

## Tensile testing at the nano-scale

***Citation for published version (APA):***

Bergers, L. I. J. C., Hoefnagels, J. P. M., & Geers, M. G. D. (2011). Tensile testing at the nano-scale. In *Proceedings of Euromat 2011, 12-15 September 2011, Montpellier, France* (pp. D22-O-3-4-1702/1-2)

***Document status and date:***

Published: 01/01/2011

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

***General rights***

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

***Take down policy***

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

Topic Area	D Characterization and Modelling	D22-O-3-4
Topic	D2 - Mechanical Characterisation Techniques	1702
Symposium	D22 - Mechanical characterization of small-scale structures and advanced nanostructured materials	
Session	Small-scale Testing 1	

### Tensile testing at the nano-scale

**L. Bergers (Eindhoven University of Technology, Eindhoven, Netherlands), J. Hoefnagels, E. Dekkers, M. Geers**

L. Bergers ( Eindhoven Univ. of Technology, Dept. of Mech. Engg., P.O.Box 513, 5600MB, Eindhoven, NL; Foundation for Fundamental Research on Matter, P.O. Box 3021, ), [l.i.j.c.bergers@tue.nl](mailto:l.i.j.c.bergers@tue.nl)

J. Hoefnagels ( Eindhoven Univ. of Technology, Dept. of Mech. Engg., P.O.Box 513, 5600MB, Eindhoven, NL,)

E. Dekkers ( Eindhoven Univ. of Technology, GTD, P.O.Box 513, 5600MB, Eindhoven, NL,)

M. Geers ( Eindhoven Univ. of Technology, Dept. of Mech. Engg., P.O.Box 513, 5600MB, Eindhoven, NL,)

### Abstract

Mechanical testing for material behavior characterization has brought much understanding into the mechanics of materials at the macroscale. Nowadays, however, miniature devices with dimensions at the sub-micrometer scale, such as MEMS, are processed routinely, which has revealed unexpectedly new mechanical micro-mechanisms. This has spurred research into new mechanical characterization techniques to understand the physical fundamentals at the (sub)-micron scale, e.g. nano-indentation [1], FIB-enabled in-situ micro-tensile testing [2], fully integrated and dedicated tensile test MEMS [3]. One important outcome of this research is that testing at the nano-scale is far from trivial [4,5]! To address this issue, a novel nano-tensile methodology is presented here for which all fundamental aspect of tensile testing have been reconsidered in its design.

A suitable testing methodology faces a number of challenges. First of all, such a methodology needs to be sensitive enough to measure the nano-Newton forces and nanometer deformations involved at this scale. Well-defined loading conditions are preferred to facilitate interpretation of the deformation state, thus favoring the uni-axial tensile test. Boundary conditions should also be carefully controlled to minimize undesired influences, such as surface roughness or friction effects, while challenges of specimen handling, loading and alignment need to be addressed as well. Furthermore, easy specimen variation is required to enable systematic studies of the influences of, e.g., mechanical size-effects. Finally, in-situ SEM testing capability is necessary to unravel the physical origin underlying (the often complex) microscopic deformation mechanics.

In the authors' opinion, the here-presented nano-tensile methodology is the first technique that meets all of these requirements simultaneously, see figure. Its design solutions and calibration routines are discussed, and the strength of the methodology is demonstrated through highly accurate measurements of uni-axial stress-strain curves of on-chip  $\mu\text{m}$ -sized free-standing Al-(1wt%)Cu beams (used in RF-MEMS applications).

[1] Nix, Metall. Trans. A, 1989

[2] Kiener et al. Acta Mater., 2008

[3] Haque, Saif, Exp. Mech. 2002

[4] Hemker, Sharpe, Ann. Rev. Mater. Sci., 2003

[5] Kang, Saif, J. Microelectromech. Syst., 2010

