Nanowire Based Flexible Piezoelectric Sensor

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Introduction: Gallium Nitride (GaN) nanowires are used as active material for capacitive flexible piezoelectric sensors dedicated to structural health monitoring applications. Nanowires are grown by Metal Organic Vapor Phase Epitaxy (MOVPE) on sapphire substrate [1] and their geometrical characteristics (L, α) are tuned by growth conditions. This work quantifies by COMSOL simulation the impact of both parameters on nanowire's electro-mechanical characteristics.

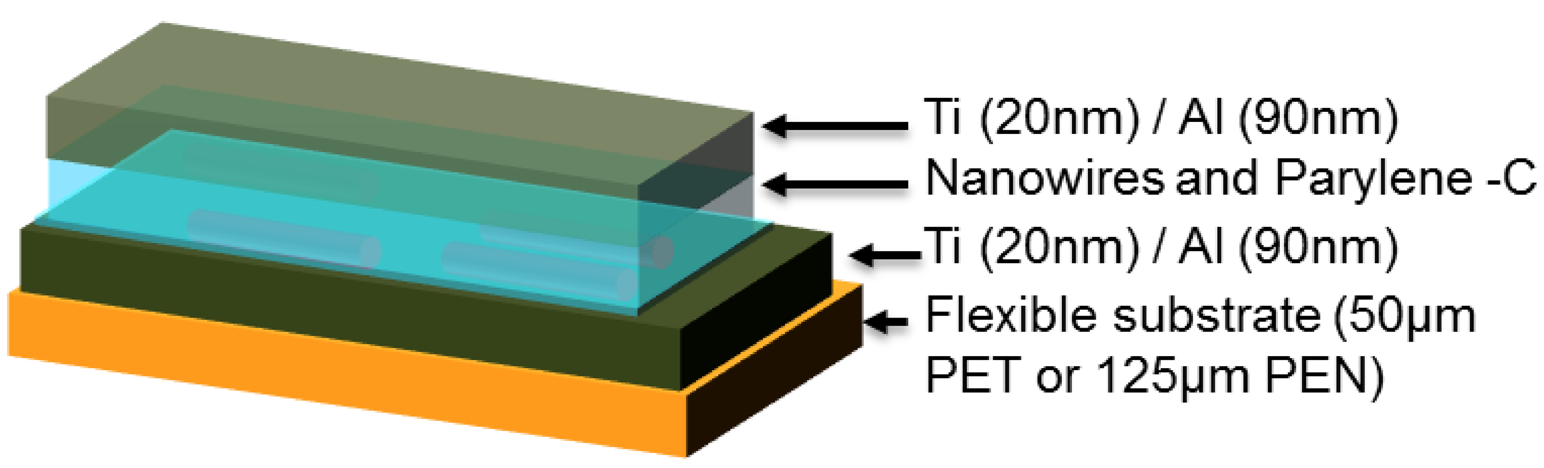

Figure 1. Schematic figure of the device stacking [2]

Finite element model : Electrical response of a single cone-shaped wire embedded into a dielectric layer under a bending constraint is studied. MEMS and piezoelectric modules are used. Main electrostatic equations being computed within the simulation are solved for the dielectric displacement field and the piezo-potential. In the piezoelectric material domains, the displacement field involves an additional term of the piezo-polarization P_{pze}.

$$\vec{\nabla}.\vec{D} = \rho_V$$
$$\vec{E} = -\nabla V$$

with $$\vec{D} = \varepsilon_0 \cdot \varepsilon_r \cdot \vec{E} + P_{pze}$$

The simulated structure consists of a conical wire with hexagonal cross-section. Wire geometry is defined through three main parameters : R_{top}, L and α. Parameters were properly adjusted to achieve realistic shapes consistent with microscopy observations.

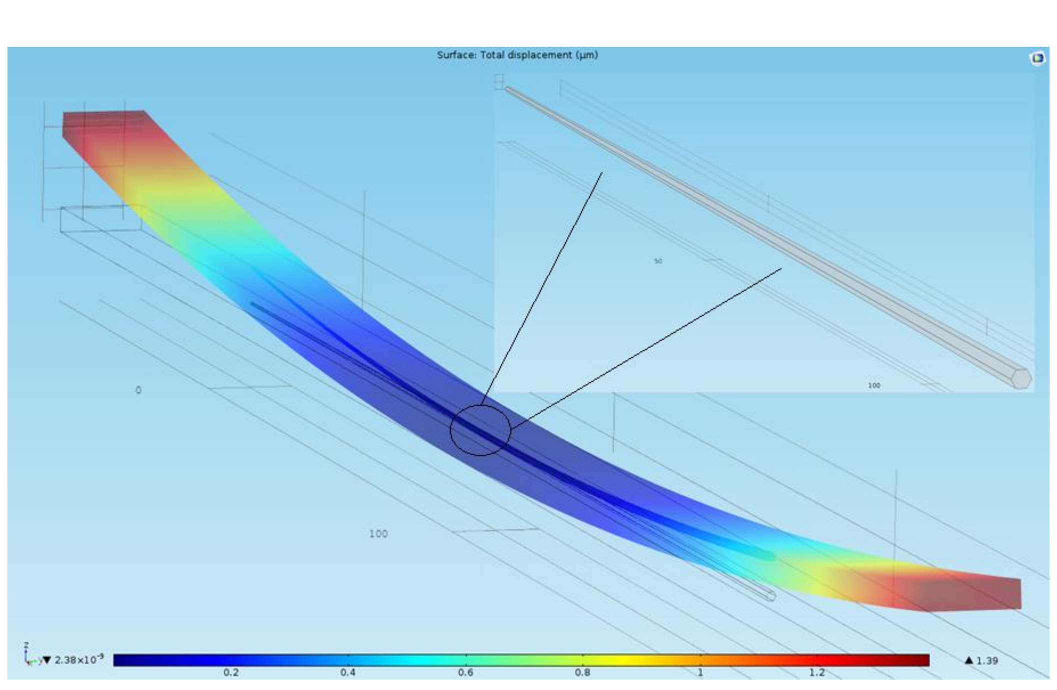

Figure 2. Simulated structure consisting of single wire embedded into 2 µm dielectric layer under 10 cm bending

Results: Simulation shows that the generated potential exhibits peaks at extremities due to charge accumulation at both wire ends. Moreover, a net degradation of the generated potential has been confirmed for long wires regardless the modelling approach : constant wire volume or constant wire surface.

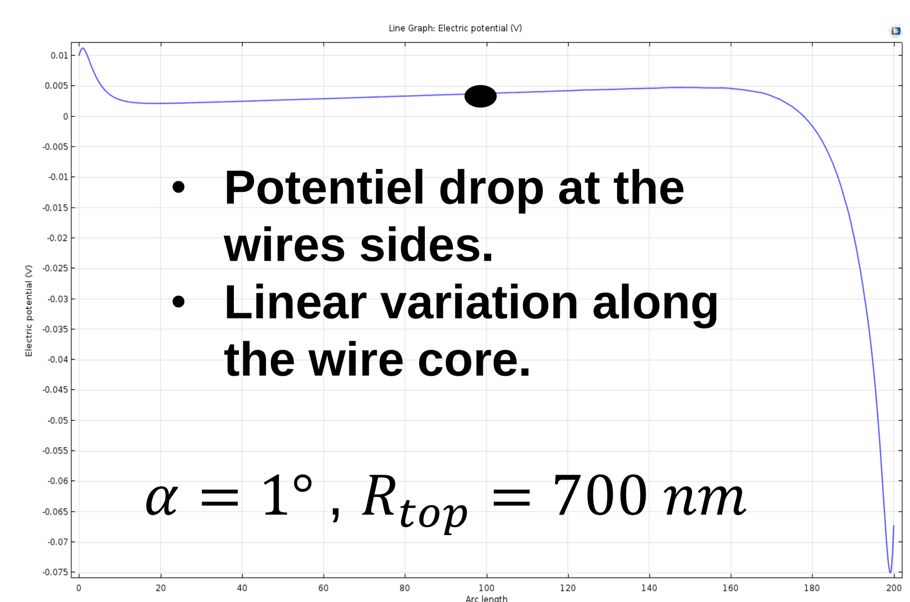

Figure 3. Piezo-potential shape taken along the wire top face.

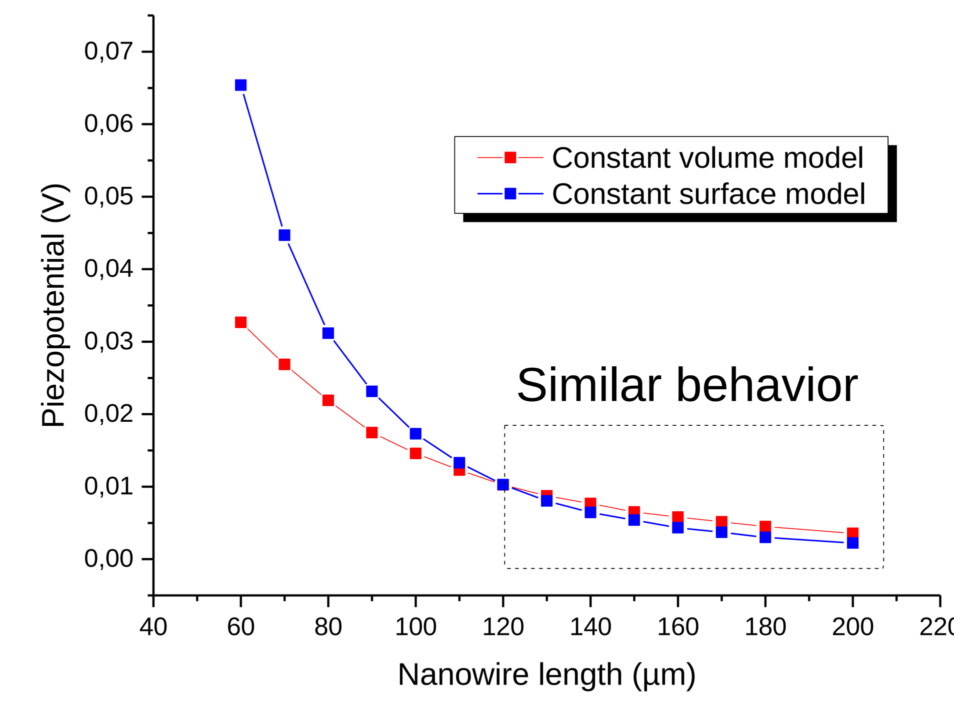

Figure 4. Potential evolution with wire length.

Furthermore, we also demonstrate the importance of conical shape for potential generation (Fig5) as well as the high sensibility of short wire to conicity variations (Fig6).

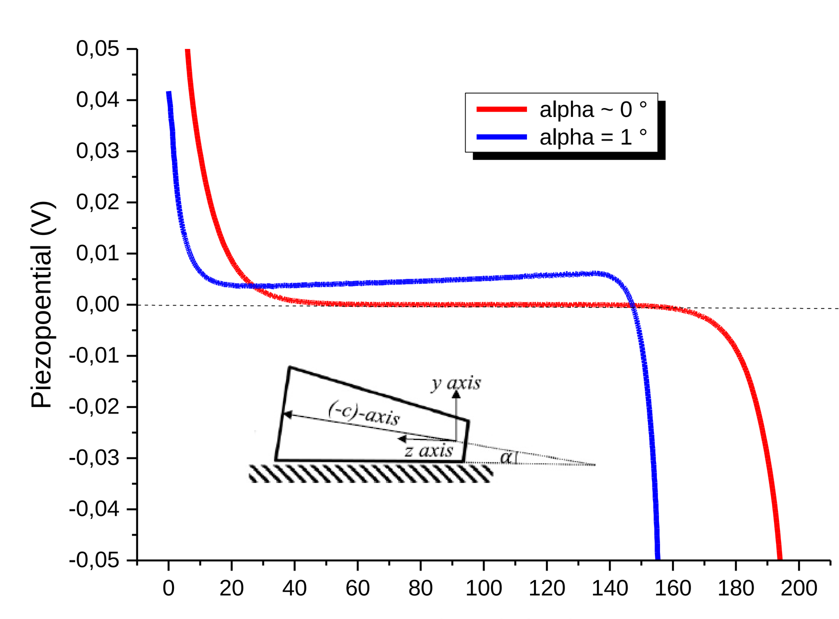

Figure 5. Piezo-potential generated with conical and non conical wire.

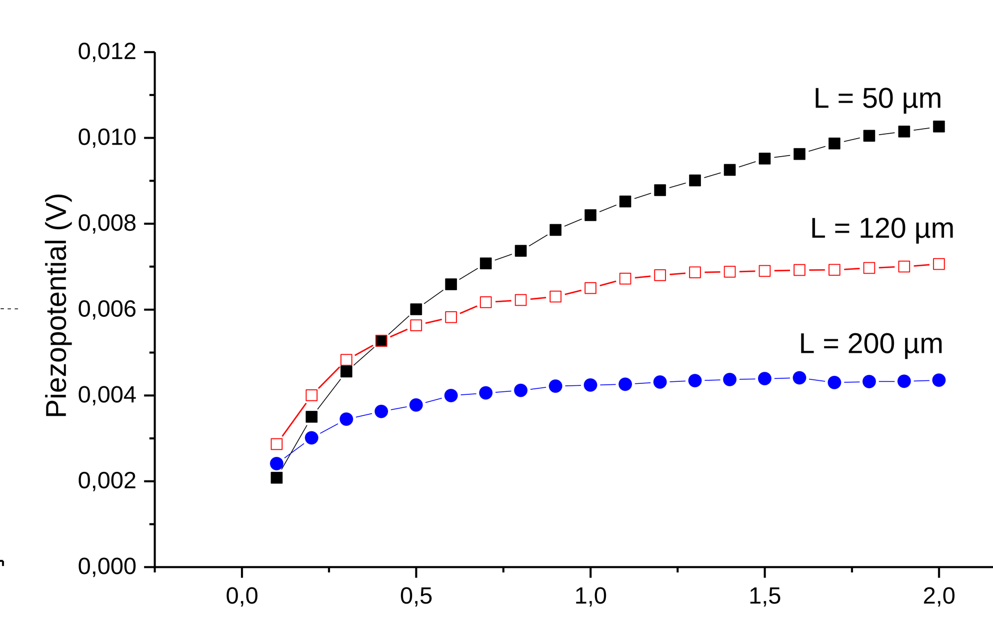

Figure 6. Potential evolution as function of wire angle.

Conclusions: The significant impact of L, α on wire electro-mechanical properties have been investigated. Short wires exhibit better performances than longer ones. This study gave a clear insight about further improvement that are still to be brought to wire growth processes to enhance device performances.

References:

1. J. Eymery et al, Self-organized and self-catalyst growth of semiconductor and metal wires by vapour phase epitaxy: GaN rods versus Cu whiskers, C. R. Physique 14, pp 221–227, (2013)
2. S. Salomon et al, GaN wire-based Langmuir–Blodgett films for self-powered flexible strain sensors, Nanotechnology 25, pp 375502, (2014)

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