High Frequency Resonators using Exotic Nanomaterials

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Introduction:

- Recent innovations in area of 1-D and 2-D nanomaterials has resulted in significant interest in the use of such materials for metrology, mass sensing, biosensing, telecommunication, and high frequency resonator applications.
- While important, it may be time consuming and prohibitively expensive to characterize them all experimentally.
- COMSOL multi-physics models could potentially be useful to characterize these materials as high frequency devices for future applications.

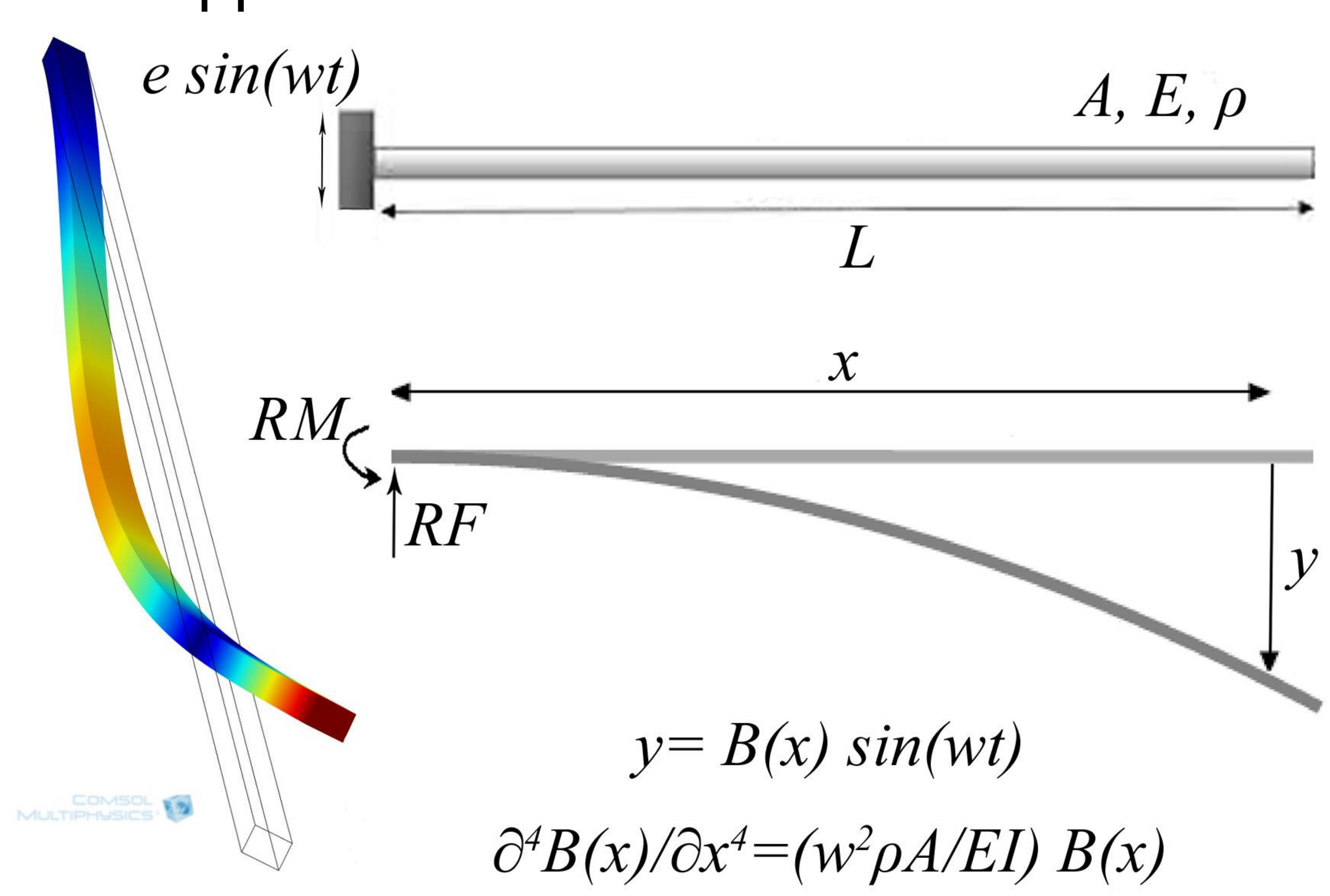

Figure 1. Nanoresonator model as an Euler-Bernoulli beam

Computational Methods:

- Instead of beam element, we used structural mechanics module using 3D cubic element that is elongated along the axis of the beam in COMSOL.
- Clamp-free was considered as the boundary conditions of the beam and base motion vibration with ~500 nm amplitude at the clamp end was applied as the input.
- Mechanical damping function was imported into the model by defining loss factor that was equal to inverse of quality factor of resonator.
- We compared experimental data on Ag_2Ga nanowires, carbon nanotube, and ZnO nanoresonators to validate this model.

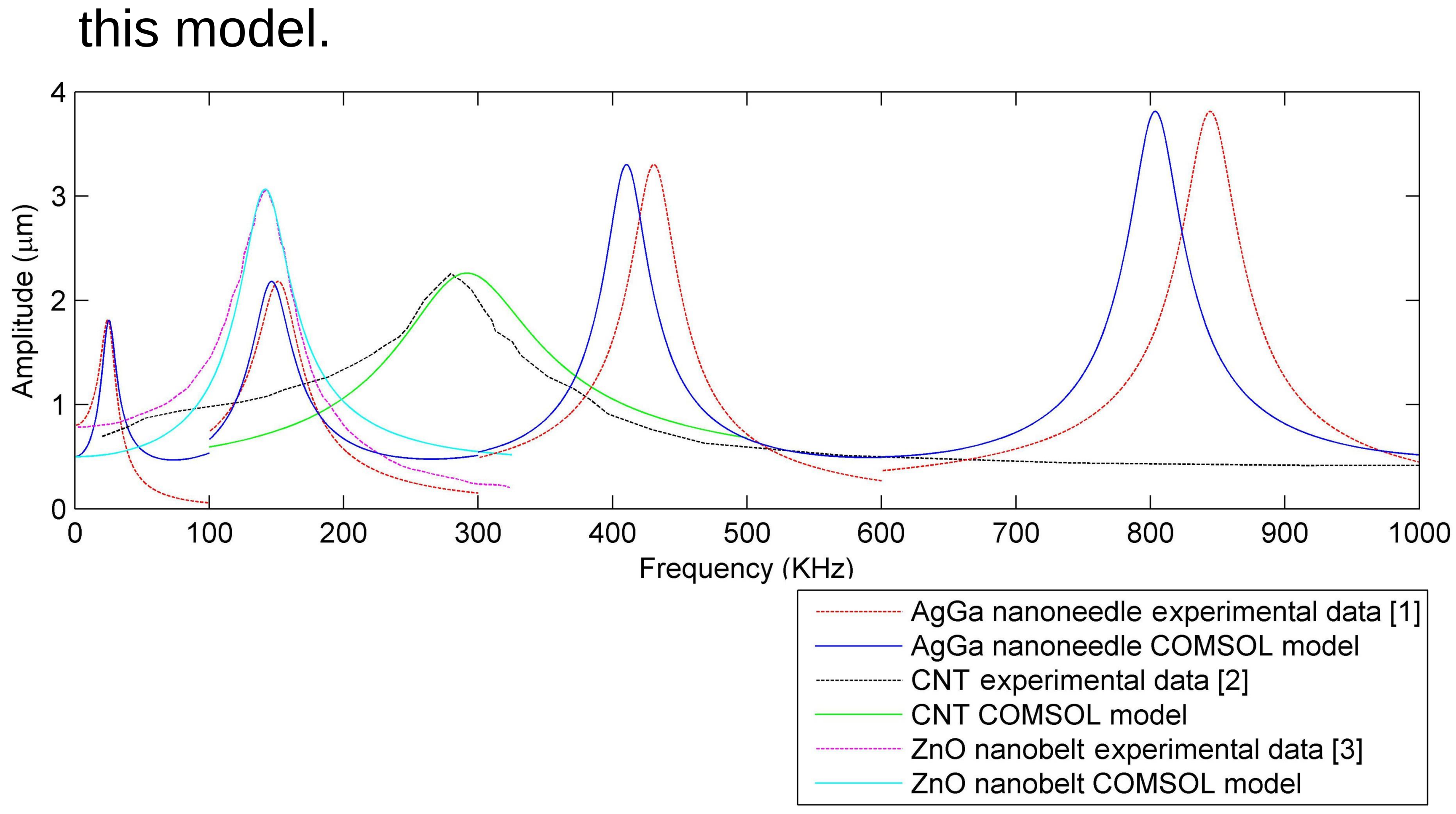

Figure 2. Frequency response comparison of nanoresonators from experimental data and COMSOL.

Results:

- Figure 2 compares the results of COMSOL model with data reported in references [1-3]. The experimental peaks were normalized to their relevant simulations peaks from COMSOL.
- The resonance frequencies from COMSOL simulation were in match with the experimental data and the maximum difference in resonance frequencies was within ~4.1% (Ag_2Ga 4^{th} mode).
- The first mode of ZnO nanobelt had higher vibration amplitude at the tip, higher stored elastic energy (Fig 3a), and lower stress at the clamp end in comparison to 2^{nd} mode of Ag_2Ga nanoneedle (Fig 3b).
- Also, CNT had very low stress at the clamp end (Fig 3d), however its stored elastic energy was low (Fig 3c) in comparison to the other two nanoresonators.

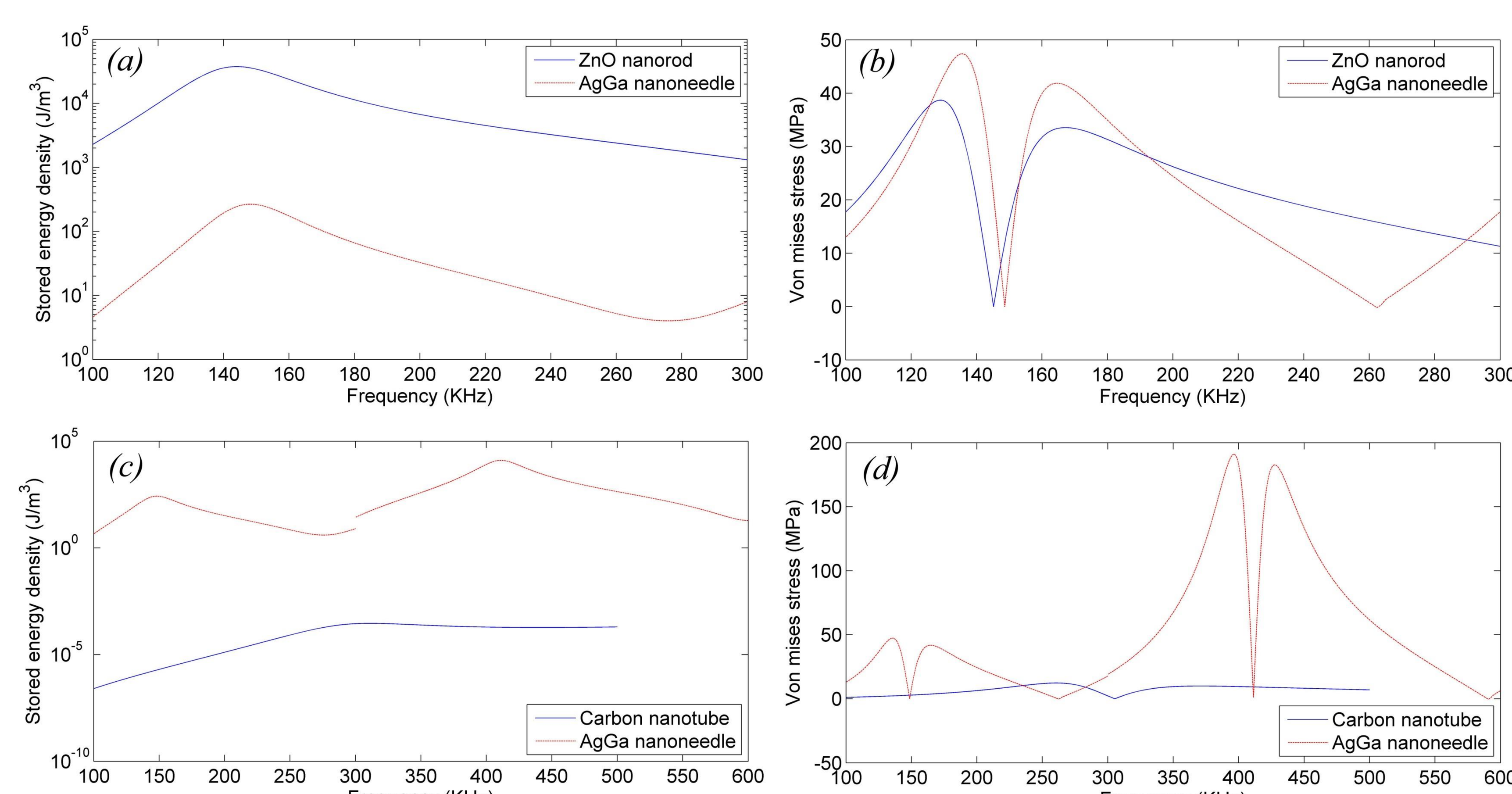

Figure 3. Comparison of stored energy and von Mises stress at the clamping end for different nanoresonators.

Conclusions:

- The presented COMSOL model is developed to simulate the frequency response of nanoresonators with different geometries (cubic, cylindrical, tube) for various materials (ZnO, Ag_2Ga, CNT).
- COMSOL results for nanoresonators are in good match with experimental data and it can be used to predict the behavior of other exotic materials including graphene, MoS_2, nanodiamond, BN, SiC and others.
- Among the materials studied here, ZnO nanobelt is a wonderful candidate as a mechanical nanoresonator.

Acknowledgements:

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References:

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