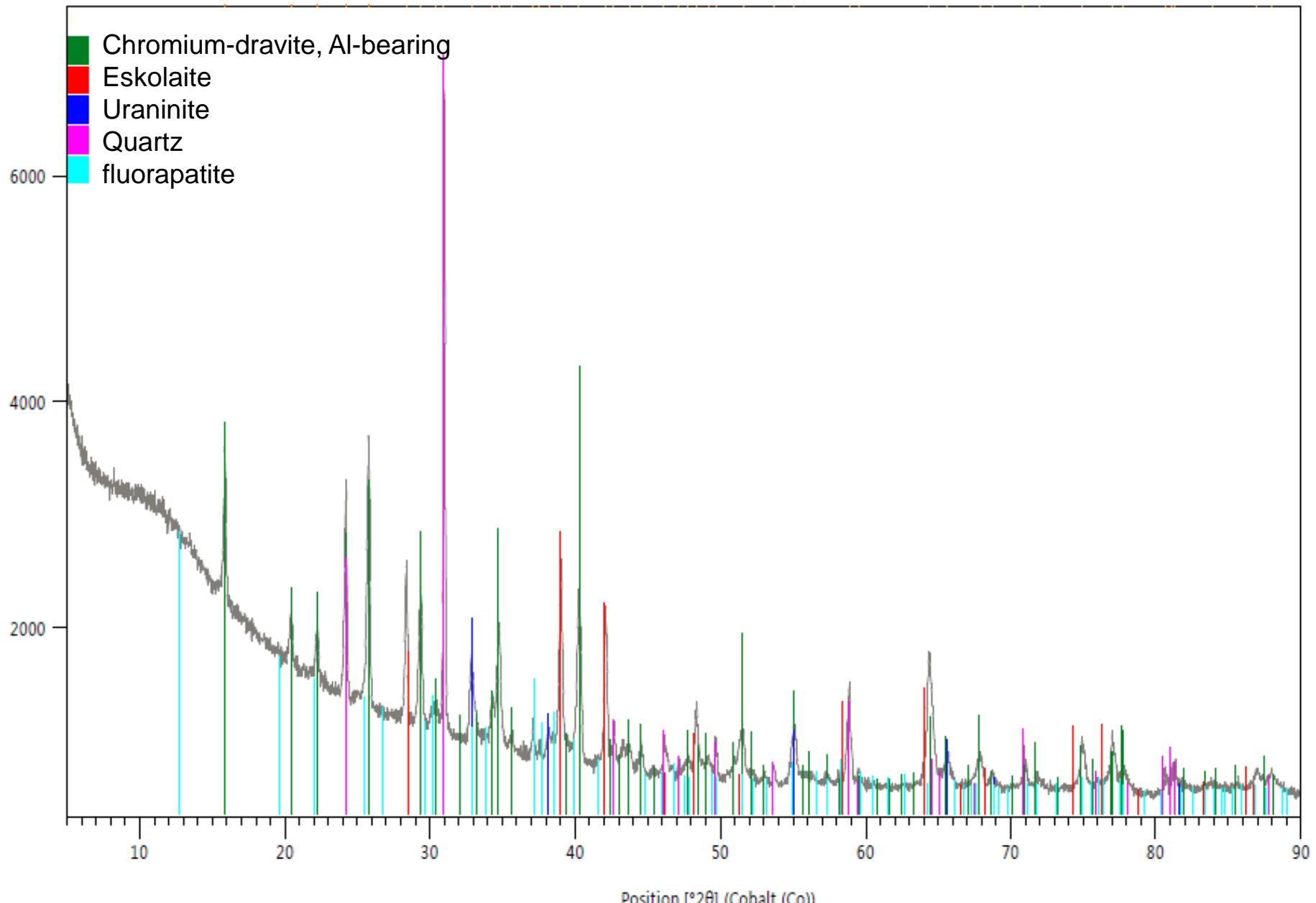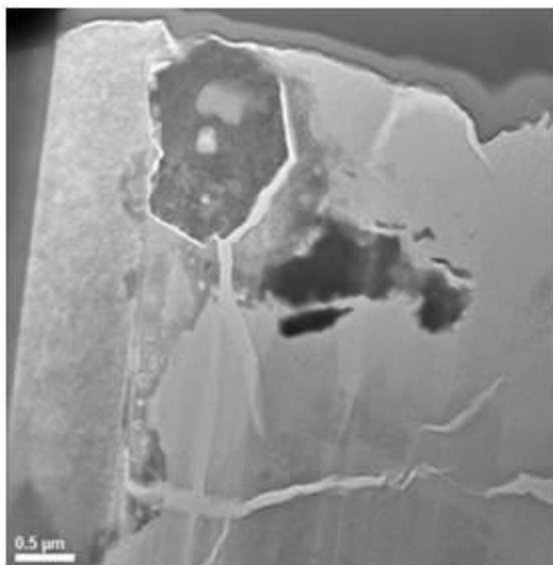# Supplementary data
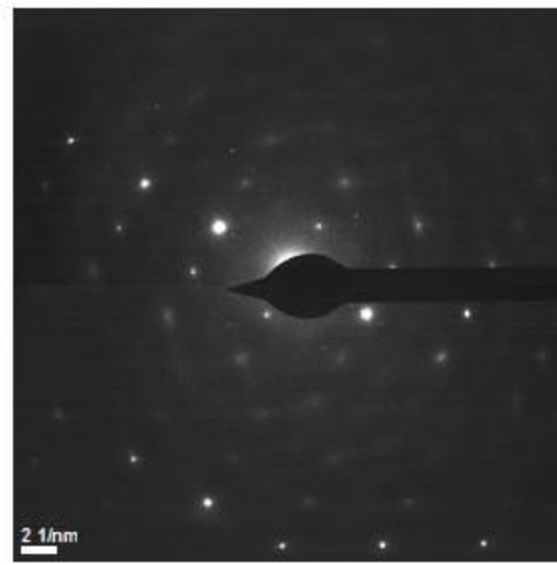
X-ray diffraction pattern of bulk material
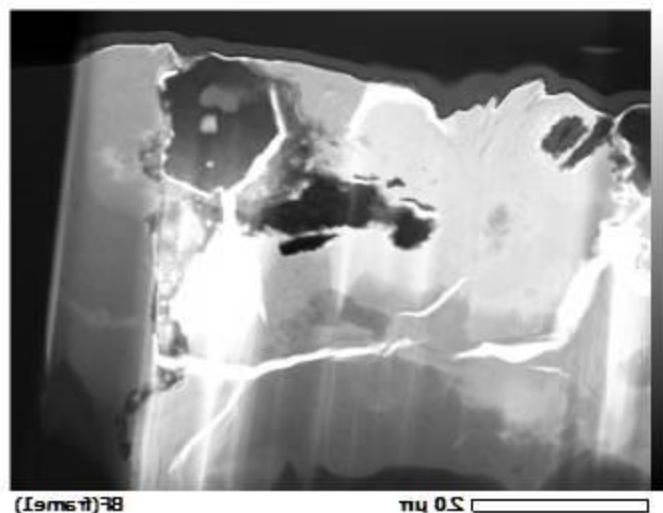
SAED pattern and EDS-STEM maps for Galena

Galena

Selected d-values

3.4 Å (111)
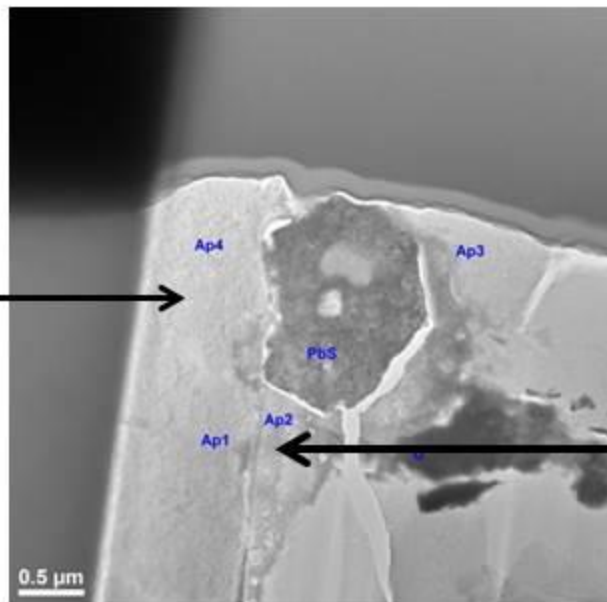2.0 Å (220)
1.78 Å (311)
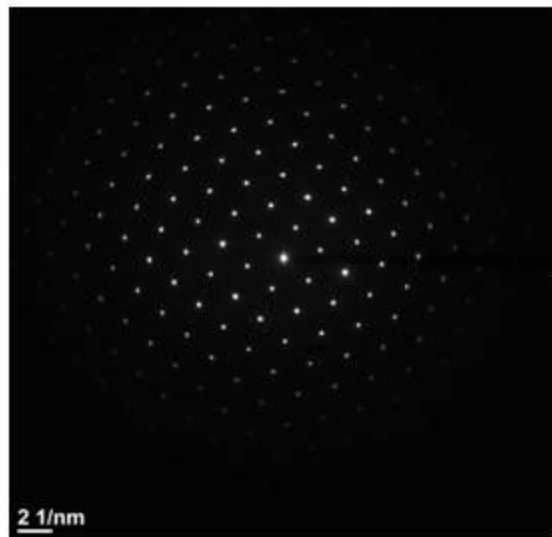
Pb = galena

Ca = apatite
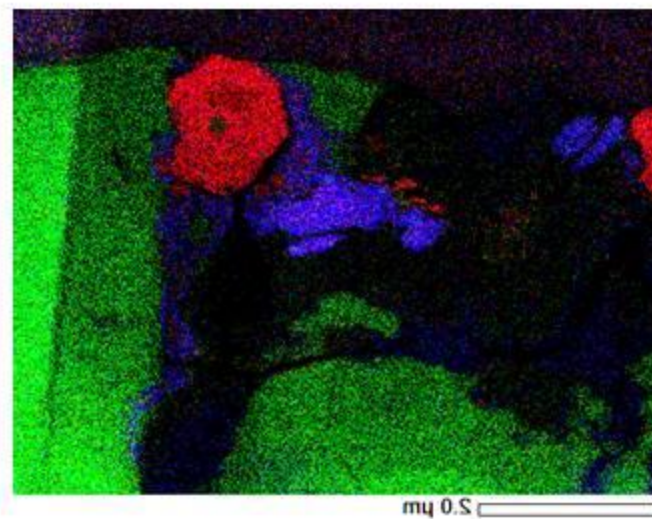
U = uraninite

SAED pattern and EDS-STEM maps for apatite
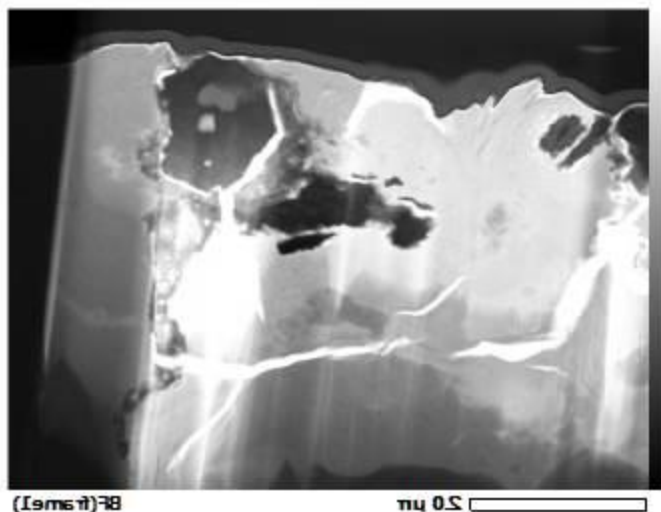
Apatite 4 (Ap 4)

Apatite 1 (Ap 1)

2 1/nm

0.5 µm

2 1/nm
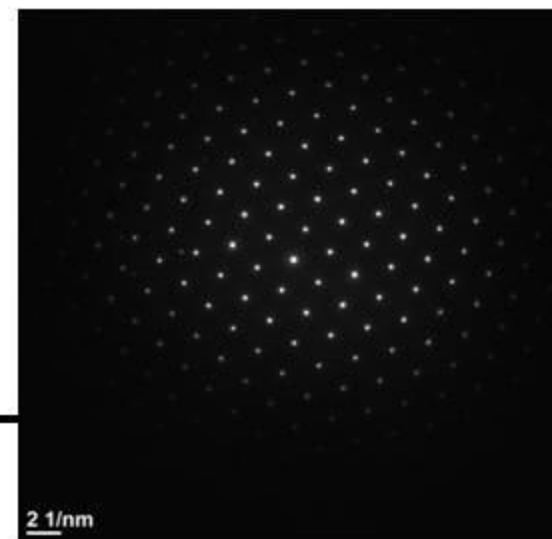
Selected d-spacings
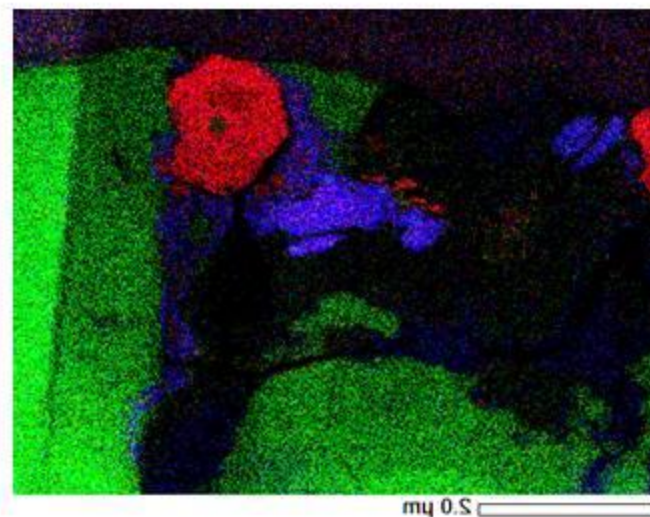
5.25 Å (101)
3.1 Å (102)
2.6 Å (202))

● Pb = galena

● Ca = apatite

● U = uraninite

BF(frame) 2.0 µm

2.0 µm
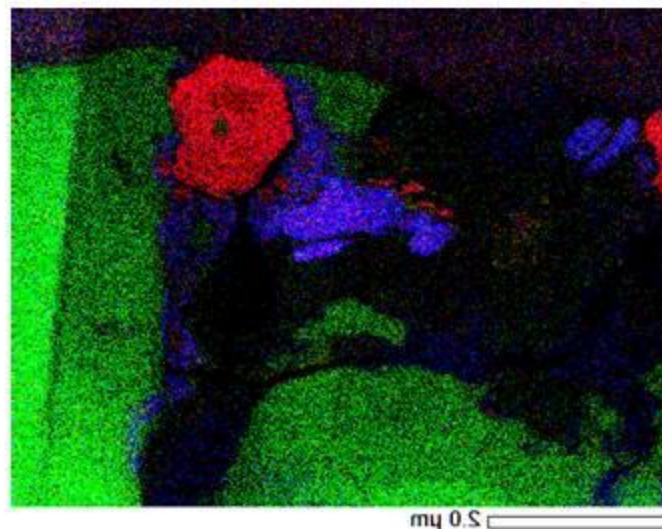
SAED pattern and EDS-STEM maps for uraninite around galena and apatite
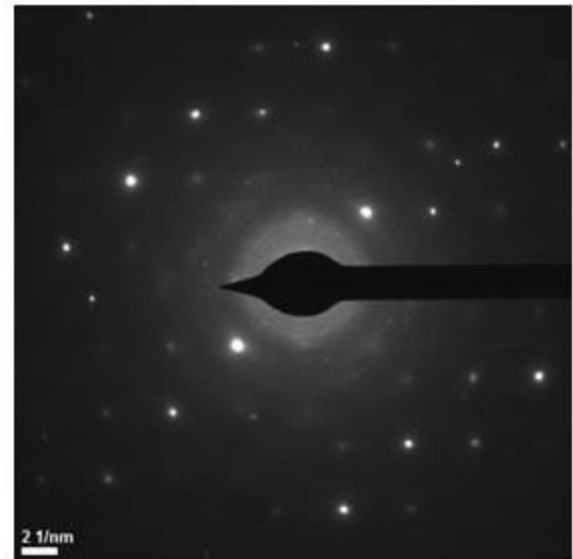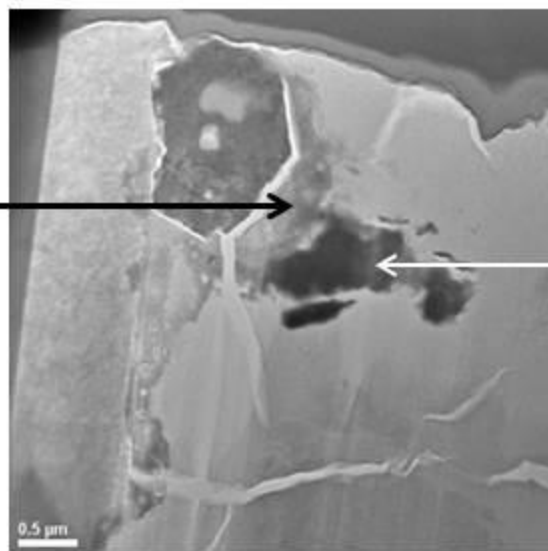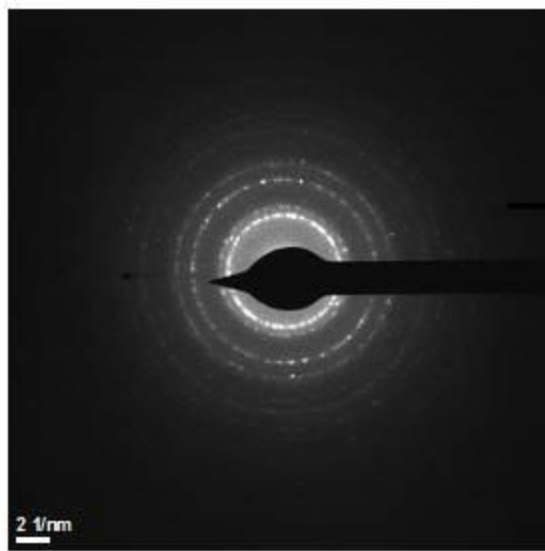
nanoparticles
Selected d-spacings

1st ring: 3.13 Å (111)
2nd ring: 2.6 Å (200)
3rd ring: 1.9 Å (220)
4th ring: 1.58 Å (222)

Single crystal
Selected d-spacings

1.92Å (220)
0.91Å (600)
0.76Å (460)

3.06Å (111)
weak reflections
nanoparticles might be
present

● Pb = galena
● Ca = apatite
● U = uraninite

SAED pattern and EDS-STEM maps for uraninite at Cr-rich matrix-Cr-rich mica interface
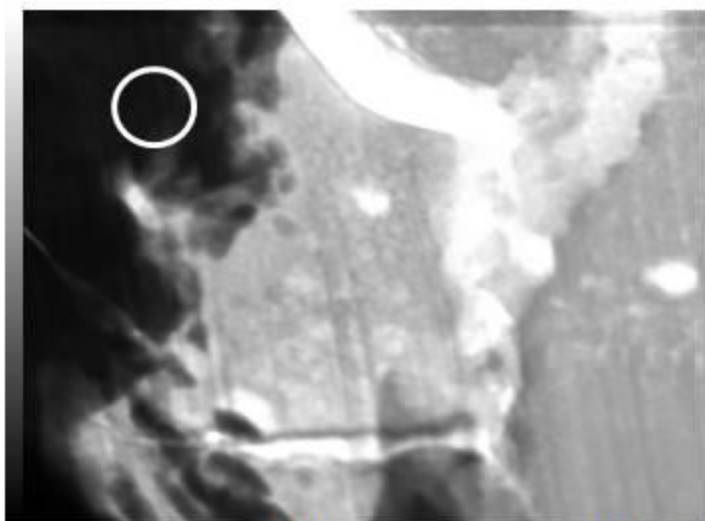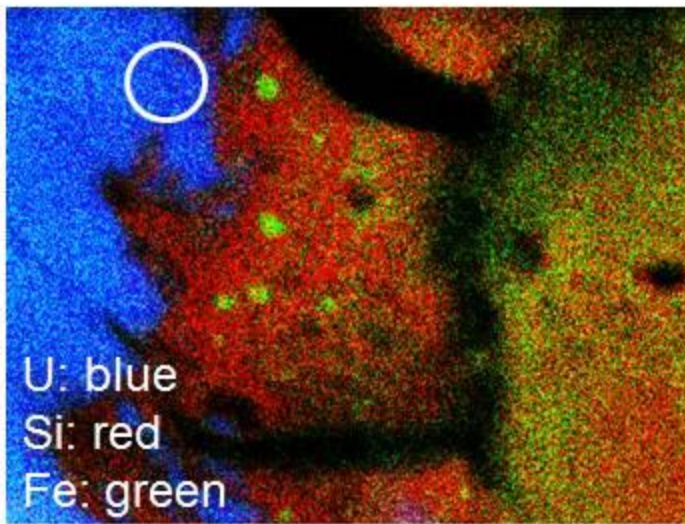
U: blue
Si: red
Fe: green
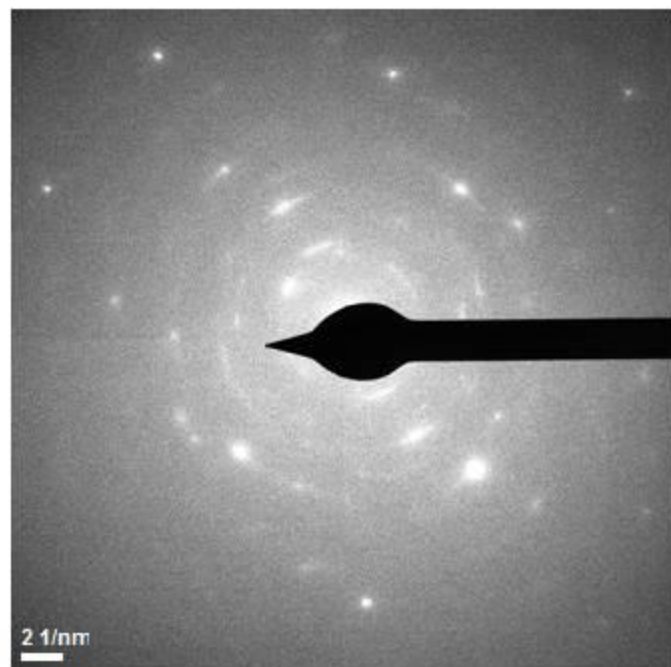
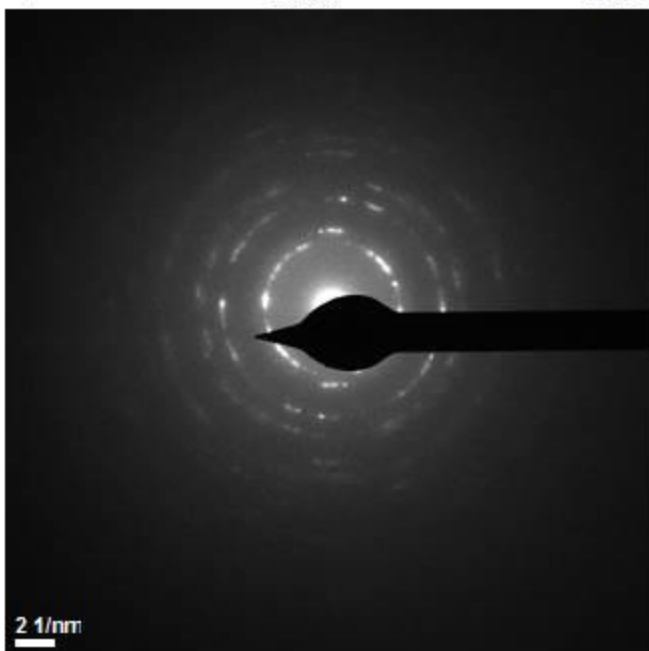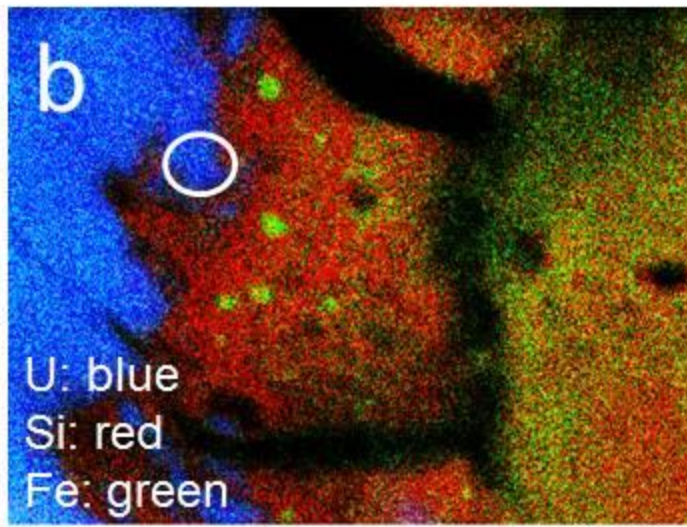Uraninite crystals(s)
With minor
nanoparticles

Selected d-spacings

    3.1 Å (102)
    2.6 Å (200)
    1.6 Å (311)
    1.1 Å (422)

🔴 Si = amorphous layer
🟢 Fe = chromceladonite
🔵 U = uraninite

a

0.5 µm   BF(frame1)

b

U: blue
Si: red
Fe: green

2 1/nm
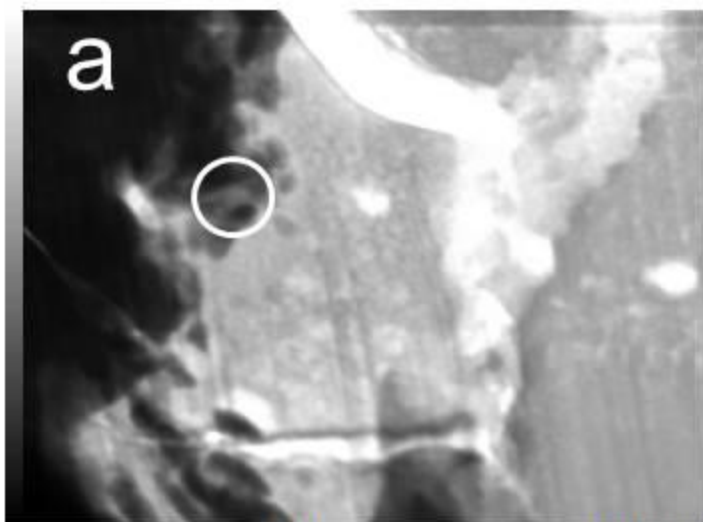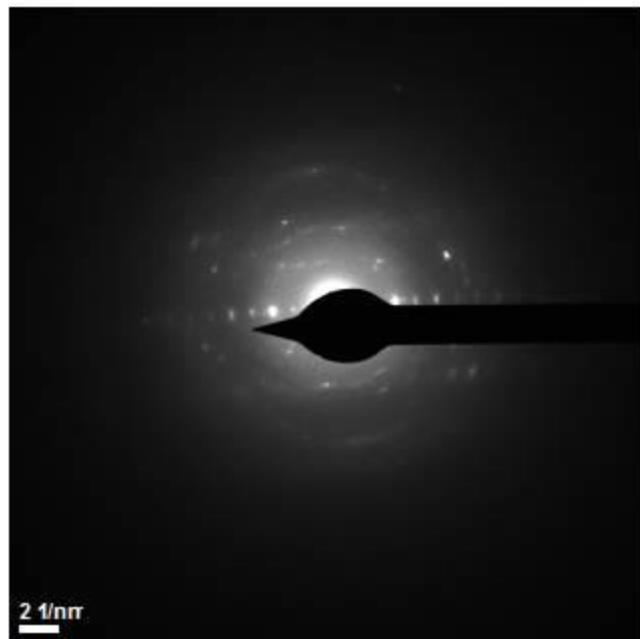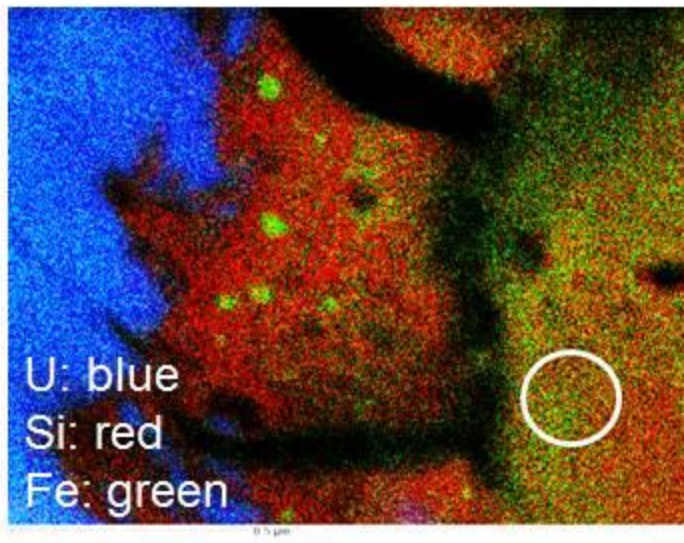
Predominantly
uraninite
Nanoparticles

Selected d-spacings
1st ring: 3.1 Å (102)
2nd ring: 2.6 Å (200)
3rd ring: 1.9 Å (220)

● Si = amorphous layer
● Fe = chromceladonite
● U = uraninite

U: blue
Si: red
Fe: green

Si = amorphous layer
Fe = chromceladonite
U = uraninite

Cr-rich mica (chromceladonite)
Space group C2/m

Selected d-spacings
5.0 Å (002)
3.3 Å (003)
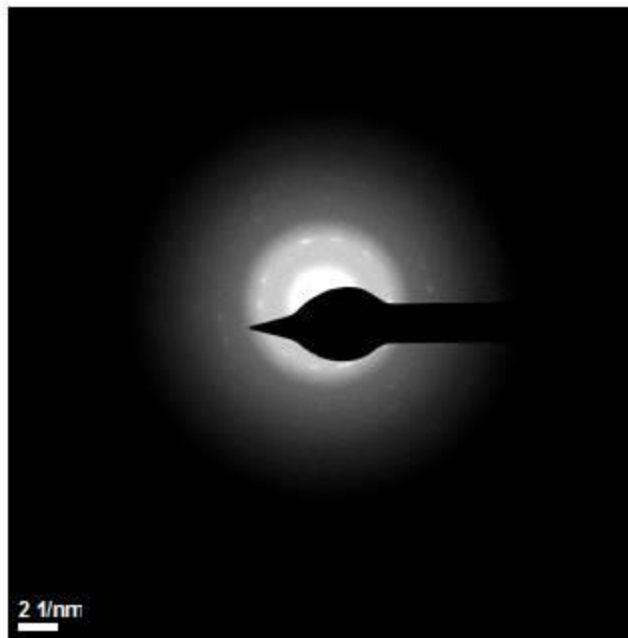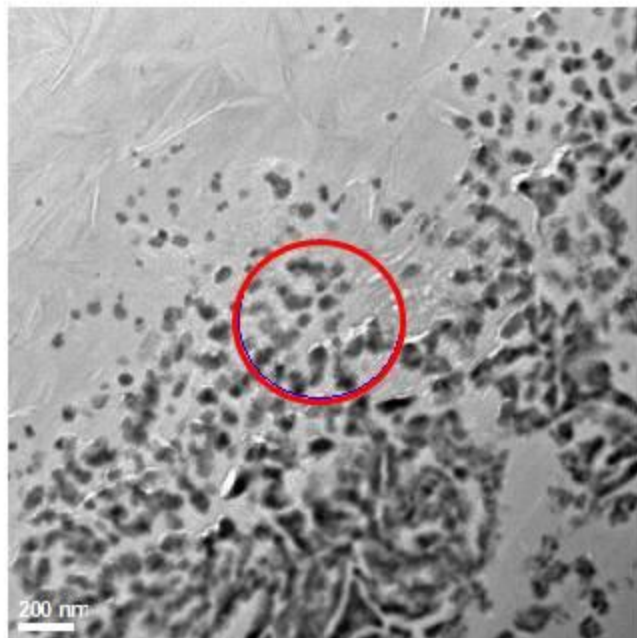2.5 Å (004)

Note that the peak at d = 5.0 Å
is extinct for C 2/c, the space group
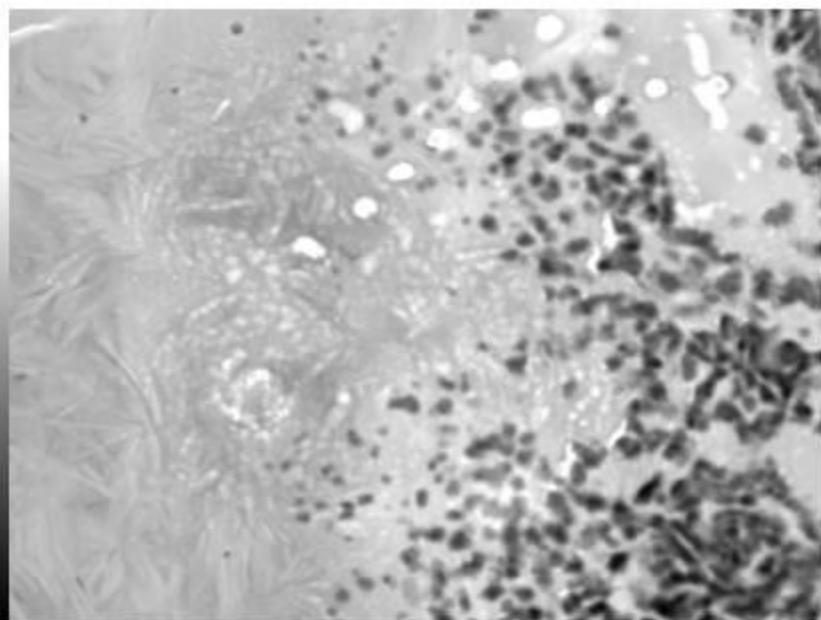for chromphyllite

Coffinite and uranium nanoparticles in amorphous Cr-rich matrix

Uraninite nanoparticles

Selected d-spacing
3.11Å
1.9Å

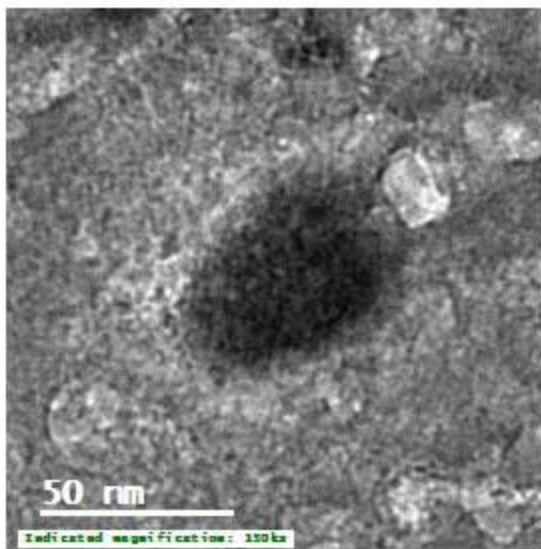🔴 Si = amorphous layer
🟢 Fe = chromceladonite
🔵 U = uraninite

200 nm

2 1/nm

1.0 µm

BF(frame1)
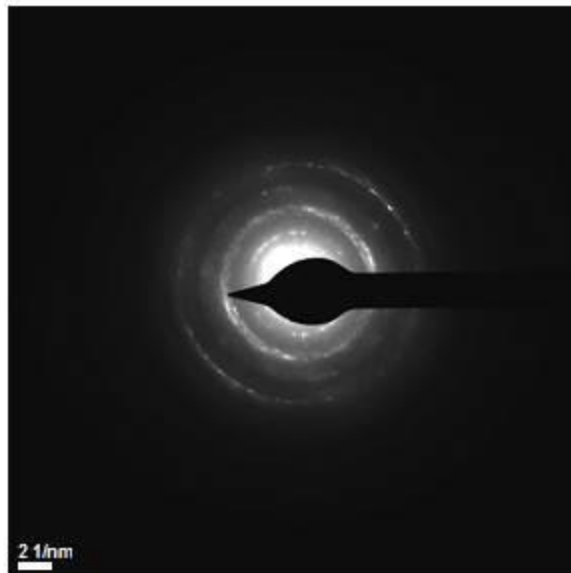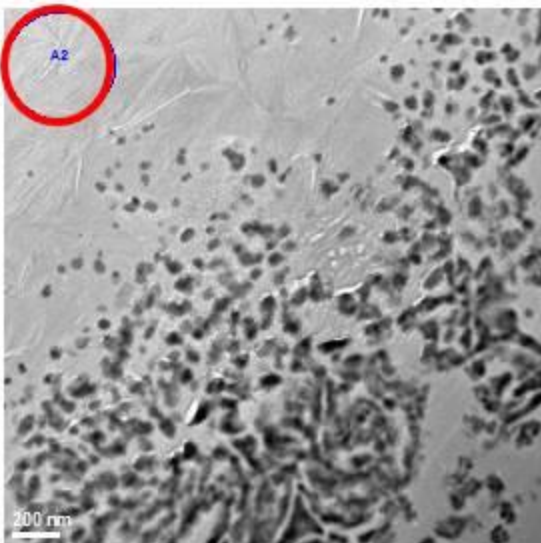
1.0 µm
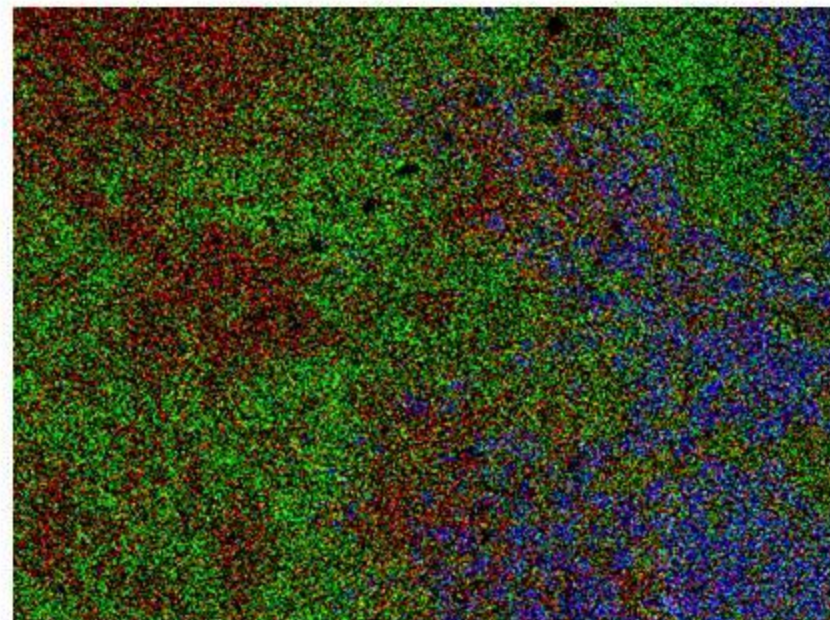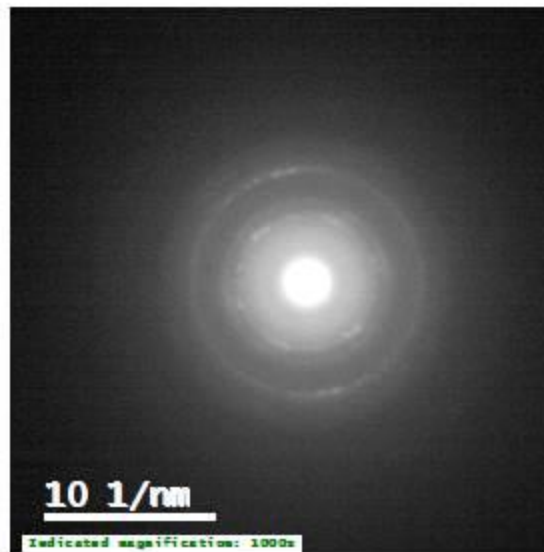
Coffinite

Selected d-spacings
3.5Å (200)
2.6Å (220)
2.1Å (301)
1.5Å (420)

Coffinite could not be unequivocally identified with EDS-STEM chemical distribution due to their size and the surrounding silica rich matrix; the estimated much lower abundance of coffinite relative to Uraninite is based on SAED pattern

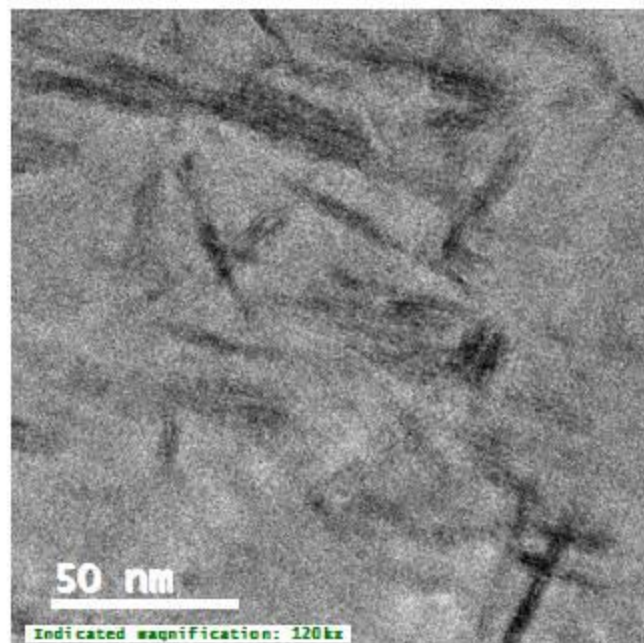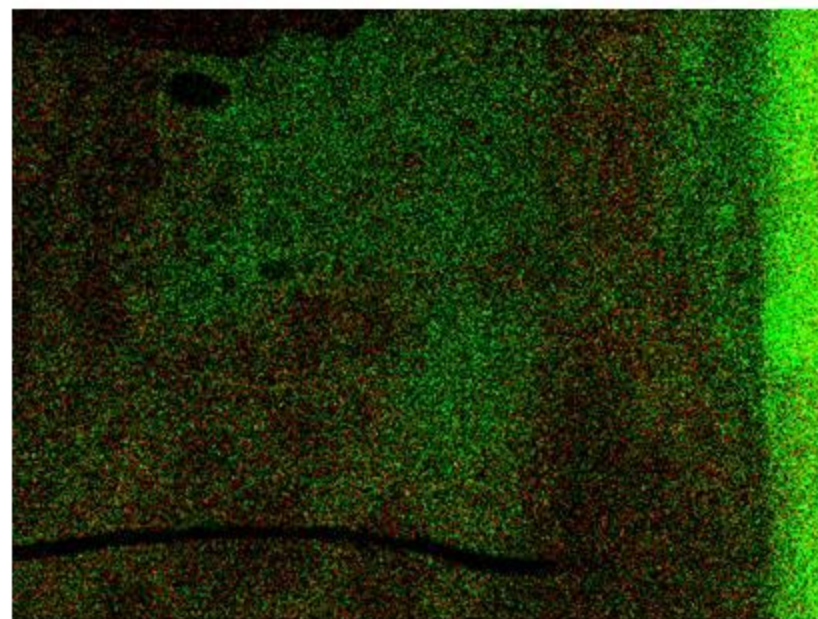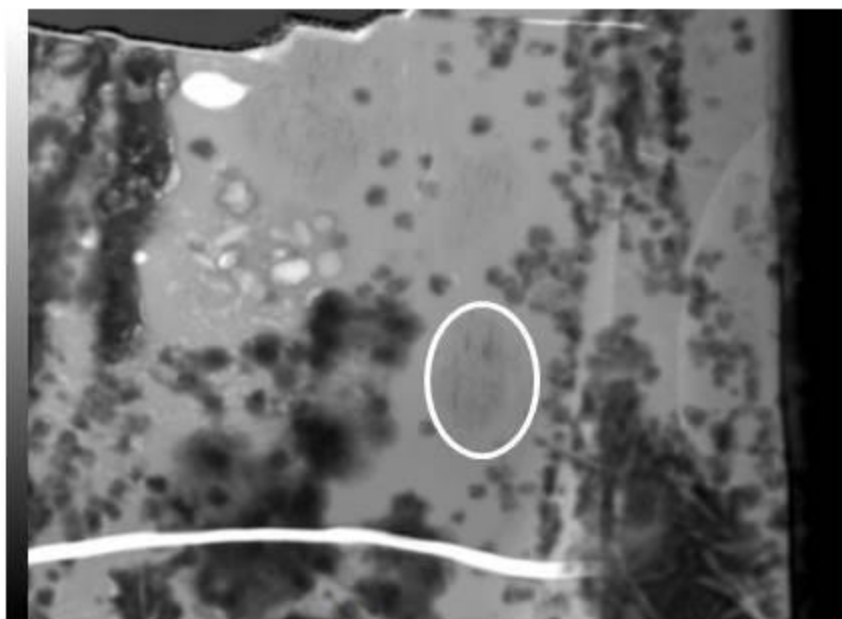# Cr-rich mica adjacent to uraninite nanoparticles

Cr-rich mica
Selected d-spacing
9.6 Å (001)
4.8 Å (002)
3.2 Å (003)
2.4 Å (004)

🔴 Si = amorphous layer

🟢 Fe = chromceladonite

🔵 U = uraninite

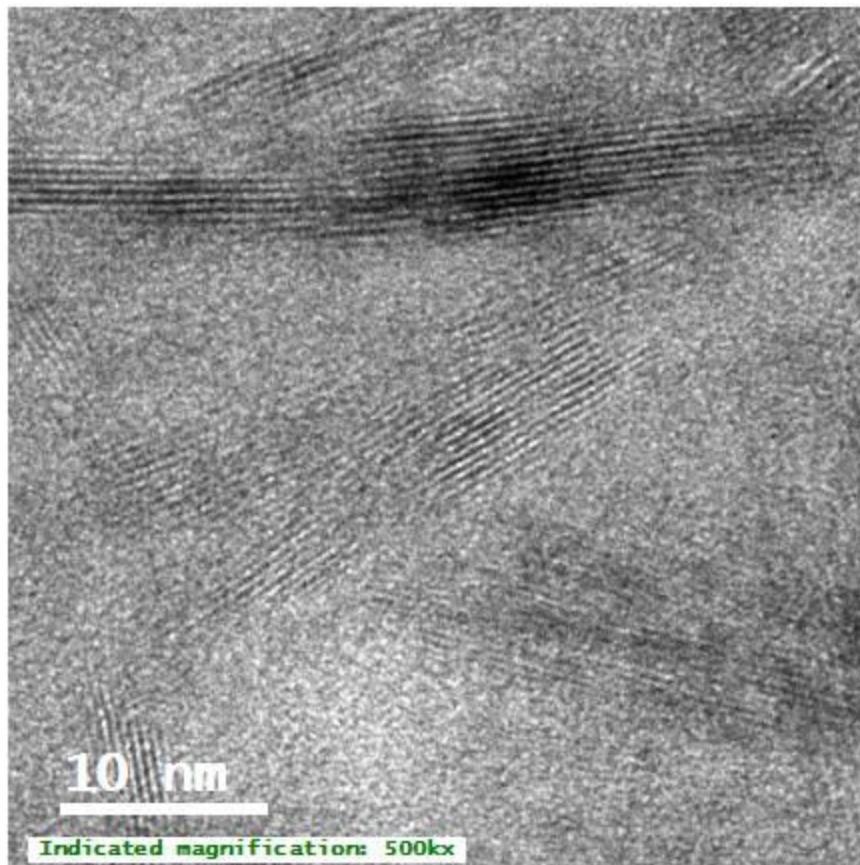BF(frame1)

1.0 µm
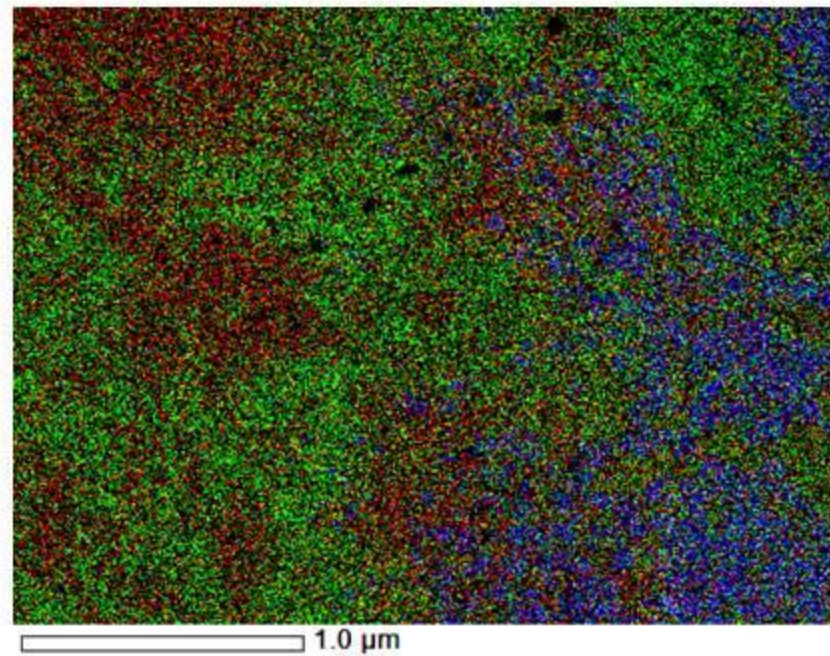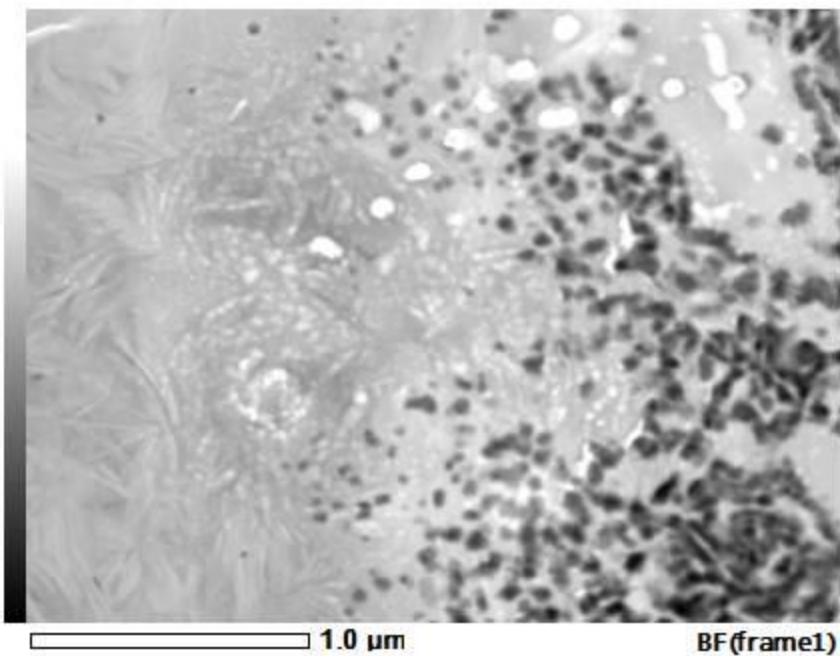
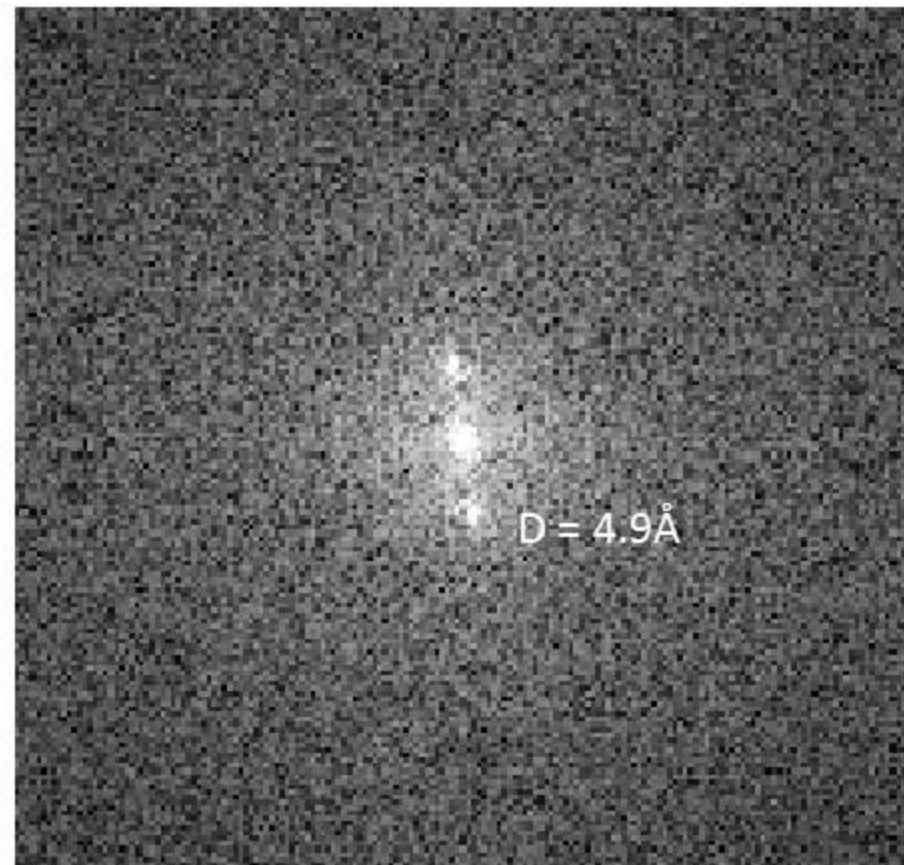# SAED pattern and EDS-STEM maps for Bracewillite

BF(frame1) 1.0 μm

1.0 μm

● Si = amorphous layer

● Cr = Cr-rich matrix plus bracewillite

Isolated bracewillite crystals
Selected d-spacings
4.9Å (020)
2.41Å (111)

50 nm
Indicated magnification: 120kx

10 1/nm
Indicated magnification: 1000x

Isolated bracewillite crystals

FFT pattern
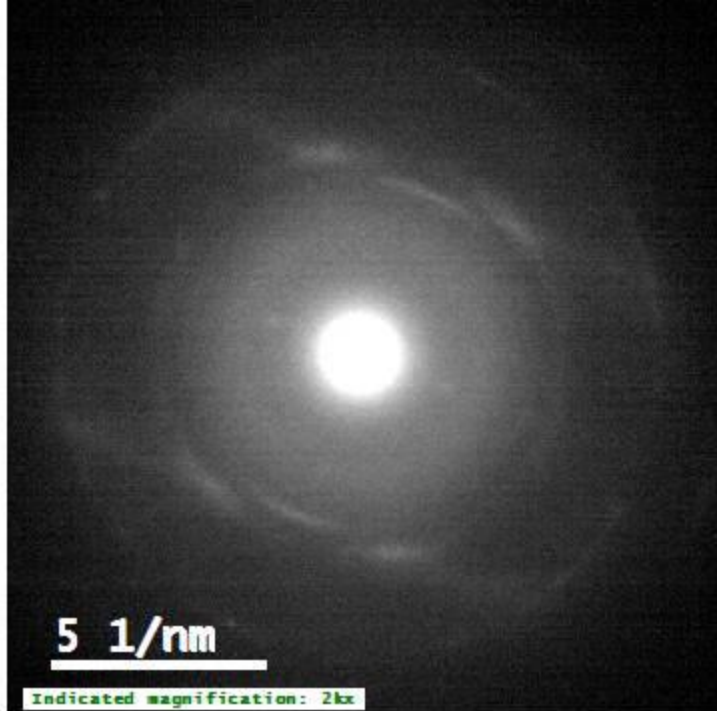
Bracewillite within uraninite nanoparticles

Selected d-spacings

4.9Å (020)

2.41 Å (111)

U: blue
Cr: orange

300 nm

BF

300 nm