

# In situ compression in Transmission Electron Microscopy and mechanical analysis of ceramic nanoparticles

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Nanometer-sized objects are attracting large attention nowadays due to their amazing mechanical properties in comparison to their bulk counterparts. In particular, they can exhibit far larger and size-dependent elastic limits [1]. Several mechanisms have been proposed, among which dislocation nucleation at the surfaces.

Large numbers of studies are nowadays dedicated on plastic deformation of metals at the nano-scale. On ceramic materials, the works from Korte et al. [2] on MgO, or Calvié et al. [3] on transition alumina nanoparticles showed that these materials can exhibit significant plastic deformation, whereas the corresponding bulk materials are brittle. A better comprehension of the mechanisms involved in the deformation of ceramics at the nanoscale could help optimizing their fabrication process.

The mechanical properties of ceramic nano-objects of a few tens of nanometer can be studied using in situ compression tests in TEM. This technique will be applied on MgO nanocubes. Firstly, deformation mechanisms will be proposed from the contrasts in the images and Molecular Dynamics simulations [4]. Secondly, a mechanical behavior law will be identified from the images and the force-displacement curves through Digital Image Correlation and Finite Elements Simulations. The parameters (Young modulus, yield stress) will be discussed in function of the observation conditions as well as the nanocube size, to study a possible size effect.

[1] Kraft O. et al. *Annual Review of Materials Research***40**, 293-317 (2010)

[2] Korte S. et al. *Acta Materialia***59**, 7241-54 (2011)

[3] Calvié E. et al. *Journal of the European Ceramic Society***32**, 2067-71 (2012)

[5] Issa I. et al. *Acta Materialia***86**, 295-304(2015)

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### **Education**

1998 PhD, speciality “Condensed Matter, Surfaces and Interfaces”, Ecole Centrale de Lyon, France.

2006 Habilitation thesis, Institut National des Sciences Appliquées de Lyon, France

### **Professional Experience**

Postdoc fellow, University of Western Ontario, Canada, 1999

Contractual lecturer, INSA-Lyon, France, 1999-2000.

Associate professor, Nancy I University, France, 2000-2002.

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### **Fields of Research**

Electron microscopy (SEM, TEM), *in situ*, environmental, tomography

### **Publications**

1. Issa I, Amodeo J, Réthoré J, Joly-Pottuz L, Esnouf C, Morthomas J, Perez M, Chevalier J; Masenelli-Varlot K, *Acta Materialia*, **86**, 295-304 (2015)
2. Jomaa MH, Masenelli-Varlot K, Diguët G, Seveyrat L, Lebrun L, Wongtimnoi K, Véchambre C, Chenal JM, Cavaillé JY, *Polymer*, **62**, 139-147 (2015)
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4. Calvié E, Joly-Pottuz L, Esnouf C, Douillard T, Gremillard L, Malchère A, Chevalier J, Masenelli-Varlot K, *Acta Materialia*, **61**, 174-182 (2013)
5. Calvié E, Joly-Pottuz L, Esnouf C, Clément P, Garnier V, Chevalier J, Jorand Y, Malchère A, Epicier T, Masenelli-Varlot K, *Journal of the European Ceramic Society*, **32**, 2067-2071 (2012)