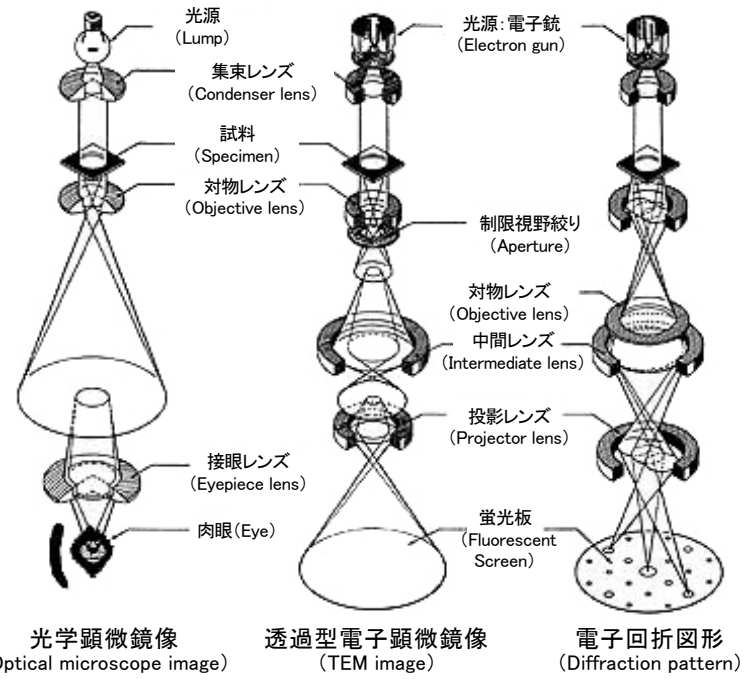
透過型電子顕微鏡
Transmission Electron Microscope (TEM)

基本仕様 / Specifications

日本電子株式会社（JEOL） JEM-2010

- 加速電圧 / Accelerating Voltage : 80-200 kV
- 理論分解能 / Theoretical resolution : 0.194 nm
- フィラメント / Filament : LaB_6
- エネルギー分散型X線分析装置搭載 / Attached with Energy dispersive X-ray spectroscopy (EDX)

基本原理 / Mechanism



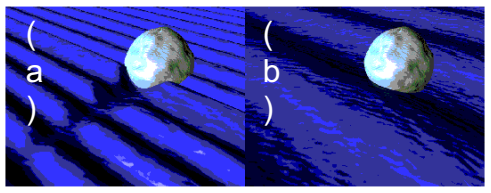


Fig. 1 Ripples caused by the difference in the magnitude of the wave. Wavelength is (a) shorter or (b) longer than size of the rock.

透過型電子顕微鏡は、可視光よりも波長の短い電子線を用いることで、光学顕微鏡では到達できない原子レベルの構造を識別することができます。

電子線は真空中で細いフィラメントの加熱又は、強い電界をかけることで発生する電子の束で、光よりも波長の短い「波」の性質をもっています。この「波」の性質は、池に小石を投げたときに生ずる波紋に例えて説明すると分かり易いことでしょう。池の水面に発生した波紋が水面上に突き出た岩を横切るとき、波の山と山との長さ（波長）よりも大きい岩であれば岩の後ろに波紋は回り込みません（Fig.1）。これが影に相当します。もし、岩が波長よりも小さければ、波紋は岩の後ろまで回りこみ影が出来ません。この事は、岩の存在を認識出来ないことにあたります。実際に人の目に見える光（可視光）の波長は400～800nm（1ナノメータは1mmの100万分の1）です。一方、電子顕微鏡の照明（光源）に用いる電子線の波長は、一般的におよそ0.0037nm（100kV）～0.0025nm（200kV）です。この波長は光の波長よりはるかに短く、原子（1nm未満）の並びまで識別するのに十分と言えます。

さらに、得られる電子回折図形から、結晶性試料内の分子・原子の配列を調べることができます。

TEM can distinguish smaller objects down to atomic level, which is not possible to observe by optical microscope, by using electron beam with shorter wavelength than visible light.

Electron beams are flows of electrons generated in the vacuum by heating or by applying a strong electric field to a fine filament, and have the nature of a “wave”, with a wavelength shorter than that of visible light. The nature of this “wave” may be easily understood by comparing it to the wave pattern arising when a small stone is thrown into a lake. Assume the waves on the water surface come into contact with a rock protruding above the surface. If the rock is larger than the length between the crests of the waves (wavelength), then the wave pattern does not continue behind the rock (Fig,1). This creates a shadow. If the rock is smaller than the wavelength, however, the wave pattern will not be interrupted behind the rock and there is no shadow. In this case, the existence of the rock cannot be detected. Whereas the wavelength of visible light is 400 to 800 nm (1 nanometer is one millionth of 1mm), the wavelength of the electron beam is about 0.0037 nm (100 kV) to 0.0025 nm (200 kV). This wavelength is far shorter than that of light, and sufficient to distinguish the arrangements of atoms (subnanometer level).

Furthermore, the obtained electron diffraction pattern can also reveal the arrangement of molecules and atoms in a crystalline specimen.

https://www.jeol.co.jp/science/em.html

実用例 / Application Examples

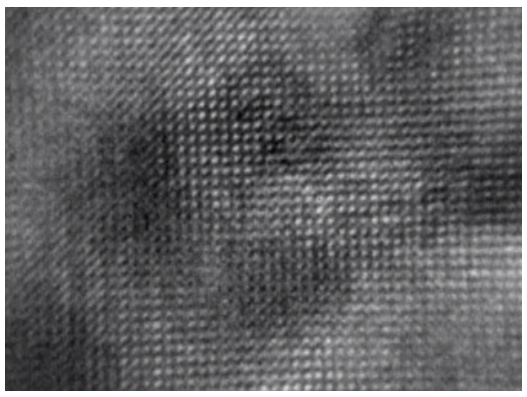


Figure 1 TEM image of Au thin layer. Accelerating voltage: 200kV. Magnification: ×1,000,000.

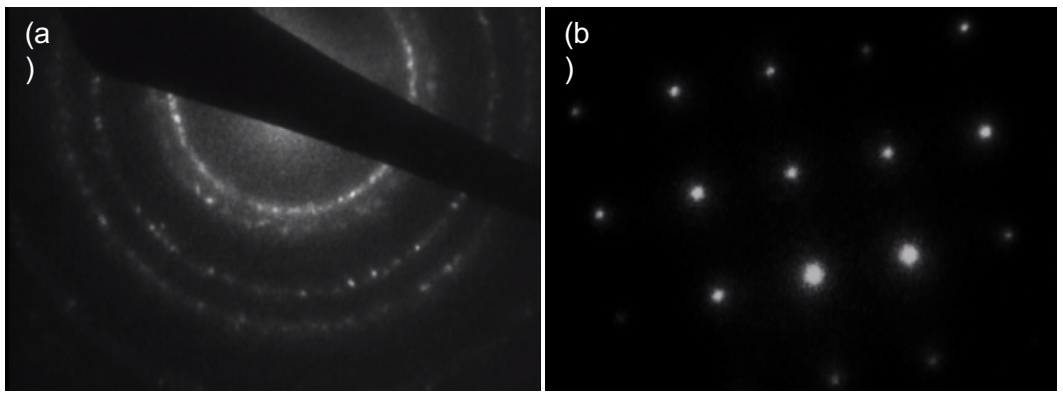


Figure 2 (a) Electron diffraction patterns of (a) NaCl polycrystal (Fcc) and (b) NaCl single crystal ([001] zone axis).

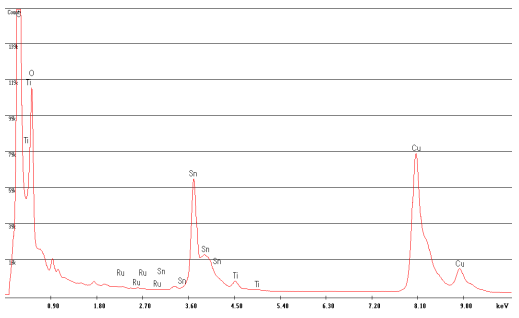


Figure 3 EDS spectrum of Ru-Sn catalyst grafted on TiO2.