MAT\_SCI 360

Introduction to Electron Microscopy

Spring 2023

# TEM Laboratory 3:

**TEM Bright field and Dark field imaging**

### Introduction

This laboratory is designed to introduce one of the basic TEM techniques, bright field and dark field imaging. In this laboratory, you will learn to acquire bright-field, dark-field, especially the central-beam dark-filed images from a single crystal. With a given TEM specimen, at low magnification, the contrast of image is dominated by absorption of electrons, which is called mass-thickness contrast. Diffraction spots in diffraction patterns represent electron beams diffracted to different directions by their corresponding lattice planes, as we learnt in the previous lab. Objective aperture can be applied to select a certain diffraction beam, or several beams, to form an image. Such an image formed by electron beams diffracted to desired directions shows diffraction contrast. When only electrons transmitted forward along the TEM optical axis (without diffraction) are selected (experimentally by selecting only the transmitted spot by using objective aperture), the image formed is called bright filed image. Normally a bright-filed image has better contrast compared to normal TEM image formed without using the objective aperture. When only electrons diffracted to a certain direction (defined by diffraction spots in the pattern) are selected (experimentally by selecting only one diffraction spot or several diffraction spots by using the objected aperture) to form an image. Such an image formed is called dark-field image. Dark-field imaging has many advantages in studying defects, such as dislocations, stacking faults, etc. to reveal subtle microstructural features.

**Learning Objectives:** By the end of this laboratory session, you should be able to:

1. Do bright-field imaging by putting in the objective aperture with right size.
2. Do normal dark-field imaging by selecting a diffraction spot by moving the objective aperture.
3. Do the central dark-field imaging by tilting the beam in the “Dark-Field” mode.
4. Tilt a single crystal inside the TEM by using a double tilt holder to align the crystal to 2-beam condition.
5. Under the 2-beam condition, tilt the beam to center –g in the “Dark-field” mode to acquire central-dark imaging.

**Lab procedure:**

Aims: The aim of this lab is to familiarize you with TEM Bright field and Dark field imaging. This lab covers:

* Simple BF/DF imaging by positioning objective aperture
* BF/CDF imaging under 2-beam condition

TEM: JEOL 2100F TEM

Sample: Al-Ni based superalloy

*Note: It is* ***critical*** *that you check the* ***sample tilts are <<5-10 degrees*** *before beginning the BF/DF portions of this lab, as otherwise they may interfere with the objective aperture.*

1. Simple bright field (BF)/ dark field (DF) imaging by positioning objective aperture

Simple Bright field imaging:

1. Find and center an interesting specimen area.
2. Make sure that the sample is at eucentric height and **BRIGHT** field mode is selected (Std Operation Window).
3. Focus (**BRIGHTNESS**) the beam to crossover and press **SA DIFF.**
4. **C**enter the direct beam of the diffraction pattern if necessary (w/ **PLA**).
5. Insert **OBJECTIVE APERTURE** (which is situated at the back focal plane) into the beam by selecting **OL** and then choosing the aperture size. Note: **One of the 2 apertures should be centered**. If you cannot see the aperture you want to use, do not touch the aperture X and Y controls right away. You should load the second aperture and see if it is near the center. Then you may center this aperture and turn to the first one and center it again. You repeat the procedure until you find the one you want to use.
6. Press **MAG1** to see a bright field image (Now the viewing screen is conjugated to the initial image plane indicated in the figure below).
7. Focus the specimen image using (fine) **OBJ FOCUS** and **OBJ STIG** if necessary.

**Note:** The image has high diffraction contrast now because the objective aperture is in.

* + **Lift screen (F1) and record image by using CMOS camera**

See instruction in TEM room separately



Simple Dark field imaging (by displacing the OBJ aperture):

A dark field (DF) image is formed using a diffracted beam or a group of adjacent diffracted beams. The objective aperture is used to select the diffracted beam by either shifting the aperture or tilting the beam. The transmitted beam is excluded in dark field imaging.

 Tip: It is difficult to focus a DF image. Image focus should be done in BF mode

1. Follow the procedure to form a BF image (IX. 1-7).
2. Focus the beam and press **DIFF**.
3. Take out the **OL APERTURE** and have a look at diffraction pattern.
4. Re-insert the **OL APERTURE** and position it around a diffraction beam.
5. Press **MAG1** to see a dark field image

*Question: The vacuum area is dark and sample area is bright in a DF image. Why?*

1. Adjust **BRIGHTNESS** to open the beam so that the interesting area is homogeneously illuminated.
2. Cover the viewing window.
3. Use CMOS to record a DF image (you may need a long exposure time).

II. Bright/Dark field imaging under 2-beam condition (including centered DF):

1. Make sure that the illumination is centered in both bright field and dark field modes.
2. Find and center a crystalline area and form a convergent beam diffraction pattern from the area. Make sure the diffraction pattern remains the same in **Bright** and **Dark** field modes. If not, adjust the **Beam Tilt** in dark field mode.
3. Check a) and b) till both the illumination and diffraction pattern remain the same when Bright and Dark knobs are pressed alternatively.
4. Form an electron diffraction pattern from an interesting area in **Bright** field mode and center the transmission beam.
5. Tilt the specimen so that the pattern is under or nearly under a required two-beam condition (one transmission disc and one strong diffraction disc **g**).

**Note:** Make sure that tilts are not higher than 5-10 degrees before you insert OL aperture.Your specimen may move during tilting (especially for the second tilt). You should keep the sample at the screen center.

1. For BF: insert the **Obj Aperture**. Check the tilt angles or contact EPIC staff if the aperture does not go in smoothly. In **DIFF** mode, center the aperture around the transmitted spot. Press **MAG1** to see the BF image.
2. For DF: Take out the **Obj Aperture**. Press **DARK** field mode. In **DIFF** mode, adjust **Beam Tilt** to shift the **–g** weak disc to the screen center. **Note:** the **–g** weak disc will become strong one when it is centered. Make sure that the illumination is not shifted when it is tilted.
3. Make sure that the tilts are not higher than **5-10** degrees
4. Insert and center **Obj. aperture**. Press **MAG1** to get a dark field image.

**Tip**: Bright field image can be easily obtained by pressing **BRIGHT** button. Image focus and OBJ astigmatism can again be checked in bright field mode. Press **DARK** button to return to DF image.

**Tip**: If time is allowed, try to record BF/DF images using different g and compare their contrast. Some defects may disappear under certain conditions, which is useful to determine the nature of the defects.

1. Select the correct exposure time to record a few dark field images on the CMOS camera. (The exposure time to record a dark-field image is normally longer than that of a bright field).

### Laboratory Questions:

In your laboratory report you should provide a description of all micrographs taken and concise discussion of differences you see. The handouts and your textbook should be sufficient for you to interpret your results, but you should provide an explanation in your own words. It is recommended to section your report into different sections including Introduction, Experimental, Results, and Discussion etc.

In your Experimental section, you will need to

1). Record one normal TEM image.

2). Record one bright-field and one normal dark-field image showing dislocations.

3). Tilt the crystal to have 2-beam condition; and then tilt the beam in dark-field mode to center the –g spot. Acquire a bright-field image and a central dark-field image showing dislocations, under the 2-beam condition.

**-g** (weak)

O

**+g** (strong)

OBJ APERTURE

OBJ LENS

OBJECT

Incident beam