: Distribution of the misalignment in the x and y direction and plot of the spot diameter as function of the exposure doses at different temperatures.

3) Self-assembly of thiolated, 115 nm long linear DNA double strands was attempted onto the gold anchoring pads. AFM images show specific binding of DNA on some of the gold spots. Disruption of the DNA filaments connecting two adjacent 7 nm high spots by the AFM probe was observed. Filaments spanning the metal anchors can be observed by FEG-SEM at low acceleration voltage. Single connecting DNA strands are rare, as DNA tends to coalesce into lumps during sample preparation and drying for imaging.

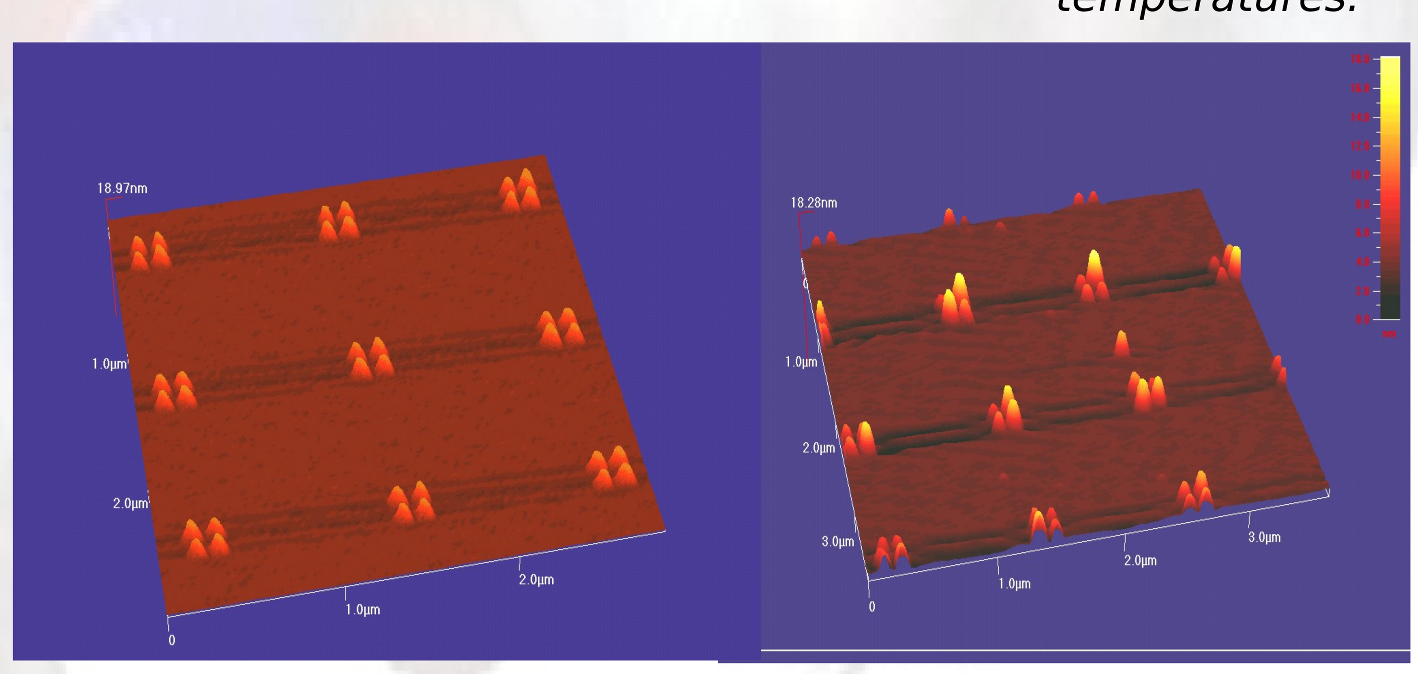


Fig. 6 Thiolated DNA bound on the gold nanopadss (right) compared to naked gold nanopads (left) . AFM topography

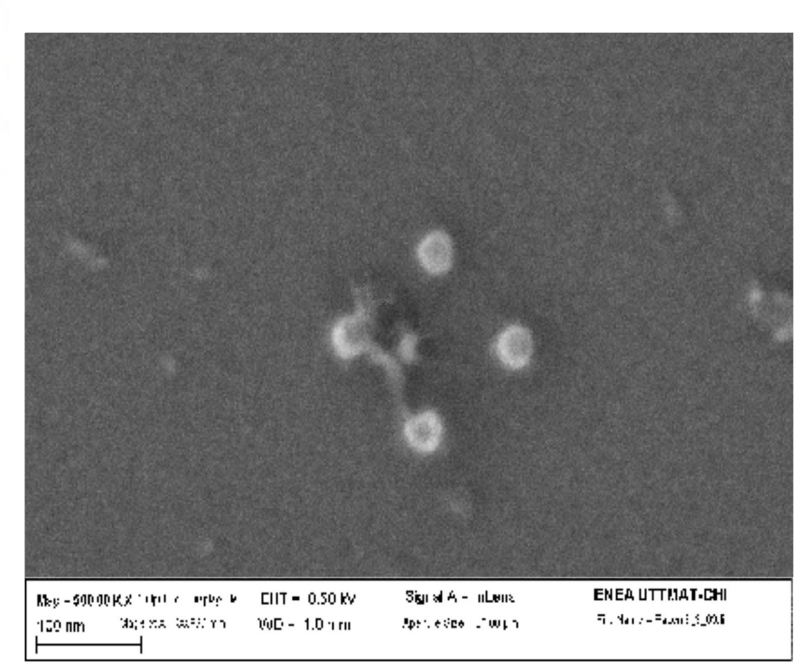


Fig. 7: A single DNA filament joining two nanopads (FEG-SEM image)

REFERENCES

1. Seeman N. (2007) Mol. Biotechnol 37: 246
2. Seeman N. and Belcher A.(2002) PNAS 99: 6451
3. LaBean T. et al *(2006) Angew. Chem. Int. Ed. (2006) 45: 775*

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