SOME CURRENT AND FUTURE TRENDS OF HIGH VOLTAGE TRANSMISSION ELECTRON MICROSCOPY

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The Optimum Voltages for Electron Microscopy - The advantages of high voltage electron microscopy are now well established, and many applications, such as use of environmental cells both in metallurgy and biology, are now possible. However recent experiments at Toulouse (1) indicate that except for light elements, there is no appreciable gain in transmission for a given resolution level as the energy is increased above 1 MeV (see Fig. 1). These results are not as optimistic as theory might indicate (2). Special effects such as critical voltages above 1 MeV are of interest, but knock-on radiation damage imposes limitations on many applications. Thus it would appear that 1 MeV is a reasonable upper limit for most applications in materials science.

In organic and biological materials, whilst high resolution is not always a requirement, and thick sections can be examined so as to obtain three dimensional configurations thereby reducing the tedium of serial sectioning, the difficulties of radiation damage severely limit observations. For example, in order to achieve 10Å resolution, the current density incident upon the specimen required to form a detectable image is 10^{-3}A cm^{-2} at a magnification of 10^5. At this intensity level, however, many organic materials are destroyed before an image can be photographed. For example, the critical dose for 1-valine at 650kV is $\approx 10^{-3}$ coul/cm^2 and so 10Å resolution is impossible (3).

Some hope for improvements may come from ultra high voltage microscopy, and it is already clear that 3MeV is advantageous over 1MeV. There is a critical need for more data on radiation damage in order to determine the optimum voltage, always assuming that high voltage stability will be good enough for the high resolutions desired (for 5Å about 2 parts per 10^6 volts is needed).

At the present time, plans exist in Japan for the construction of a 10MeV electron optical instrument and there are 3MeV microscopes only in Toulouse and Osaka. In the USA, the highest energy microscope appears to be 1.2MeV.

Examples of Some Current Research Projects at Berkeley - Many beam interactions become important at high voltages. Besides the phenomenon of critical voltages, many beam effects account for the increase in resolution of lattice defects when imaged in bright field at ng s>0, where ng is the nth order of the systematic set of reflections g (4). Recent work has shown that there is an optimum diffracting condition for resolution. Fig. 2 shows examples for defects in Si. The dark field weak beam images are all in $\bar{2}20$ with ng satisfied.

Further work is continuing on the analysis of faulting and ordered domain structures (for work on lithium spinel see the paper by O. van der Biest in these proceedings). Fig. 3 shows examples of observed domain boundaries in anorthite from lunar breccia 15459. Fig. 4 shows a 6-beam systematic calculation for c antiphase domain boundaries (5). Comparison between observed domains and such calculations have confirmed that the APB vectors are of the type 1/2 [110] for b domains and 1/2 [111] for c domains.

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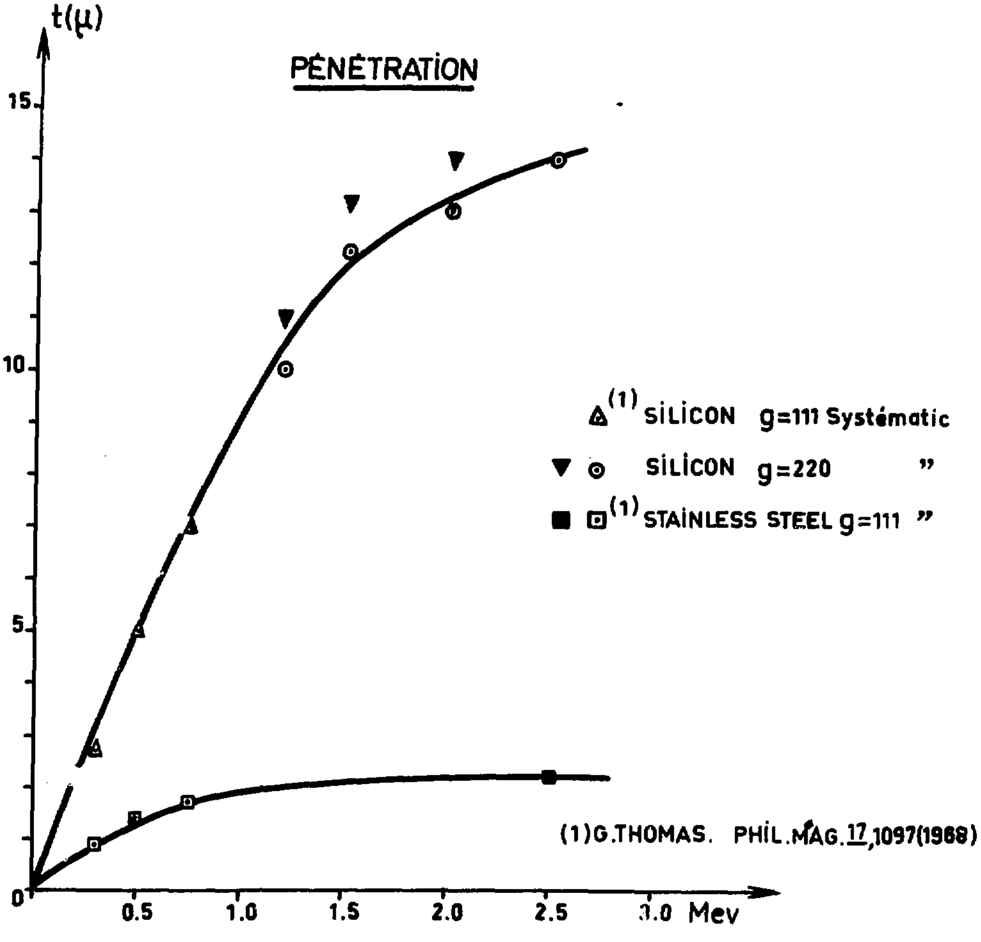

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Fig. 1 Penetration for Al and stainless steel
vs kV (ref. 1).

a b c d

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Fig. 2. Bright and dark field weak beam images of ion implanted defects, a) $g = 2\bar{2}0$ b) $g = 3.4, \overline{3.4}, 0$ c) $g = 4\bar{4}0$ d) $g = 6\bar{6}0$. Best resolution e.g. defects A,C, is for $g = 4\bar{4}0$. 650 kV (L. Chen and G. Thomas).

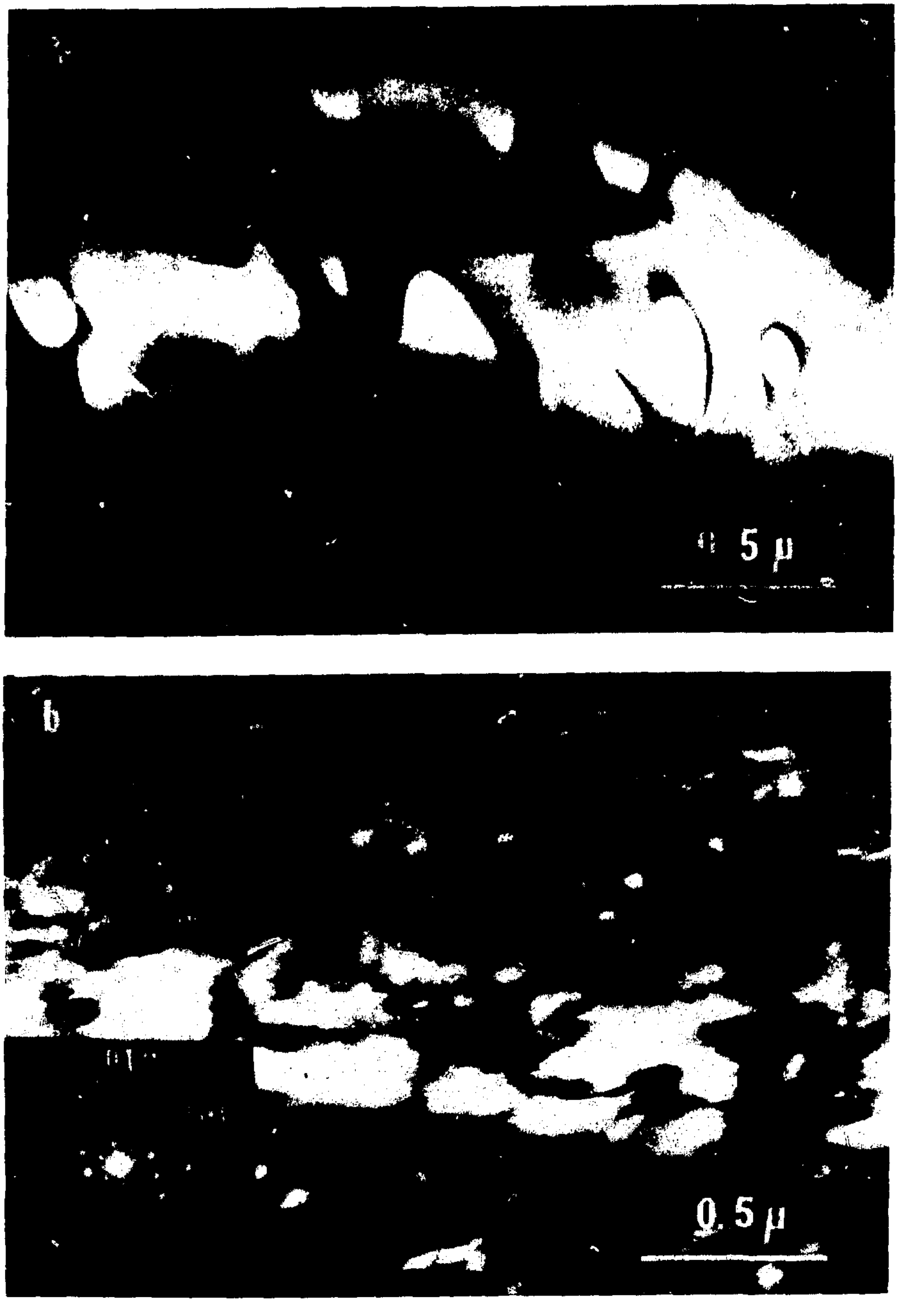

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Fig. 3. APSs in lunar anorthite (An 92.5) a) type c APBs dark field images 650 kV (ref. 5).

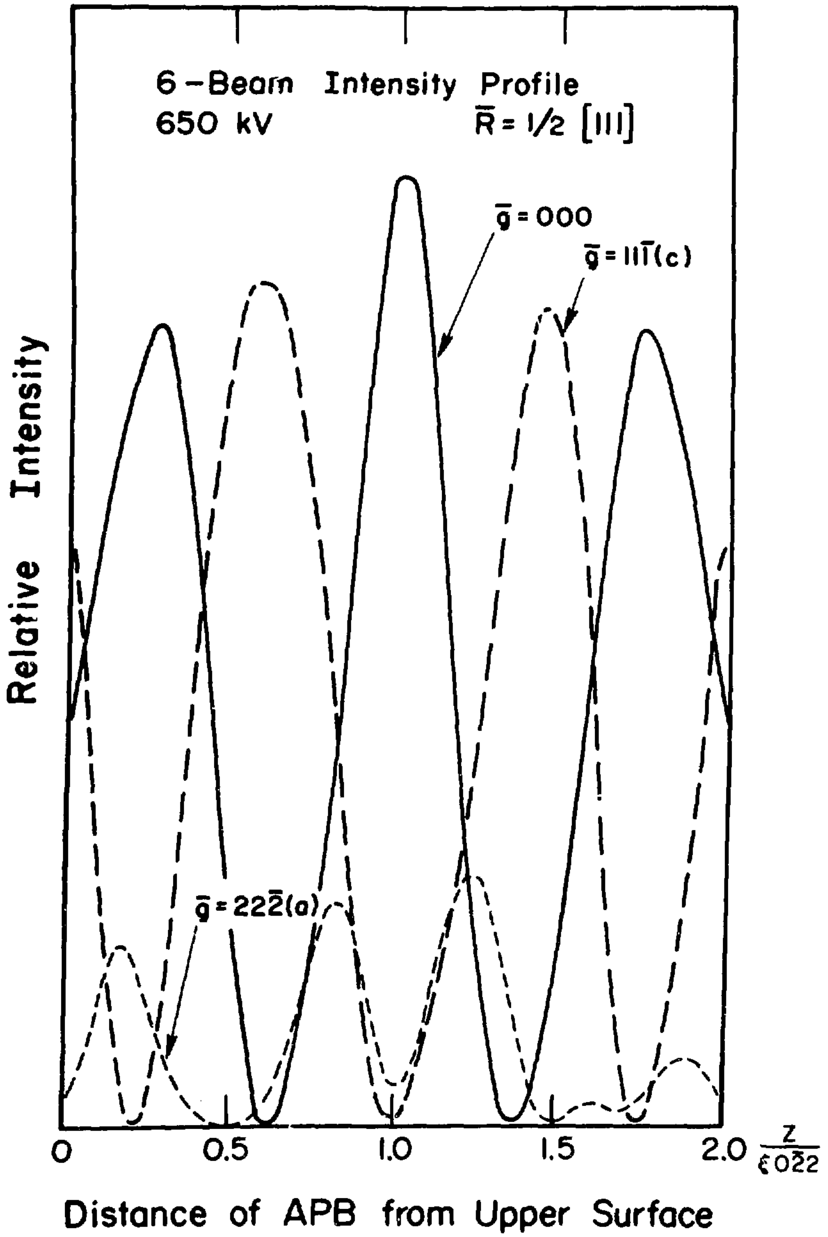

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Fig. 4. 6 beam computer calculation for c type APB bright and dark field profiles for 11$\bar{1}$c and 22$\bar{2}$c type reflections are shown. Foil thickness = 2 g ≅ 1.2μ. Dynamic interactions are responsible for APB visibility in 22$\bar{2}$ images even though g · R = 1 in this case (ref. 5).