Growth and structural properties of piezoelectric ZnO-magnetostrictive alloy nanowires for nano magneto- electro- mechanical systems (NMEMS)

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The presented hybrid nanowires (H-NWs) are 1-dimentional objects with promising physical properties because their core is made of piezoelectric material (ZnO), while the shell is a magnetostrictive alloy (FeGa or MnAs). Both phenomena couple together by mechanical deformation at the core-shell interface and generate a magnetic field around H-NW under the influence of voltage, and vice versa. Nanoobjects designed in this way are sensitive to fluctuations in the environmental electromagnetic field. The H-NWs cores were obtained using the modified carbothermal method on a a-sapphire substrate.Vertical NWs hadlengths of 20-60 µm and diameters of 80-500 nm. Focused Ion Beam (FIB) technique was used to prepare thin cross-sections of NWs and the interface between the substrate and NWs. Spontaneously formed $ZnAl_2O_4$ spinel layer between the substrate and NWs was observed. Thick, thin and bent ZnO NWs are defectless. ZnO NWs underwent the shell growth process in two ways: using MBE technique (MnAs and FeGa shells) and magnetron sputtering (FeGa shells). The MBE growth setup was equipped with thermal effusion cells for Ga,Mn and Fe. Additionally vertically oriented ZnO NWs were transferred to UHV magnetron sputtering machine. The quality of the H-NWs equipped with thermal effusion cellsfor Ga,Mn and Fe. Additionally vertically oriented ZnO NWs were transferred to UHV magnetron sputtering machine. The qualityof the H-NWs was examined with TEM imaging which revealed polycrystalline textured shells structure with some grains having an epitaxial relation to the monocrystalline core. The influence of the substrate temperature during the shell growth process on the core decoration with shell atoms was examined. Also, the impact of temperature on the interdiffusion of the shell elements was studied in-situ with EDS using heated TEM holder.

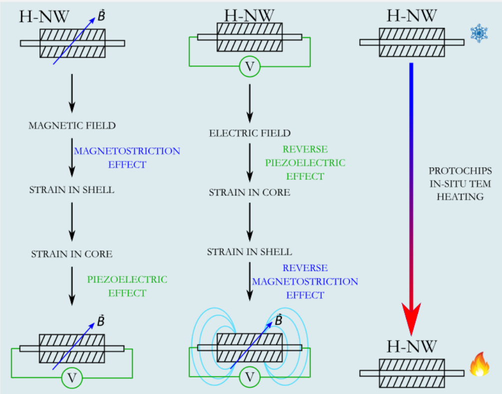

Fig. 1 The idea of the in-situ TEM examination approaches.

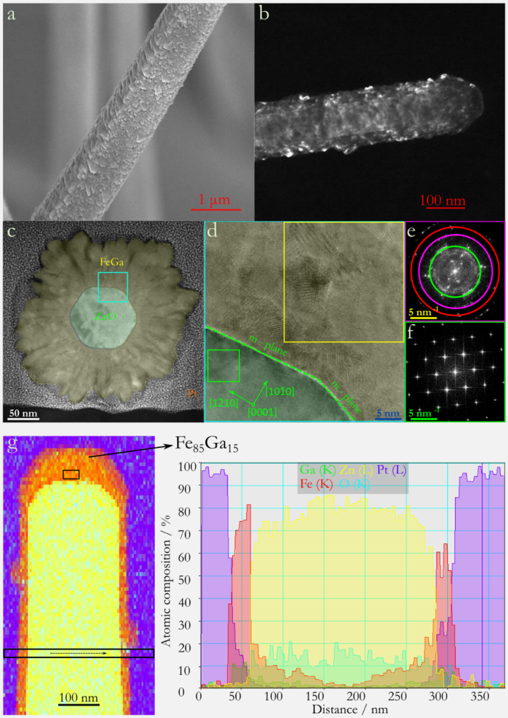

Fig. 3 H-NW SEM image (a), HR-TEM image in dark field mode enabling observation of core and shell (b). STEM image of H-NW cross section (c), zoomed in (d) panel and FFT of shell (e) and core (f). EDX map with composition profile (g).

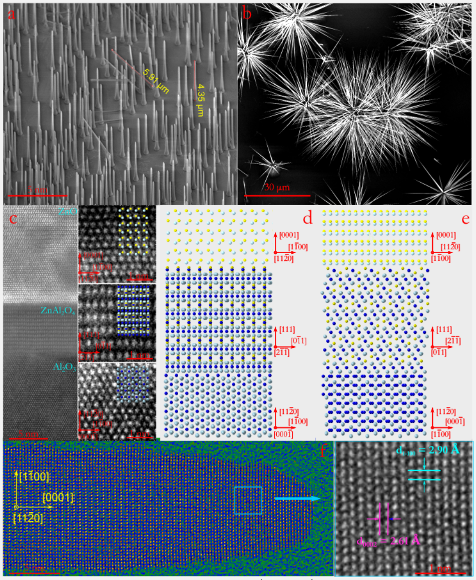

Fig. 2 SEM images of ZnO NW grown on a-sapphire (a)[1] and Si (b)[1] substrates. STEM image of Al_2O_3-$ZnAl_2O_4$-ZnO NWs structure (c)[2], atomic reconstruction of the structure in two orientations (d,e)[2]. Thin ZnO NW presented in HR-TEM image using GPA technique in order to provide colors; zoomed area with (1-100) and (0002) planes marked as blue and pink lines, respectively (f)[1].

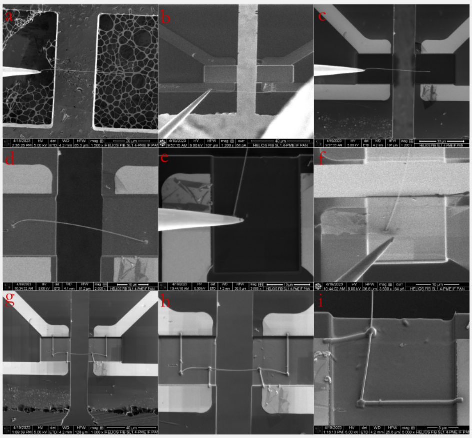

Fig. 4 ZnO NW contacting process: transferring NW with Omniproble: taken from TEM grid (a), NW deposition on a chip seen with electron (b) and ion (c) gun. Bent NW, attached on one side (d), NW straightening seen with electron (e) and ion (f) gun. Contacted NW with the 4-probe technique (g, h). Platinum paths visible at 45° (i).

The work is supported by Opus 18: *Własności i stabilność strukturalna nanodrutów o piezoelektrycznych rdzeniach i magnetostrykcyjnych powłokach w badaniach elektronomikroskopowych in-operando.*

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