through its scattering from near-neighbour atoms, with the unscattered part being used as the reference wave (part *b* in the figure). Suitable sources are core photoelectrons, X-rays emitted in core-level fluorescence processes, and γ-rays emitted by atomic nuclei. This idea was initially expanded on for the case of photoelectrons[4,5], and it has now been applied in several forms to surface studies[6–14].

Electron holographic methods have already become useful for minimizing trial-and-error searches in some aspects of surface structure determinations. But what of holography with X-rays, which are expected to scatter more ideally and thus provide more accurate atomic images? The potential for local-source X-ray holography has already been discussed from a theoretical point of view[15,16], but it is only with the work of Tegze and Faigel[1] that the method has been given the first exciting experimental realization.

The authors exposed a single crystal of the perovskite $SrTiO_3$ to X-rays from a standard source at about 17.4 keV to generate fluorescent X-rays from the strontium atoms in the crystal at about 14.1 keV (corresponding to an atomic-scale wavelength of 0.88 Å). Fluorescence X-rays are sufficiently monoenergetic to produce a holographic interference pattern. The hologram was recorded by rotating the crystal and the detector to measure the intensity profile at 14.1 keV over a large solid angle above the surface (part *b* in the figure).

The strontium atoms in this crystal all occupy the same lattice position, so the outgoing X-rays probe geometrically identical local atomic neighbourhoods and the final hologram is thus a sum of identical holograms for all the strontium atoms in the lattice. Although there is some scattering from titanium and oxygen atoms, scattering from strontium is much stronger because of its higher atomic number (38), so the holographic image should show, to first order, a cubic array of strontium atoms.

One negative aspect of using X-ray scattering is that the diffraction effects are weak, being only 0.1% of the total intensity or less (compared with perhaps 50% for electrons). In spite of this difficulty, Tegze and Faigel were able to measure approximately 0.3% X-ray diffraction effects. Measured intensities were inverted mathematically to form an atomic image, using a Fourier transform-like procedure from optics known as the Helmholtz–Kirchoff formula[4]. The first local-source X-ray holographic images resulting from this procedure are shown on page 51 of this issue.

By choosing to excite a certain ray fluorescence preferentially (for example with a tunable synchrotron radiation X-ray source) it should be possible to probe the atomic neighbourhood of each type of atom in a multi-component material or molecule. Because synchrotron sources are much brighter than ordinary X-ray tubes, and are getting brighter all the time, it will be possible to reduce the counting times needed to measure weak diffraction patterns accurately and to study atoms that are present in much lower concentrations. With sufficiently fast next-generation detectors one might think of studying the local environment around dopant atoms in semiconductors or metal atoms at active sites in biological molecules.

Localized sources of γ-rays from nuclear decay would produce even stronger scattering and diffraction effects involving the nucleus, and would be sensitive to magnetic or chemical effects via small shifts in γ-ray energy from emitter to scatterer.

One difficulty with the method is the presence of strong Bragg diffraction effects known as Kossel lines, which can appear at certain directions even in the fluorescence X-ray emission pattern, but these effects are expected to have a much sharper angular profile than the local-neighbourhood hologram, and so could be simply filtered out[15]. A second problem is the presence of twin images, which might confuse the interpretation through overlaps and destructive interference[15,16], but this could be solved if some way is found of obtaining local-source X-ray holograms at several energies[5,16]. □

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1. Tegze, M. & Faigel, G. *Nature* **380,** 49–51 (1996).
2. Gabor, D. *Nature* **161,** 777–778 (1948).
3. Szöke, A. in *Short Wavelength Coherent Radiation: Generation and Applications* (eds Attwood, D. T. & Bokor, J.) 361–467 (American Institute of Physics, New York, 1986).
4. Barton, J. J. *Phys. Rev. Lett.* **61,** 1356–1359 (1988).
5. Barton, J. J. *Phys. Rev. Lett.* **67,** 3106–3109 (1991).
6. Saldin, D. K. & de Andres, P. L. *Phys. Rev. Lett.* **64,** 1270–1273 (1990).
7. Harp, G. R., Saldin, D. K. & Tonner, B. P. *Phys. Rev. Lett.* **65,** 1012–1015 (1990).
8. Thevuthasan, S. *et al. Phys. Rev. Lett.* **67,** 469–472 (1991).
9. Thevuthasan, S. *et al. Phys. Rev. Lett.* **70,** 595–598 (1993).
10. Tong, S. Y., Li, H. & Huang, H. *Phys. Rev. Lett.* **67,** 3102–3105 (1991).
11. Tong, S. Y., Li, H. & Huang, H. *Phys. Rev.* B**51,** 1850–1854 (1995).
12. Wu, H. & Lapeyre, G. J. *Phys. Rev.* B**51,** 14549–14553 (1995).
13. Terminello, L. J., Barton, J. J. & Lapiano-Smith, D. A. *J. Vacuum Sci. Technol.* B**10,** 2088–2091 (1992).
14. Terminello, L. J., Barton, J. J. & Lapiano-Smith, D. A. *Phys. Rev. Lett.* **70,** 599–602 (1993).
15. Tegze, M. & Faigel, G. *Europhys. Lett.* **16,** 41–46 (1991).
16. Len, P. M., Thevuthasan, S., Fadley, C. S., Kaduwela, A. P. & Van Hove, M. A. *Phys. Rev.* B**50,** 11275–11278 (1994).

DAEDALUS

Simple tastes

SPICES were once the most craved of products. For centuries they were the main, highly lucrative, export from Asia to Europe. This is hard to understand these days. Possibly the basic European diet was so bland and boring that almost any price was worth paying to liven it up; more likely, it was always on the edge of putrefaction, and disguise was desperately needed. This strategy, says Daedalus, is chemically simplistic. What is needed is not more additions, but judicious subtraction. He recalls that a poor red wine can be strikingly improved by filtration through activated charcoal, which removes the tannins and coarser flavours. Probably the finest cooking owes its delicacy not to what is present, but what is absent.

So DREADCO biochemists are seeking to identify the key flavour components of bad cooking. They are heroically patronizing 'greasy spoon' restaurants, ancient school refectories and the staff canteens of failing companies, while DREADCO's cooks do their own worst with the oldest and nastiest ingredients. With luck, these essays in culinary disaster will reveal a common chemical motif. A few crucial trace components, perhaps specific smelly amines and thiols from oxidation or bacterial attack, will dominate most of the worst flavours.

The team will then devise a chemical antidote, to sequester and inactivate these compounds. Subtle and delicate chelating agents will probably not work. To withstand the rigours of cooking, an absorbent as stable and robust as activated charcoal will be needed. DREADCO chemists are modifying selected charcoals by incorporating molecular sieve minerals and adding selectively reactive side chains.

DREADCO's 'Antispice' will resemble a fine black pepper. Added to the ingredients, it will raise the tone and appeal of any meal. It may not lift it to the heights of the best cordon-bleu artistry; but it will certainly rescue it from mediocrity, and even from the depths of disaster. It will be welcome in the best kitchens, and even more welcome in the worst ones.

But Daedalus goes further. These days many consumers are very fearful of nasty chemical additives in their diet. So for dedicated diet-worriers, the DREADCO team is seeking a range of 'subtractives' to sequester and neutralize artificial colouring, anti-oxidants, monosodium glutamate, cholesterol, salt and so on. Sadly, a subtractive to absorb all fats would be a major component of the meal in itself; and even Daedalus cannot dream up a simple way of selectively absorbing all calories. David Jones