KN18

Acta Cryst. (2011) A**67**, C12

Atomic-resolution Real-space Imaging and Aberration Corrected Electron Microscopy

Stephen J. Pennycook *Oak Ridge National Laboratory, Materials Science and Technology Division, Oak Ridge, TN 37831-6071 (USA).* E-mail: pennycooksj@ornl.gov

The successful correction of lens aberrations has greatly advanced the ability of the scanning transmission electron microscope (STEM) to provide direct, real space imaging at atomic resolution [1]. Very complementary to reciprocal space methods, it is especially advantageous for aperiodic systems, nanostructures, interfaces and point defects.

Al-Co-Ni decagonal quasicrystals provide an excellent illustration of both the benefit of aberration correction in allowing light atom columns to be seen clearly, and in the power of the direct image to reveal broken symmetry within the 2-nm clusters, the origin of the quasiperiodic real space tiling [2].

Nanocrystals exhibit structures and properties with no relation to the bulk, for example the room-temperature catalytic activity of nanosized Au or the white-light emission from nanosized CdSe. Real space imaging combined with density functional calculations can unravel the origin of such surprising properties.

Aberration corrected STEM images can provide (projected) atomic coordinates with precision of a few pm. While not comparable to that achievable with reciprocal space methods, real-space imaging can provide such data unit cell by unit cell across an interface. Examples will be shown of $BiFeO_3$, mapping polarization and lattice parameter direct from a Z-contrast image, mapping octahedral rotations across interfaces with electrodes and finding evidence for interfacial charge [3]. EELS also can provide independent indication of interfacial charge transfer, and examples will be presented from complex oxide heterostructures illustrating how the origin of interfacial conductivity can be revealed [4].

The aberration-corrected STEM can also be used to provide depth resolution. Although not at the atomic level, the interior of a Si nanowire can be imaged free from any surface influence, and several Au point defect configurations have been revealed [7].

Finally, the direct imaging and identification of point defects in monolayer BN [8] and graphene will be presented, including the observation of local changes in dielectric function through single atom EELS.

[1] S. J. Pennycook, in *Scanning Transmission Electron Microscopy*, eds. S. J. Pennycook and P. D. Nellist, Springer, pp 1-90, **2011**. [2] E. Abe, Y. F. Yan, and S. J. Pennycook, *Nature Materials* **2004,** *3*, 759-767, [3] H.J. Chang, S.V. Kalinin, A.N. Morozovska, M. Huijben, Y.-H. Chu, P. Yu, R. Ramesh, E.A. Eliseev, G.S. Svechnikov, S.J. Pennycook, A.Y. Borisevich, *Adv. Mater.,* **2011,** *23,* 2474-2479, [4] J. Garcia-Barriocanal, A. Rivera-Calzada, M. Varela, Z. Sefrioui, E. Iborra, C. Leon, S.J. Pennycook, J. Santamaria, *Science,* **2008,** *321,* 676-680, [5] S.H. Oh, K. van Benthem, S.I. Molina, A.Y. Borisevich, W.D. Luo, P. Werner, N.D. Zakharov, D. Kumar, S.T. Pantelides, S.J. Pennycook, *Nano Lett.,* **2008,** *8,* 1016-1019, [8] O.L. Krivanek, M.F. Chisholm, V. Nicolosi, T.J. Pennycook, G.J. Corbin, N. Dellby, M.F. Murfitt, C.S. Own, Z.S. Szilagyi, M.P. Oxley, S.T. Pantelides, S.J. Pennycook, *Nature,* **2010,** *464,* 571-574.

Keywords: STEM, real-space imaging, aberration correction

KN19

Acta Cryst. (2011) A**67**, C12

Life at the single molecule level

Xiaoliang Sunney Xie, *Department of Chemistry and Chemical Biology, Harvard University, Cambridge, MA, (USA).* E-mail: xie@chemistry.harvard.edu

In a living cell, gene expression—the transcription of DNA to messenger RNA followed by translation to protein—occurs stochastically, as a consequence of the low copy number of DNA and mRNA molecules involved. Can one monitor these processes in a living cell in real time? How do cells with identical genes exhibit different phenotypes? Recent advances in single-molecule imaging in living cells allow these questions to be answered at the molecular level in a quantitative manner [1-4]. It was found that low probability events of single molecules can have important biological consequences [5].

[1] Yu et al. *Science* **2010***,* 311, 1600. [2] Cai et al. *Nature* **2006,** 440, 358. [3] Elf et al. *Science* **2007**, 316, 1196. [4] Taniguchi *et al. Science* **2010***,* 329, 533. [5] Choi et al. *Science* **2008***,* 322, 442

Keywords: single molecule, gene expression, imaging

KN20

Acta Cryst. (2011) A**67**, C12-C13

From plane groups to quasilattices: Hispano-Islamic art of the Alhambra, Cordoba and Sevilla

Emil Makovicky, *Department of Geography & Geology, Univ ersity of Copenhagen*. Email: emilm@geo.ku.dk

The palaces of the Alhambra in Granada, the Royal Alcázar of Sevilla and the Great Mosque of Cordoba are treasures of Hispano-Islamic art, spanning several centuries, since about 780 to post-reconquest times of so-called Mudéjar art. The non-representative ornamental art applied to adorn this architecture developed over time from plane group-based ornaments through the interlaced and/or dichroic as well as polychromatic versions to intricate octagonal and decagonal quasilattices. The colourful brick-and-marble ornaments of Cordoba astonish us primarily by the intricate pattern-construction methods. The fact that 80% of the plane group patterns (especially the mosaics) in the Alhambra belong to *p*4*gm*, *cm* and *cmm* does not detract at all from their large variety and beauty. As elsewhere in the Islamic world, interlacing of the original mesh boundaries was frequently applied, either imaginary on the walls and in the mosaics or real, in openwork trellis. Layer groups must be applied to these patterns so that, for example, the familiar *p*6*mm* becomes *p*622 on interlacing. Another form of interlacing are the modular wooden ceilings in the Alhambra and the white quasiperiodic lattices in the Alhambra and Sevilla. About one half of the magnificent stucco ornaments on the walls and tympana of the patios of the Alhambra are interlaced, most often as interlacing of two different motifs, each with its own layer symmetry, e.g. the interlaced arch pattern *p*2*an* can be combined with the filling pattern which has *cm* or *p*211 as the plane/layer group of symmetry.

Dichroic mosaics were favoured by the Islamic artisans and they served as a basis for their special ways of constructing polychromatic patterns. One of them was to leave the white tile subset of the dichroic stage untouched and apply a colour modulation wave only to the black tile subset. Similar was the application of a concept of ‘colour supertiles’ to the latter subset, often as if interference of colour waves from two directions. The most sophisticated approach created what we can call ‘sequentially dichroic patterns’, when a new dichroic colouring was applied to the ‘black’ subset of the previous dichroic stage; this could be repeated several times. Perfect colouring as we know it was not used, the shimmering white subset appears to have been essential.

Creation of quasiperiodic octagonal and decagonal mosaic patterns in the 14th century can be considered as pinnacles of the Hispano-Islamic ornamental art. In these colourful cartwheel patterns, white interlacing describes Ammann-type quasilattices, with quasiperiodic sequences of unit and $\sqrt{2}$ intervals in the octagonal case and similar sequences of unit and τ (i.e., $(1+\sqrt{5})/2$) intervals in the decagonal case. The rosette- and star-studded quasiperiodic octagonal patterns adorn