XRM 2005 – Conference Summary

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X-ray microscopy is at a state of rapid development. The presentations at the Conference covered the latest developments in the field.

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XRM 2005 set a new record in attendance, and in the number of papers presented at the Conference. Figure 1 shows the history of this series of meetings in terms of the number of papers published in the proceedings, or the attendance where available.

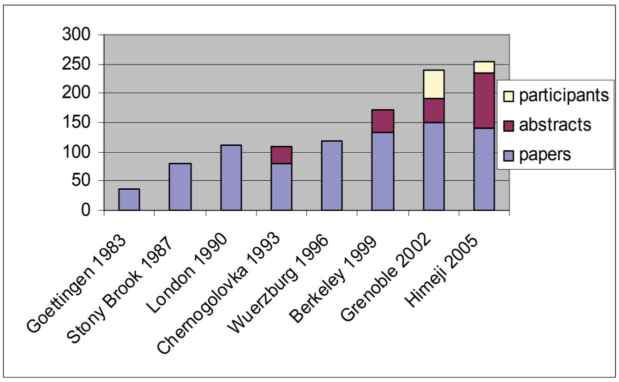

Figure 1. Growth of XRM Conferences

In my view the numbers do not really represent the true extent of the growth in the field. This Conference demonstrated remarkable growth in the field over a broad front. Hard X-ray microscopy in particular has made major strides. There were so many new results presented, that their enumeration was not possible within the time available

A critical parameter in any microscopy is the resolution. We have seen major advances toward the goal of reaching the molecular scale using several techniques. Zone plates remain the most widely used focusing elements, and the best reported resolutions with soft X-rays have reached the 15 nm level, while in the hard X-ray range the record is around 25 nm. Recent results using a multilayer Laue lens are at the 30 nm level using 19.5 keV radiation. I would not have imagined this much progress on such a short time scale.

Using Kirkpatrick-Baez mirrors, a resolution of 36 x 48 nm has been demonstrated – a truly impressive advance! Refractive lenses with 55 x 47nm resolution are not far behind. We heard an interesting discussion regarding the ultimate limits for resolution achievable by optical elements. It will be fascinating to see how fast the 10 nm level will be reached, or surpassed.

Other approaches to high resolution use electron optics, as in the PEEM instrument, and there is substantial progress here as well. Several presentations discussed imaging without optical elements, and we have seen impressive reconstructions from oversampled diffraction patterns in two and three dimensions.

In general there was much discussion about the move toward three dimensional imaging. The third dimension is often spatial, as in tomography, but there is also much work done where the third dimension is the energy of the illuminating or the detected X-rays or the detected electron. These forms of spectromicroscopy provide much chemical, elemental, or electronic structure information at high spatial resolution.

At this Conference there was a significant amount of exciting new work reported where time is the third dimension. This included stroboscopic and pump/probe approaches in the picosecond to microsecond time frame, as well as the observation of slower processes that occur over minutes or hours. Other work involved crystallinity, strain or orientation as the third dimension. Overall I see this as an area of rapid growth, and more dimensions are likely to be explored before the next conference.

The contrast mechanisms exploited in X-ray microscopy have been established before. Bright field, dark field, Zernike, differential and Nomarsky phase contrast, magnetic dichroism (both circular and linear), chemical, elemental, and strain contrast were all represented in the contributions. With the increasing number of hard X-ray efforts, phase contrast has received special attention, since absorption contrast in bright field is quite limited at the higher energies.

At this Conference there was considerable discussion regarding ways to exploit the data in the micrographs, and about strategies to optimize the information. The use of the Transport of Intensity equation has been demonstrated, as well as techniques of Principle Component analysis combined with Cluster Analysis. Various iterative reconstruction techniques have been discussed especially for 3D reconstruction of relatively thick specimens. A welcome development is the initiation of shared software to do some of this sophisticated analysis.

The range of applications is wide. It includes biology, medical radiology, environmental science, geochemistry, meteoritics, nanoscience, polymer science, magnetism, archeology, and industrial applications such as the analysis of electromigration, or the inspection of computer chips.

Are we in a position to gauge the impact of X-ray microscopy today? I believe that we are, and that we can assert that with this Conference X-ray microscopy has become "mainstream". There are at this point multiple microscopes operating at all major light sources around the world. There is a lot of effort (and considerable progress) towards developing smaller scale alternatives that would be suitable to be placed in the laboratories of individual microscopists. X-ray microscopy is being used in combination with visible light, infrared and electron microscopes to solve problems that could not be solved without the special attributes of X-rays. There are X-ray microscopes and components commercially available, and in considerable demand. This Conference has had a substantial vendor show – a sure sign of "mainstream" status.

Another sign of "mainstream" status is that the number of papers on applications outnumbered the number on instrumentation. Yet we are not yet in the state of "maturity" that would make the instrumentation aspects less than exciting. This is a wonderfully rewarding period in the development of our field!

Acknowledgments

I want to express my deep appreciation to the organizers of the Conference for putting together a most exciting and enjoyable meeting. Organizing and running a conference of this size and scope is a large undertaking, that was carried out with exemplary skill and professionalism.

My participation was supported by the US Department of Energy.

Figure 2. Prof Aoki and some of the other organizers. (from the Conference web site)