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Investigation on the vibrational response of nano-objects studied by picosecond acoustic

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EXTENDED ABSTRACT

The constant race toward miniaturization lead to a continuously increasing interest to nano-objects. Moreover, the downsizing to the nanoscale leads to unique properties for those objects in comparison to their bulk counter-part due to confinement (e.g. optic, quantum or acoustic). In the acoustic domain confinement is responsible for modification to the dispersion relations, which in turn can impact thermal or electronic properties. More and more used as fundamental brick in the development of new devices (bio-sensors, fuel cells,...), the study and characterization of nano-objects is crucial.

Today, a significant number of techniques and methods are very well understood in order to synthesize nano-objects which lead to an important diversity of nano-objects with different sizes and materials. Among this diversity, nanowires (NWs) are quite interesting. Those particular nano-objects are qualified as 1D objects, meaning that only of their dimensions is not a nanometric one (below a couple of hundreds of nanometer) : their length which is typically in the micrometer range. It means that NWs have not only an important surface-to-volume ratio which make them sensitive to changes in their environment but also can displays some confinement properties. That's the reason why this kind of nano-objects have received a great interest for both fundamental and application point of view during the last few decades.

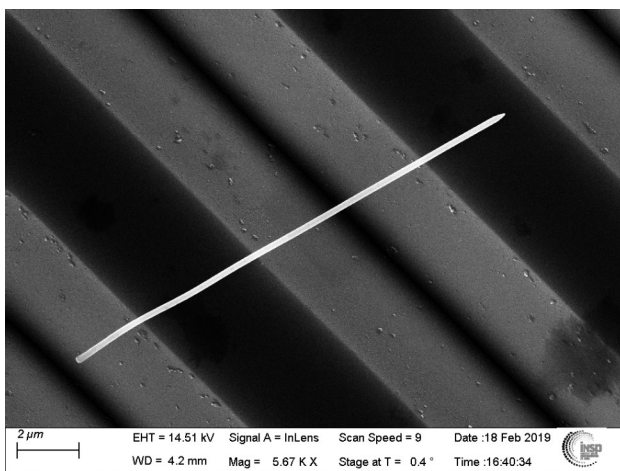


Figure 1. Scanning Electron Microscopy image of a gold nanowire suspended over a trench.

Metallic nanowires in particular have applications in a large variety of domains from electronics to magnetics or even optoelectronics due to their properties. Multicomponent heterostructure nanowires such as core-shell, alloy, multi-layered or even porous nanowires have received an even greater interest as combining different materials allow unique properties. Nevertheless, in order to use such nano-objects in new devices, it is necessary to characterizes those properties.

In the case of mechanical properties, different techniques have been proposed in order to measure for example the Young's modulus of a nanostructure. But most of those techniques that can be found in the literature are destructive, thereby only one property can be measured and sometimes it is even averaged for a high number of nano-objects.

On the other hand, time-resolved pump-probe spectroscopy is considered today as a powerful tool to address local elasticity issues at the nanoscale. It allow to work on a single nanowire and also have the advantage of being non-destructive. That's the reason why it has been extensively used in the last decade in order to measure optical, thermal or mechanical properties of a single nano-object.

In this study, an inverse method allowing to do a complete elastic evaluation of a unique nanowire. An ultrafast pump-probe spectroscopy investigation is realised for this purpose. Taking advantage of a free standing geometry as shown of Figure.1, observation of breathing harmonics modes have been achieved.

The ability to determine the frequency for several breathing mode allows one to estimate both longitudinal and transverse sound velocities thanks to the Pochhammer-Chree model. Therefore, it is possible to determine both Young's modulus and Poisson ratio's of the material composing a single nanowire.

This method has been tested and proven to be effective for metallic single-phase nanowires made of different materials (gold, silver, copper, ...). It has been used in order to determine the elastic constants of nanowires made of an alloy of gold and silver for different concentrations. The results have been compared to two effective medium models kown as the Voigt and the

Reuss models. The experimental results are in accordance with those obtained thanks to these models. It is also shown that measuring supplementary modes in addition to the breathing harmonics can be used to improve the results. Finally, some preliminary results obtained on more complex multicomponent heterostructure nanowires are presented and confirm that ultrafast pump-probe spectroscopy is a promising suitable technique for mechanical characterization