Editorial

Point electron sources and their applications

Electron microscopy meetings offer regular opportunities to present and discuss various fields at the frontiers of the technique. In these early nineties, following the regular evolution and progress in analytical electron microscopy and high resolution electron microscopy, after the emergence of a whole family of microscopes without lenses, after the confirmation of the essential contribution of computers, what is to be scrutinized?

While preparing the 1991 French-Iberic meeting, it was decided to devote a dedicated symposium to the subject "Point electron sources and their applications", which constitutes one of the promising routes where important and useful developments are to be expected during the next years. As a matter of fact, all new instruments with high spatial resolution rely on the availability of tiny and bright sources of electrons. It concerns as well high energy electron beams used in columns of electron lenses, as scanning tunneling microscopes with currents of sub-eV electrons tunneling from the atomic sites at the apex of a metal tip to the specimen surface. To review the latest developments in this domain, the organizers of the symposium, A. Baro from Madrid and myself, have invited recognized experts to cover various aspects of the subject. These few lines intend to summarize some of the highlights of the very stimulating session which took place during the Barcelona meeting, in the beginning of July.

High brightness electron beams, issued from field emission sources and accelerated to a few tens and recently to a few hundreds of keV, have been available for more than two decades, following the pioneering work of Crewe and collaborators. These electron beams have mostly been used for two major applications: subnanometer electron probes and electron holography. Electron holography requires very coherent sources and highly collimated beams (of the order of 10^{-8} rad) for specimen illumination. The off-axis mode is now considered to be the most suitable approach towards a useful electron beam holography because it eliminates the overlap between reconstructed images. Practically an electron biprism is introduced in the microscope column in order to superpose, in the image plane, the beam scattered by the object and a reference wave. The resulting interference pattern, consisting of up to a few thousand fringes, stores the phase information and is further magnified by electron lenses and recorded as the hologram. Actually digital processing is now used for reconstruction: it has been shown to be more flexible and to open new possibilities, such as the direct display of phases (with an accuracy which may reach $2\pi/100$) and amplitudes. A. Tonomura (Hitachi Ltd., Japan) has first beautifully described how this technique can be used to see the electromagnetic field, with a sensitivity permitting the clear visualization of flux quanta emerging from the surface of superconductors. Their most recent technique of recording and processing video holograms has also been demonstrated, so that one could follow in real time, the dynamics of flux lines under applied magnetic fields.

The second great challenge for electron holography is the correction of the electron microscope aberrations, as studied by H. Lichte and his coworkers at Tübingen (Germany). These authors have shown theoretically how the aberration function can be removed. The stringent requirement is that the carrier fringe spatial frequency must be three times larger than the maximum spatial frequency of the object. Consequently, to correct aberrations to 0.1 nm, the fringe spacing must be smaller than 1/30 nm. First experimental results in this direction have been shown and they confirm the validity of the approach. Further progress require higher energy, higher brightness electron beams.

The other great domain of application of field emission electron sources is for the production of small probes. The situation is well known for the case of the dedicated STEM, and its superb possibilities in point analysis with subnanometer spatial resolution. E. Munro (London, UK) has described the theory for designing combined sources and focusing lenses assemblies and optimizing the performance of versatile illumination systems, such as for low voltage SEMs, nanolithography and electron beam testing devices.

But what about future sources and novel applications? These questions were addressed during the second part of the symposium, where the cross fertilization between different techniques has become evident. The requirements for a better processing and characterization of tunnel tips for STM in particular, has induced developments, the consequences of which are unpredictable but will likely extend to unforeseen domains. And this is particularly stimulating for the future. What became also obvious during these presentations is the multinational effort which is put into these programs, more particularly at the european level. It has been demonstrated through the presentations of experimental results by V.T. Binh (Lyon, France) and theoretical models by J. Saenz (Madrid, Spain) concerning the most recent coherent electron sources made from the few atoms at the apex of nanometric protrusions. Groups from Lyon, Madrid, Cambridge, Bologna are involved in this highly promisive program.

A last contribution by R. Morin (Marseille, France) has dealt with another use, which is not strictly original, of these new point sources, i.e. for projection microscopy. It only requires an object located at a few micrometers and raised at a few hundred eV in front of the tip, and a 2D channelplate detector behind it. The resolution is mostly determined by the size of the source, so that the introduction of atomic size sources of low energy electrons has permitted remarkable progress. As shown by H. Fink and his coworkers (IBM Zürich, Switzerland) who pioneered this type of development, one can record Fresnel type images with some phase preservation similar to an hologram. Much work is yet to be devoted to the applications of this technique because contrast formation with such low energy electrons presents specific aspects.

In conclusion, it was a very stimulating session and I am sure that many of the attendees have come out with the conviction that the technology of sources will progress and offer new unpredictable possibilities for all kind of microscopies.

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