MMM2 - Project Description - 2010
Modelling of Nanogenerators

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September 6, 2010

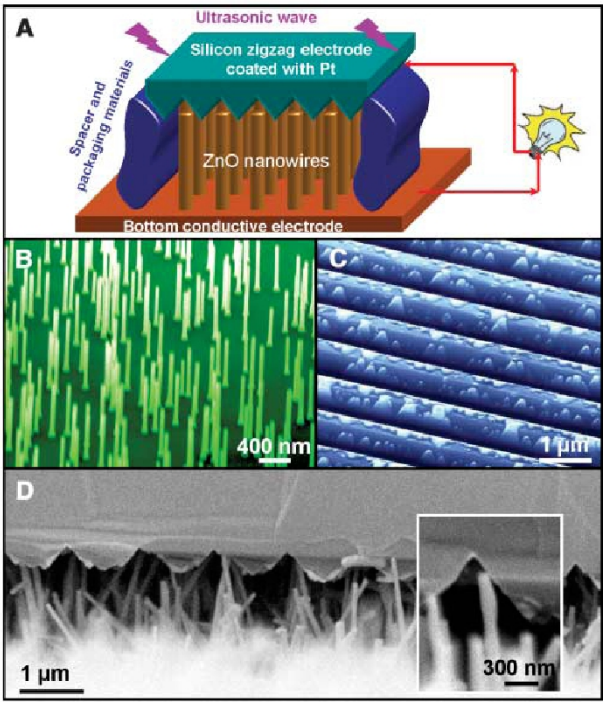

Figure 1: Schematic picture of the nanogenerator together with SEM images of the real device. (Ref. Xudong Wang et al., Science, 316, 102 (2007))

1 Introduction

There is no doubt that arrays of sensors will play an important role in the world of tomorrow. One example of this which has already started being implemented is sensor networks in buildings and bridges which serve as warning systems telling engineers when the buildings needs repair, making it unnecessary to perform costly periodic manual test. One stumbling block for the increased use of sensor nets is the need to power these devices. A promising solution to this problem is to directly scavenge the readily available ambient vibrations and turning it into useful electrical energy. In figure 2 is shown a proposal for such a device. This device proposes to use the piezoelectric effect (a physical phenomena which couples electric and mechanical fields) of ZnO nanowires to transform mechanical energy into electrical energy. The advantage of using nanowires is amongst others that the devices can be made very small making it easy to include them in the micro sensor devices of tomorrow.

In this project several mathematical models will be developed and tested against both experimental data and each others in order to investigate the strengths and weaknesses of the developed models. The models should be able to describe the deformation of the nanowire under the influence of a force exserted at the top of the nanowire and the resulting electric potential present in the nanowire due to this deformation, see figure **??**. However, the models do not need to capture how the electric potential is used to drive a current through the structure. Furthermore, free charges can be neglected for simplicity.

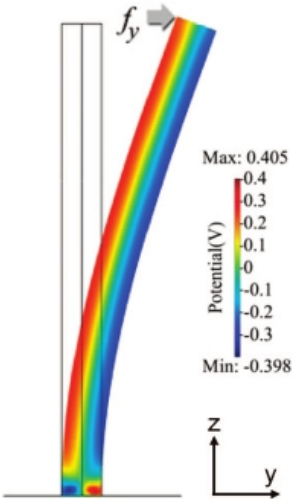

Figure 2: Piezoelectric potential distribution across the center of the ZnO nanowire assumed to be an insulator (Ref. Y. Gao and Z. L. Wang, Nano Letters, 9, 1103 (2009)))

2 Learning objectives

Here follows a list of the learning objectives for this project:

1. To understand the working principle behind the prototype nanogenerator shown in figure 2. Refer to the papers X. Wang, J. Song, J. Liu, and L. Wang, Science, 316, 102 (2007) and Z. L. Wang and J. Song, Science, 312, 242 (2006).

2. To achieve a basic understanding of the advantages and disadvantages of the proposed technology.

3. To get an idea about where and why this technology could be relevant. Refer to R. F. Service, Science, 328, 304 (2010).

4. To develop the following three mathematical models:

   - A model based on Euler beam theory (covered in class).
   - A three dimensional linear model based on the Navier's equations for elasticity (mechanical equilibrium's equations - balance of linear momentum, see Ref. Y. Gao and Z. L. Wang, Nano Letters, 7, 2499 (2007)). It is suggested to implement these equations in a finite element program for example Comsol Multiphysics.
   - A three dimensional non-linear model again based on the Navier's equations.

5. To compare the results of each mode with experiments.

6. To compare the three models against each other and to specify the expected range of validity of each model.

The final report needs to contain enough detail to show that the student has achieved the listed objectives, i.e., the report has to contain sections describing in detail the above learning objectives, however, references to basic theory is allowed.

3 Assessment

The project will be assessed based on a project report and will be graded with a passed or failed. The project needs to be passed in order to go to the written exam of MMM2. The project will be evaluated using the selfassignment program on blackboard in order to avoid plagiarism and to help the students with realizing the importance of referencing the source material.

4 Important Dates

- September 6th: Project start
- September 28th: A note describing the working principle of the nanogenerator is to be handed in.
- October 26th: A note describing where and why the nanogenerator can be used and the model based on the Euler beam theory is to be handed in.
- November 23nd: A note describing the linear and the non-linear three dimensional models based on Navier's equations is to be handed in.
- November 29th - December 14th: Period dedicated to finishing the project (no class room teaching).
- December 14th: Hand in of the final report.
- December 20th: The assessment of the project report is given.

5 References

5.1 Experiments

- X. Wang, J. Song, J. Liu, and L. Wang, Science, 316, 102 (2007)
- Z. L. Wang and J. Song, Science, 312, 242 (2006)
- M.-P. Lu, J. Song, M.-Y. Lu, M.-T. Chen, Y. Gao, L.-J. Chen, and Z. L. Wang, Nano Letters, 9, 1223 (2009)

5.2 Theory

- Y. Gao and Z. L. Wang, Nano Letters, 7, 2499 (2007)
- Y. Gao and Z. L. Wang, Nano Letters, 9, 1103 (2009)
- J. Song, X. Wang, E. Riedo, and Z. L. Wang, 5, 1954 (2005)

5.3 Application

- R. F. Service, Science, 328, 304 (2010)