MANUFACTURERS' CORNER

The HF-2000, a cold field emission transmission electron microscope

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In modern materials science such as for high T_C superconductors, semiconductors and magnetic materials as well as for biology, research objects have become very small, to a level of molecules, atoms and their associated arrangements. It has become necessary to examine these details and analyse them.

In response to these requirements, many innovative designs have been incorporated into TEMs such as electron optical lenses of smaller aberrations, higher accelerating voltages, stable columns and stages free from vibrations, and better resolving power. Energy dispersive X-ray spectrometers (EDX) and electron energy loss spectrometers (EELS) have also been incorporated in TEMs for elemental microanalysis. However, the electron sources of conventional TEMs are heated tungsten filaments or heated LaB_6 emitters which cannot deliver sufficient electrons into a small probe for microanalysis of 1 nm regions. Much more powerful electron sources have long been required for analytical electron microscopy.

We, at Hitachi, Ltd., have been working on cold field emission electron sources since 1970. These sources have already been successfully applied on many of our scanning electron microscopes (SEMs) which operate at relatively low voltages. We have developed this technology further into TEMs which generally operate at 10 times higher voltages. The HF-2000 is the world's first TEM with a cold field emission electron source that operates upto 200 kV (see Fig. 1).

The HF-2000 allows elemental microanalysis of a small area of about 1 nm in diameter by EDX due to the powerful cold field emission electron source which is 1,000 times as bright as a conventional electron source. It also allows electron diffraction of the same 1 nm area which has been impossible with conventional instruments. This capability is a clear and exciting advance for atomic structure analysis of small crystalline regions composed of a few tens or a few hundreds of atoms, study of grain boundaries and interfaces, compositions analysis of small inclusions and

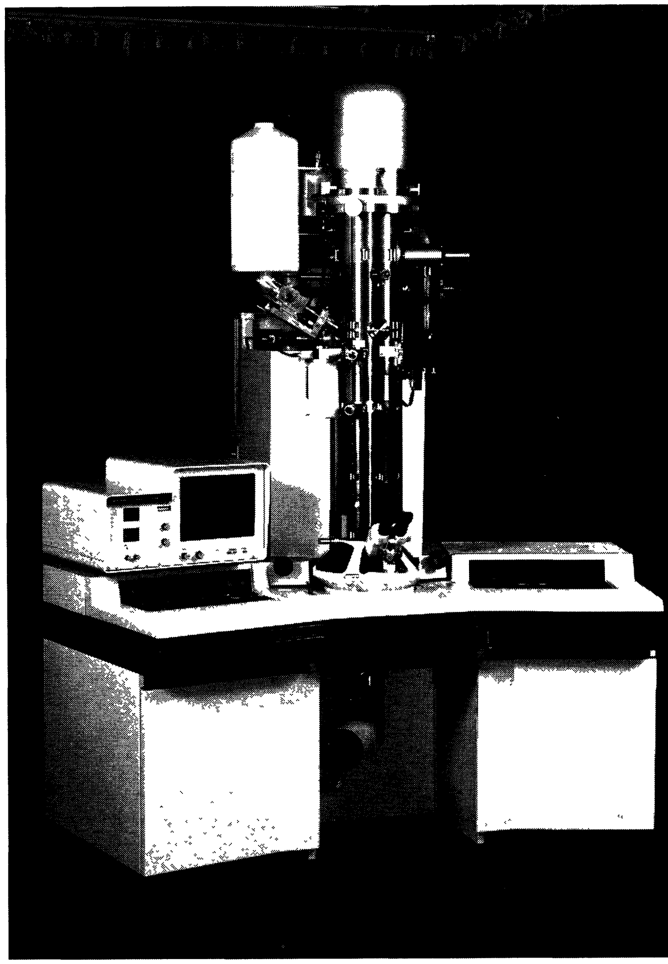


Fig. 1.

precipitates, and basic evaluation and measurement of various materials at the atomic scale. We believe that the HF-2000 will play an important and valuable role in materials science in the very near future.

The cold field emission electron source delivers electrons with a small energy spread (i.e. electron energy is uniform) which assures not only high contrast and high magnification images but also significant improvement in imaging resolution. A high resolution image of 0.062 nm crystal lattice spacing recorded at Hitachi's Central Research Laboratory with a 100 kV cold field emission TEM is the world's highest resolution today. The HF-2000 turns out sharp and crispy crystal lattice images as well as quality contrast images of polymers and biological specimens which normally exhibit poor contrast images. The small energy spread of the beam is best utilized in EELS operation. In addition to conventional chemical compositions, chemical bonding information will be made available with high energy resolution in the EELS spectrum.

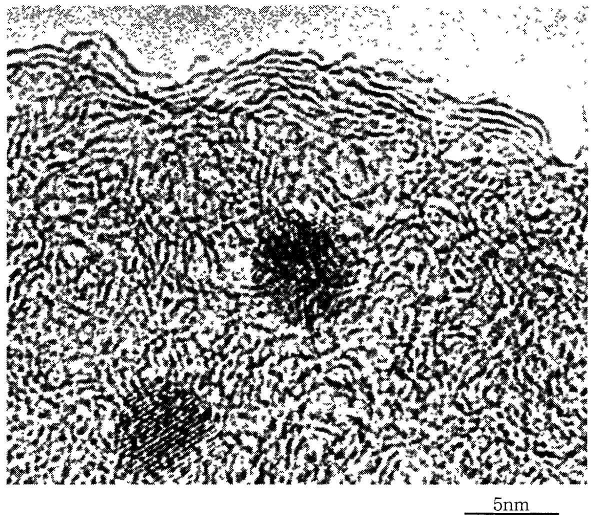
The electron beam from a cold field emission electron source also has excellent coherency which permits electron holography. Electron holography allows detection of phase information from the beam that has transmitted specimen. This technique allows direct examination of small magnetic domains and magnetic flux which have been totally unvisible upto this time. This will allow evaluation of vertical magnetic recording materials and higher density magnetic recording materials. It may also help resolve the mechanisms of superconductivity and assist in developing better materials. In biology, it may be possible to observe DNA and other high polymers without staining using the phase contrast effect in electron holography.

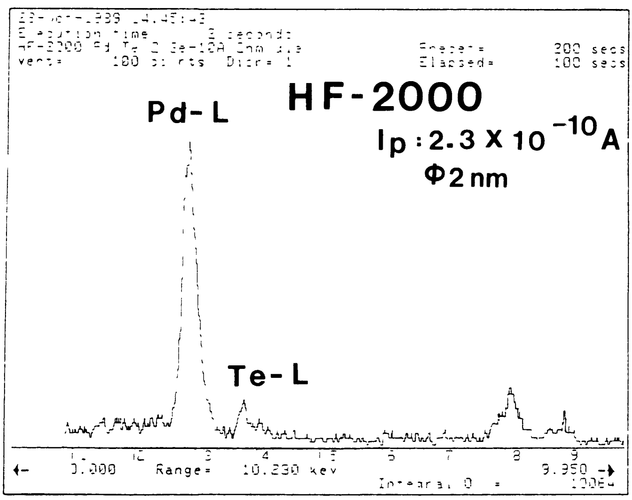
As described above, the cold field emission electron source has made possible a new high resolution analytical electron microscope, entirely different from conventional microscope limitations. We trust that the HF-2000 will be a valuable tool in materials scince, biology and physics.

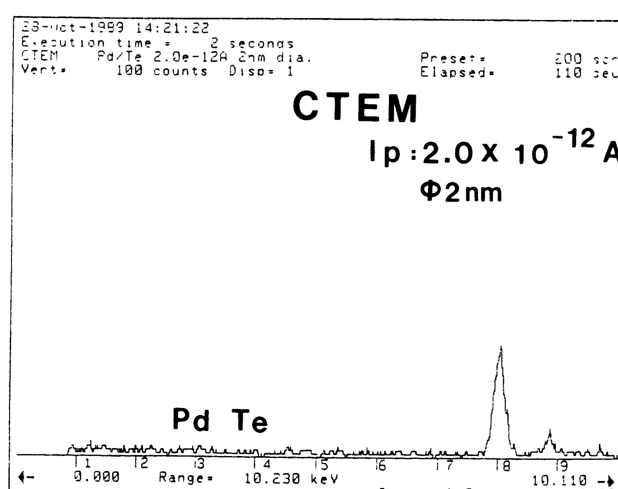
In figure 2, data taken with HF-2000 are shown. Specimen is Pd-Te catalyzer particles of about 5 nm in diameter.

Figure 2a is explaining the difference of analytical sensitivity (signal intensity) between HF-2000 and CTEM. Although probe size is 2 nm with both instruments, CTEM can not generate X-ray spectra of Pd and Te. On the other hand, X-ray spectra taken with HF-2000 are clearly showing Pd and Te thanks to high and stable probe current (Ip).

Figure 2b entitled "Fine Particle Analysis" is showing good spatial resolution in addition to analytical sensitivity. X-ray spectra from the particle "a" and "b" are taken with probe size of about 2 nm in diameter. The results indicate that the particle "a" includes Te, but the particle "b" doesn't. The electron diffraction patterns (upper left and right) are from the particle "a" and "b" respectively





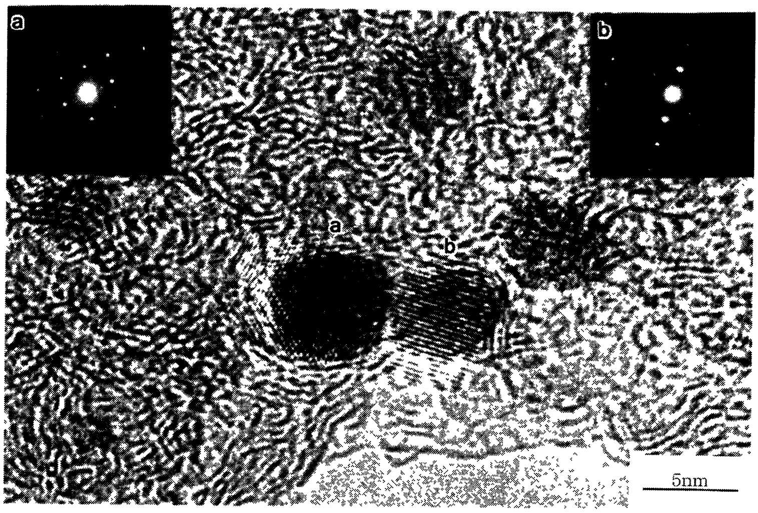


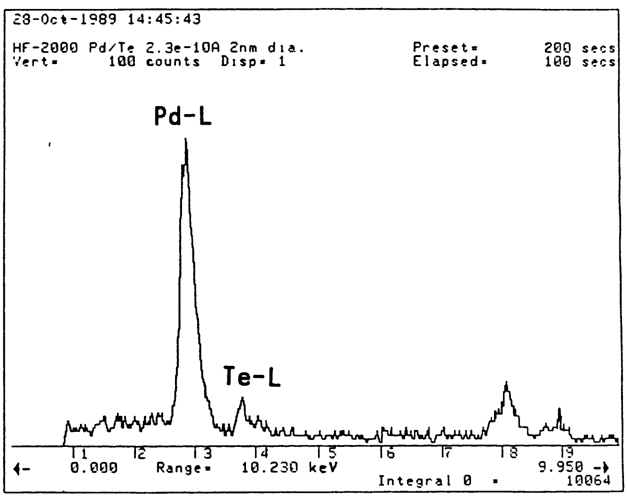
Specimen : Pd/Te particle

Taken with HF – 2000 at 200kV

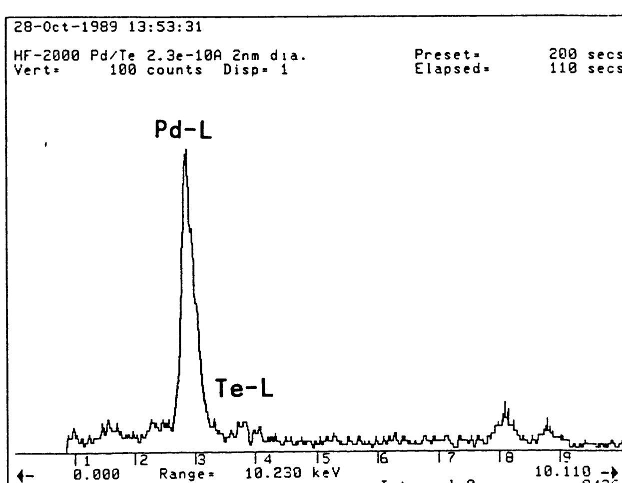
Magnification : 450,000 × 10

Fig. 2a.





(a)



(b)

Fine Particle Analysis
Specimen : Pd/Te particle
Taken with HF – 2000 at 200kV
Magnification : 450,000 × 10

Fig. 2b.