3D mechanical bottom up nano-manipulation and nano-assembling using shape memory alloy nanogripper for nano-optic, nano-photonics, nano-plasmonics

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Abstract. In this report new frontier trend in the creation of individual nano-devices based on individual nano-objects for nano-optic, nano-photonics, nano-plasmonic, photovoltaic and the methods of the fabrication of individual nano-devices is discussed. The bottleneck of this frontier trend is mission of fabrication methods for individual nano-devices. In the report new methodology, general strategy and proof of concept for the nano-assembling of individual nano-devices based on nanowire and other nano-objects is presented. This frontier technology is based on mechanical bottom up 3D nano-manipulation and nano-assembling using shape memory alloy nano-tools.

1. Introduction
There are two main paradigms: top-down and bottom up in emerging nanotechnology. Top-down technology plays a leading role in modern mass production of electronic industry. The goal of chemical bottom up paradigm, which was announced in famous Feynman paper [1], is creating new nano-materials through self-assembling and self-aggregation [2,3,4-6]. The goal of mechanical bottom up nano-assembling is creating of individual nanodevices from single nano-objects [7,8,9].

Recently new impulse the alternative bottom-up nanotechnological approach has got through the creation of multiple individual nanodevices [7,]. The modern vision of the bottom up paradigm predicts, that ultimate device miniaturization would use individual nano-objects or even large molecules (DNA, CNT, etc.) as building block of functional devices. For creating of individual nano-devices from existing single nano-objects standard top down nanotechnology is not suitable. On the other hand, for many research areas and industries, especially nano-sensorics [8], nanophononics, including nanoLED [10], nano-optics [11], nanophotovoltaic [12], etc. such individual nanodevices can provide functional properties that cannot be reached using other technologies. The background for appearance of this new stream in bottom up nanotechnology is provided be harbingers of new trends: synthesis of great number of different nano-objects, among them are: 0-D nano-objects like nanoparticles, quantum dots, 1-D nano-objects like nanotubes, nanowires, nanorods, 2- D nano-objects like graphene, Wan der Waals materials etc. with exciting properties. Also, we observe the growth of alternative bottom-up nanotechnology which exploits the methods of nanoassembling from bottom-up but has the goal related to the creation of individual nano-devices [7-13]. In this matter bottom up nano-assembling of single nano-devices can be comparable with top-down technology.

Nowadays many experiments were aimed to individual functional nanodevices creature using different bottom-up approaches: nano-manipulation and nano-assembling inside AFM [14,15], SEM [16,17, 1SEM, 2SEM], nanomanipulation and nano-assembling using optical and magnetic nanotweezers [18-20 lomt], and other methods. But all those
methods have the important limitations: they are very slow, have limited space for nanomanipulation and nano-assembling, optical tweezer can work only in liquid, or restricted to 2D working fields etc. Also, direct liquid nano-assembly [4], electric fields, microfluidic, Langmuir–Blodgett (LB) techniques [4], based on liquids technology and have fundamental limitation in accuracy because of disordered structure of liquids. In this matter alternative bottom-up approach for nano-devices creating has the main bottleneck in the problems in the 3D nano-assembling.

In nanooptics new promising research area is topological light. The structures for topological light can consist of the chains of plasmonic nanoparticles with different configuration [21-23 1tl-3tl]. The creation of such chains of plasmonic nanoparticles with any needed configuration (for example, with topological edge states in zigzag chains [21 1tl]) can be realized using MBUNA. MBUNA that can work in all media (vacuum, gases, liquids, etc.), also by special conditions it is not restricted in very small volume of microscope cameras, this allow future development of mass production of the topological light structure.

Plasmonic nano-structures are widely used electromagnetic wave confinement for application that need wavelength smaller than the diffraction limit of light. This technology follows in the strong enhancement of different nano-optical phenomena. For large enhancement of electromagnetic field very important to couple a light-emitting nano-materials efficiently with the localized electromagnetic field. gap-type plasmonic structure for example, bowtie nanoantenna and other nanostructures with quantum dots and nanowires are one of the best candidates for plasmonic nano-structures. But the despite of many attempts using electron beam (EB) , optical tweezer, (AFM) manipulation [13], simple dispersion technique has been mainly used to place nanomitters on a fabricated nanostructure and nanomanipulation technic [13 ] do not give enough suitable result. The other very important research area for nano-photonic and plasmonic is single quantum emitters coupled to different plasmonic and photonic structures. Those structured can be main elements for integrated quantum technologies, including quantum information processing. For such technology single photon source is vital. One of the most promising is nanodiamond-based single photon sources [24,26]. To deal with nano-diamonds and to create plasmonic and photonic structures with nano-diamonds and other nano-optical structures from single nano-objects like nanowires [25,26] a reliable nano-assembling and nanomanipulation method as enabling technology is crucial. Different individual nanophotonic, nanooptics, nanoplasmonic nano-devices from single nano-objects - such as large single molecules, nanowires, nanotubes, nanocrystals, quantum dots, etc. can be open new horizon in all those research areas. Such nanodevices cannot be produce using standard top-down nanotechnology. Many attempts to create new technology for nano-manipulation, nanoassembling and nanofabrication of such nano-optical nanodevices was done [13,24-26]. In this report we present a methodology, general strategy and proof of concept for the nano-assembling individual nanowire and other nano-objects based devices using mechanical bottom up 3D nano-manipulation and nano-assembling using shape memory alloy nanotools that can be used for main-photonic, nano-photonic, nano-plasmonic, photovoltaic.

2. Creating shape memory alloy nano gripper and nano manipulation for nano assembling

2.1. Creating shape memory alloy nanogripper
Nano-gripper was produced from shape memory alloy Ti2NiCu/Ni composites. The nanogripper reveals controlled reversible deformation by application of thermal heat near martensitic thermoelastic phase transition. Creation of shape memory alloy (SMA) nanogripper was described elsewhere [27-30].

2.1.1. Nanomanipulation using SMA nanogripper
Nano gripper is able to provide 3D nanomanipulation process for real nano-objects like nanotubes, nanowires, nano-particles, etc. in vacuum chamber of different microscopes like SEM or FIB. In this technological nanomanipulation process nanogripper is end-effector of some nano position system. For examples, Kleindieck or Omniprobe. Nano-manipulation can provide nanoassembling of different
individual nano-devices based on individual nano-objects. Some examples of nanomanipulation is shown on the figures 1, 2.

Figure 1. Nano-gripper pick up nanowire from nanowires forest
Figure 2. Nano-assembling of individual nano-devices from individual nanowire using nanogripper nano manipulation process.

Conclusion

In the report is it shown the possibility to create individual nano-devices for nano-optic, nano-photonics, nano-plasmonics using 3D mechanical bottom up nano-manipulation and nano-assembling using shape memory alloy nano-gripper.

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