Tellurium

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Discovery of Te

- Tellurium was discovered in 1783 by Austrian mineralogist Franz-Joseph Müller von Reichenstein.
- The name tellurium is derived from the Latin word "Tellus" which means Earth.
- Tellurium is one of the rarest elements and its presence in Earth's crust is about 0,001 ppm.
- In space tellurium is very abundant.
- From nature many tellurium containing ores can be found e.g., Calaverite $AuTe_2$ and Petzite Ag_3AuTe_2.
- More than 90 % of tellurium is produced as by product of copper refining electrolysis.
- Rest of tellurium origins from different industrial processes like lead refining and from different dusts that are generated during smelting of different metals.

Example of possible process to extract Te from the anode slime

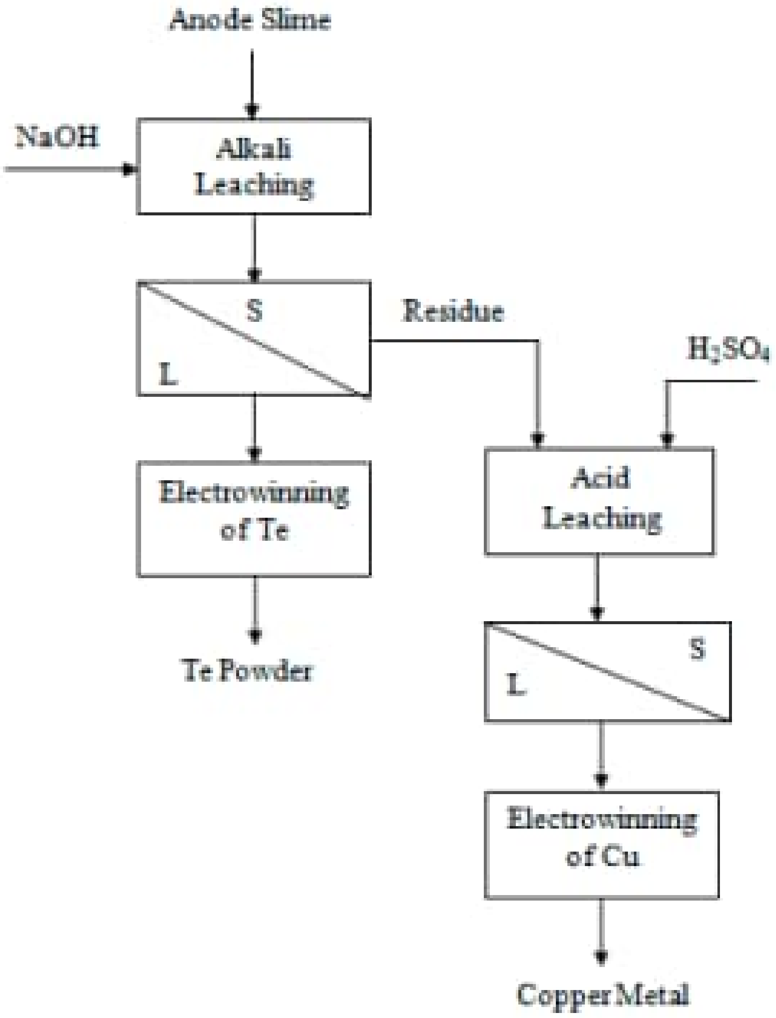
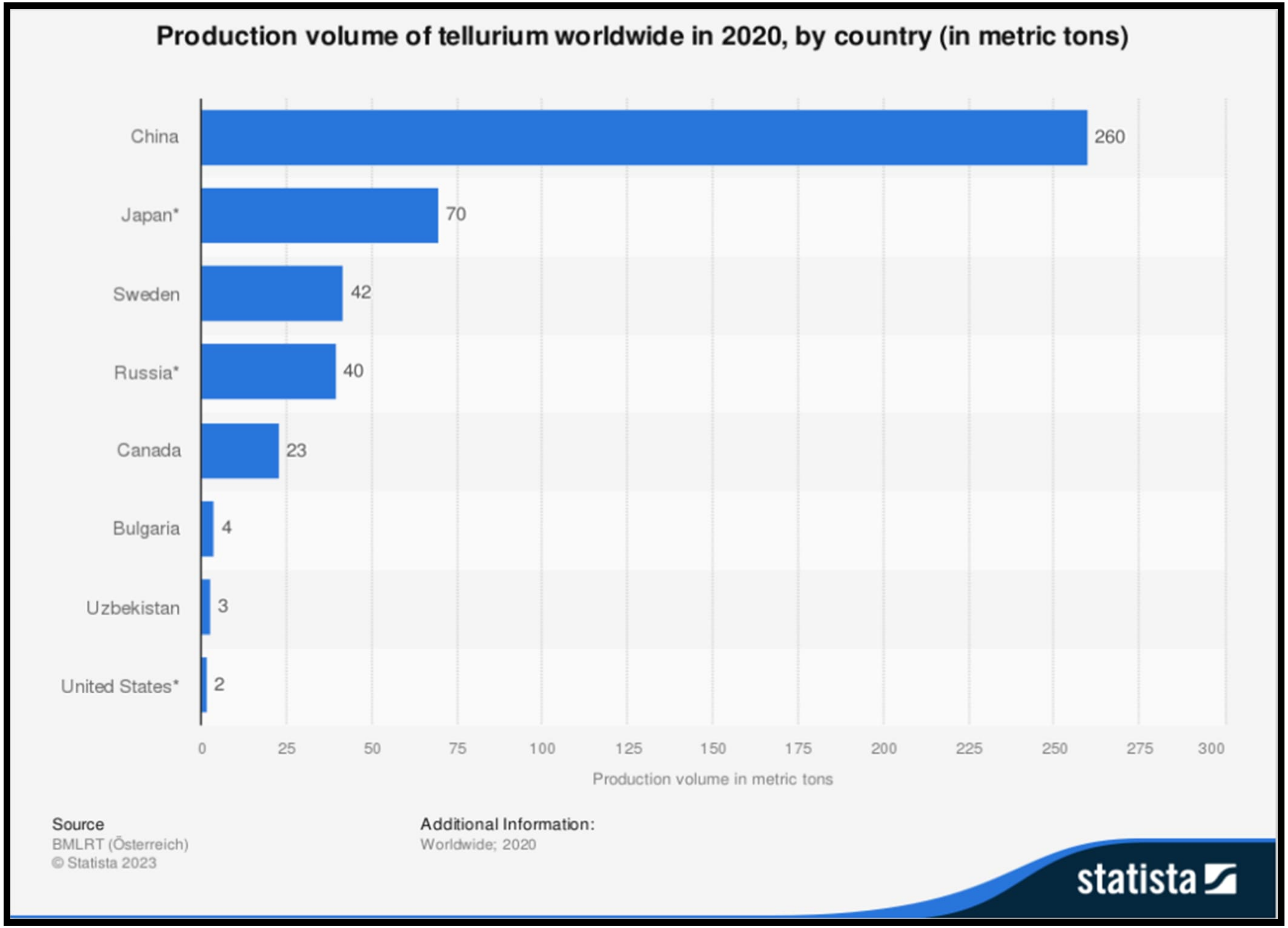


Figure 4. Process flowsheet for production of Te and Cu from anode slime.



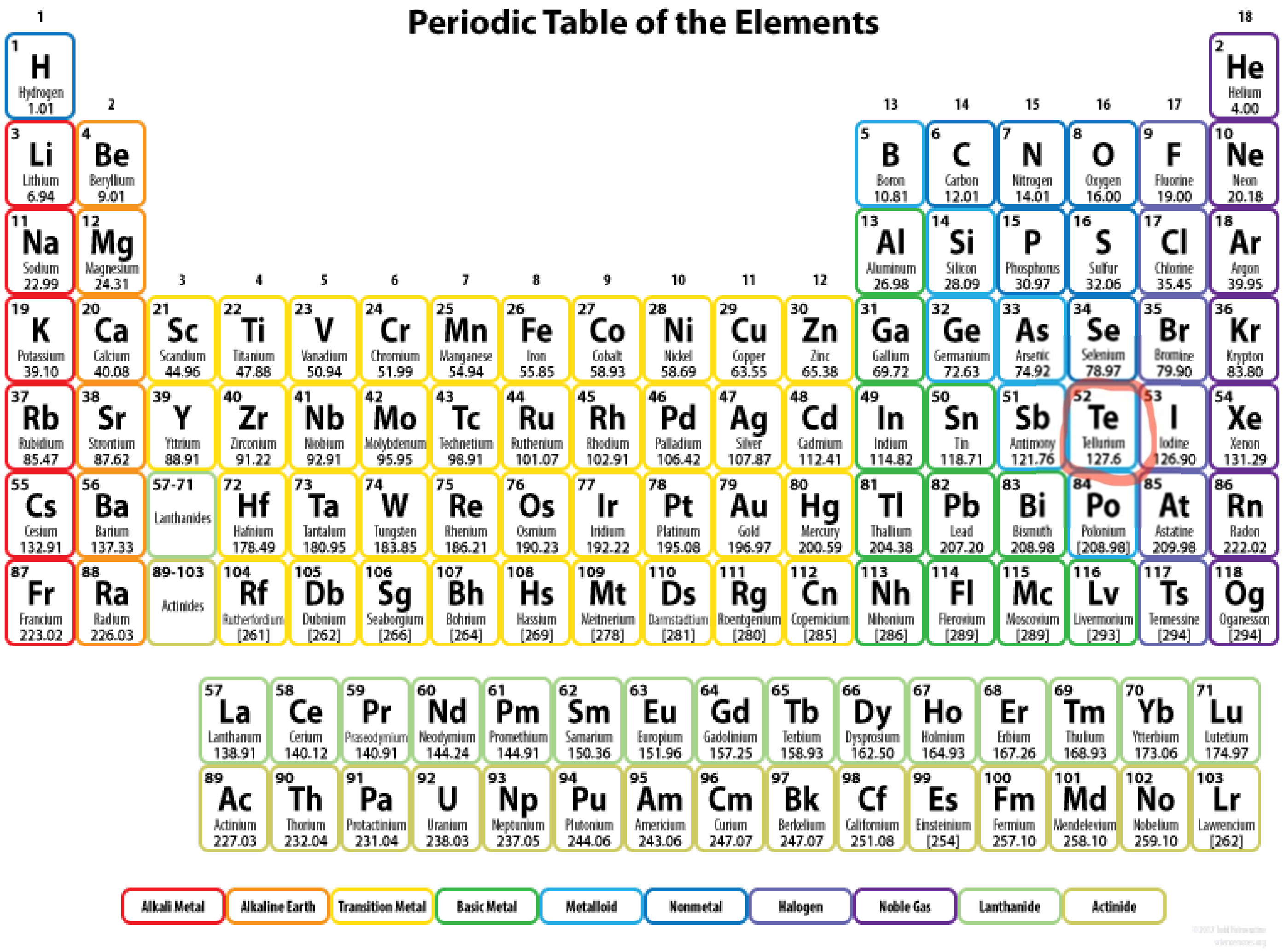
In 2022 the annual average price for tellurium in US was about 70$/kg

Tellurium, Te

- Atomic number 52
- Atomic mass 127,60 au
- Density 6,232 g/cm^3
- Melting point 452 °C
- Boiling point 988 °C
- Metalloid: Tellurium has both metallic and non-metallic features.
- In nature tellurium can be found with crystalline form and as amorphous powder.
- Appearance: Silvery and brittle metal with a typical metallic luster.
- Usually obtained as a grey powder.
- Tellurium burns in atmosphere with a greenish flame when its heated and it forms TeO_2.
- Tellurium is the heaviest element which is known to form a double bond with Boron.

Chemistry of tellurium

- Group 16, period 5
- Electronic configuration: [Kr] $5s^2\ 4d^{10}\ 5p^4$
- Oxidation states: -II, +II, +IV and +VI
- Sizes
  - Atomic radius: 1,60 Å
  - Covalent radius: 1,37 Å
  - Ionic radius: 2,21 Å (-II), 0,7 Å (+IV), 0,56 Å (+VI)
- Electronegativity: 2,1
- Semiconductor
- Isotopes
  - 8 stable
  - 31 unstable



Reactivity of tellurium

- Tellurium isn't that reactive when it's compared to oxygen and sulfur.
- It still can react with many different elements and compounds.
  - Metals
  - Halogens
  - Acids
  - Hydrogen
  - Organic compounds
- Tellurium doesn't react with HCl.
- Reaction with nitric acid:
  - $3\ Te + 4\ HNO_3 + H_2O \rightarrow 3\ H_2TeO_3 + 4\ NO$
- Reaction in air when there are used high temperatures:
  - $Te(s) + O_2(g) \rightarrow TeO_2(s)$

Compouds

Tellurium forms both inorganic and organic compounds.

Inorganic

- Tellurides ($AuTe_2$)
- Telluriumoxides (TeO_2)
- Telluriumacids (H_2TeO_3)
- Tellurium nitrides (Te_4N_4)
- Tellurium sulfates

Organic

- Dimethyl telluride: $Te(CH_3)_2$
- Diphenyl telluride: $Te(Ph)_2$

Bismuth telluride Bi_2Te_3

- Oxidation state of Te –II
- Hexagonal crystal structure
- Not soluble in water
- Gray semiconductor powder which can be alloyed with antimony or selenium to form an efficient thermoelectric material.
- Main uses in thermoelectric cooling devices within different technologies developed for militaries.
- Recent research results have confirmed that Bi_2Te_3 can increase the speed of microchips, and this has brought the basis of next generation technology called “Spintronics”.

Tellurium dioxide TeO_2

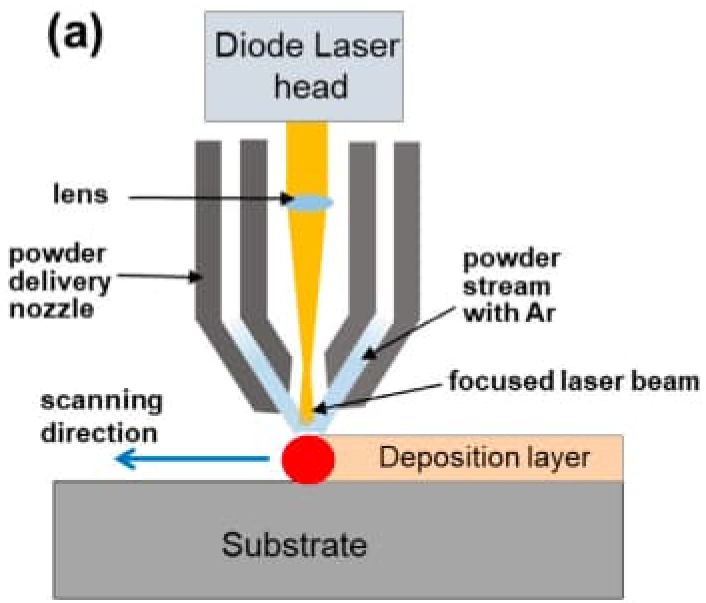
- Oxidation state of Te +IV
- Two forms α-TeO_2 white powder like and β-TeO_2 which is rare yellowish mineral
- Under pressure α-TeO_2 is slowly converting to β-TeO_2.
- TeO_2 used in the media layer of rewritable optical discs like CD-RW.
- Other uses is production of glass and color ceramics
- Not soluble in water

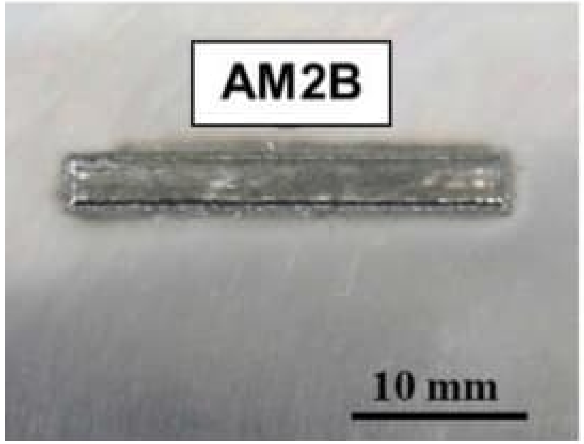
Applications

- Tellurium is used in many different applications
- Metallurgy: as an alloying element to improve certain properties of steel and copper like machinability.
- Solar cells: Through synthesis produced CdTe semiconductors are one of the most efficient materials to produce photovoltaic solar cells.
- Catalysis: Tellurium catalysts are used in oxidation of organic compounds and chlorination, halogenation, and hydrogenation reactions.
- Also there have been studied if tellurium could be utilized in biomedical applications.

Effect of tellurium on the microstructure and mechanical properties of Fe-14Cr oxide-dispersion-strengthened steels produced by additive manufacturing

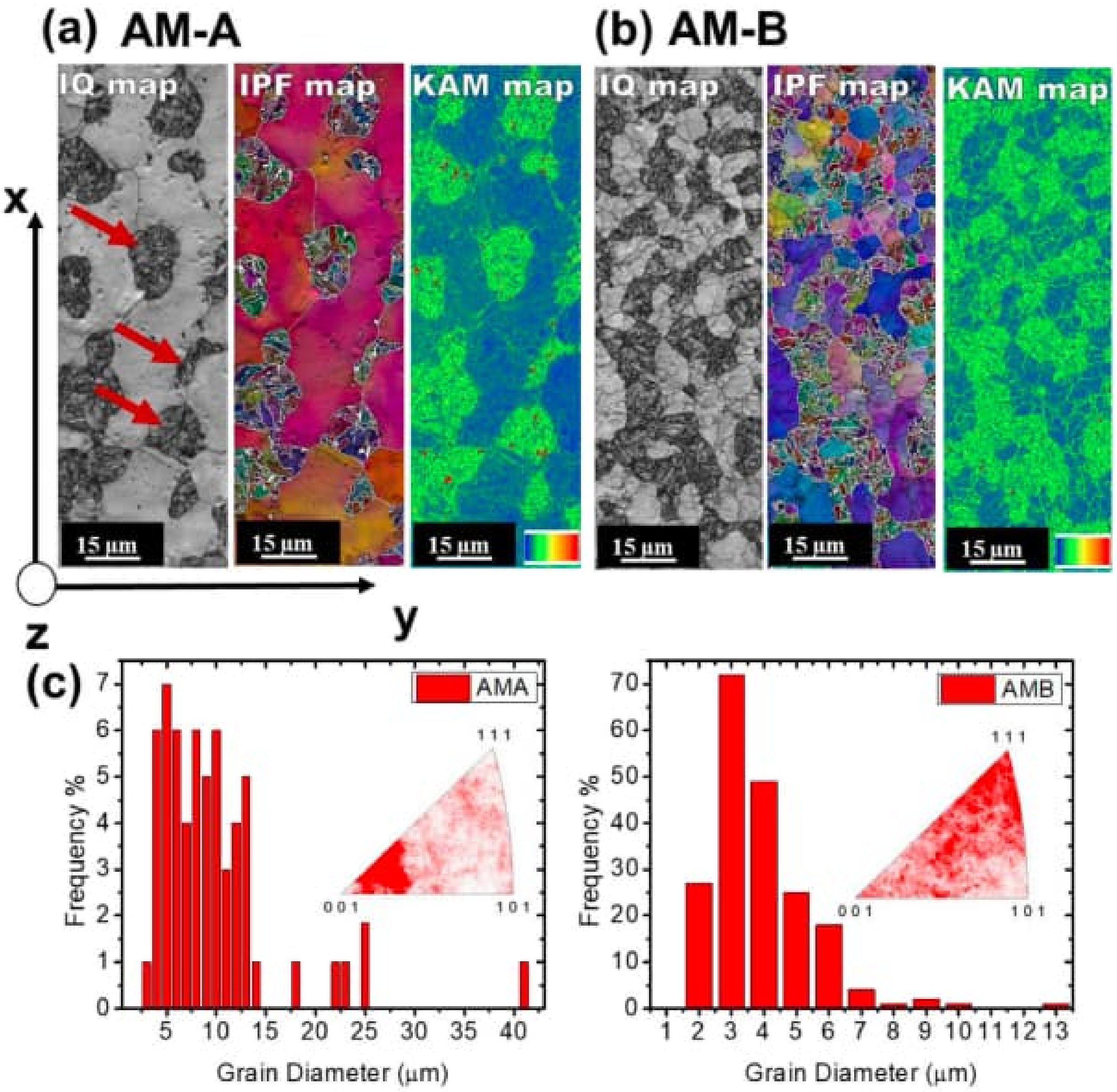
- Te effects on oxide-dispersion-strengthened steel was studied through mixing Fe-14Cr powder with Te powder and Y_2O_3 powder.
- Two slabs, other alloyed with Te and other not, were layered with those alloys by using additive manufacturing technique in inert argon athmosphere.
- Process parameters were same for both samples.





[6] M. A. Barton, H. B. Jee, Y. N. Min, J. C. Hye, G. K. Hyun, H. K. Il, J. R. Ho, H. K. Jeoung, “Effect of tellurium on the microstructure and mechanical properties of Fe-14Cr oxide-dispersion-strengthened steels produced by additive manufacturing, “ *Journal of Materials Science & Technology*, vol. 95, pp. 114-126, 2021.

- The mictrostructure and the mechnical properties of the samples were studied with different techniques.
- It was observed that Te alloyed sample had smaller grain size.
- Te alloyed sample average grainsize 3,4 µm
- Without added Te 9,4 µm.



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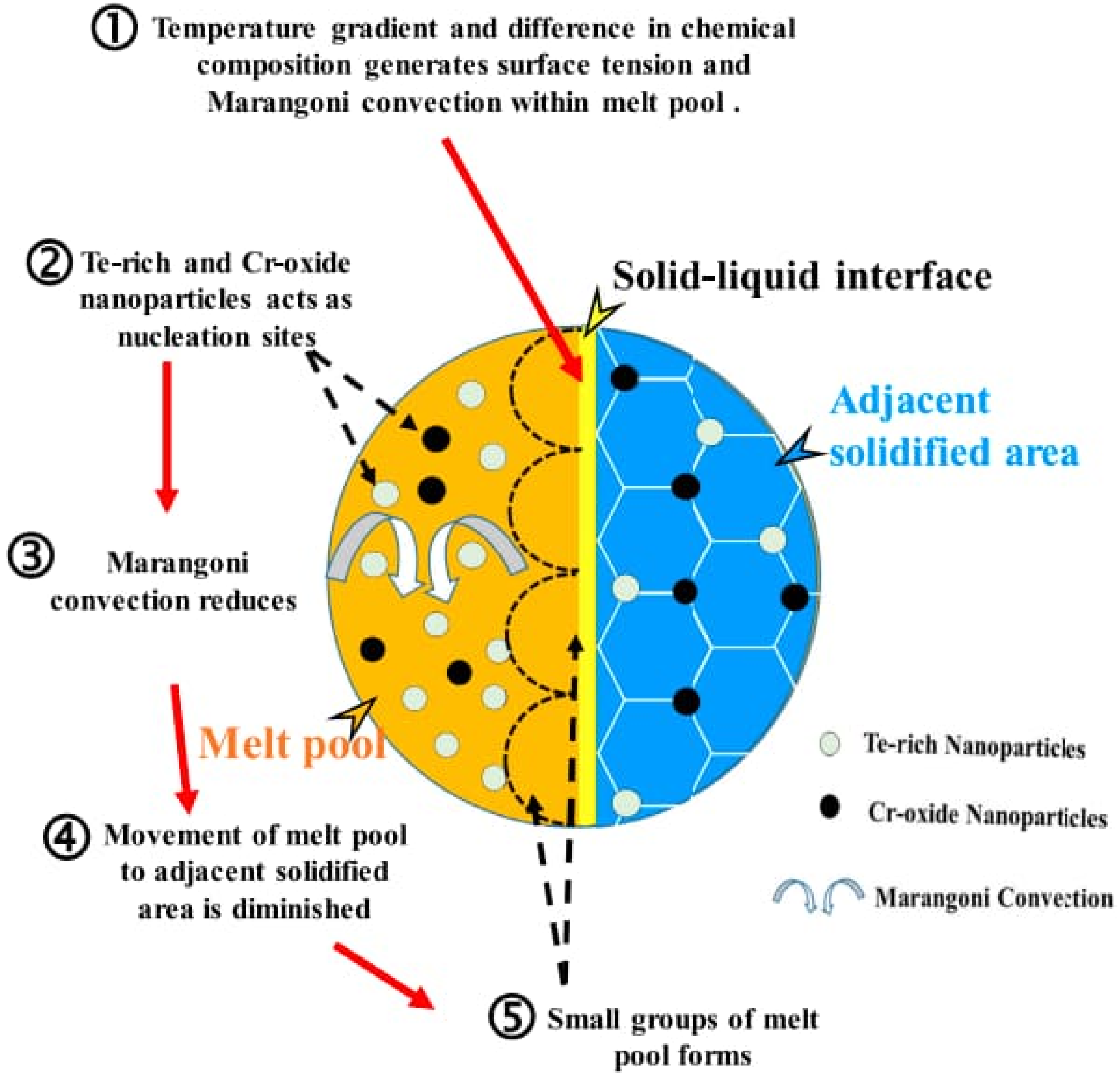

① Temperature gradient and difference in chemical composition generates surface tension and Marangoni convection within melt pool .
② Te-rich and Cr-oxide nanoparticles acts as nucleation sites
③ Marangoni convection reduces
④ Movement of melt pool to adjacent solidified area is diminished
⑤ Small groups of melt pool forms
Solid-liquid interface
Adjacent solidified area
Melt pool
Te-rich Nanoparticles
Cr-oxide Nanoparticles
Marangoni Convection

- By adding the Te mechanical properties of sample were enchanced.
- For example hardness.

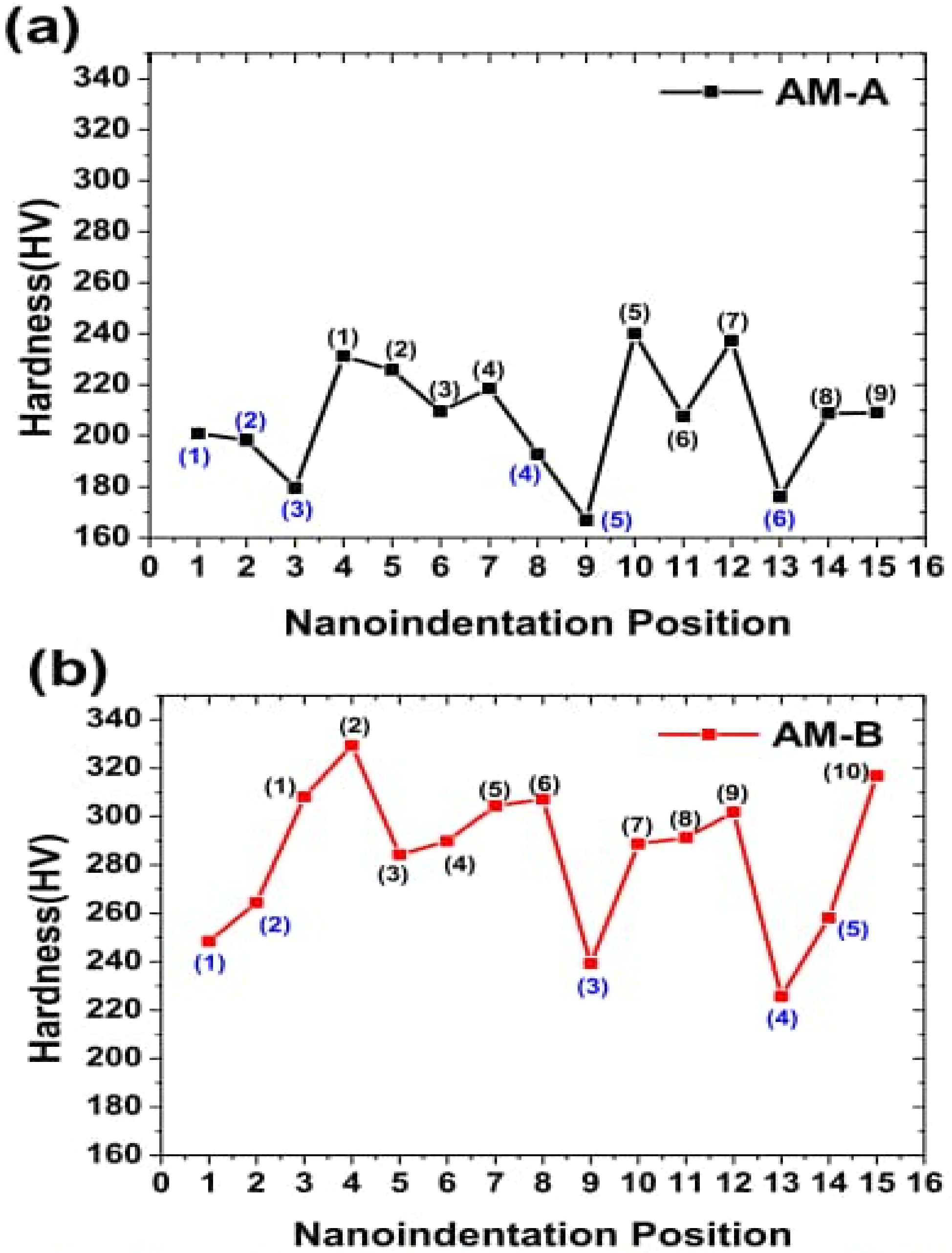
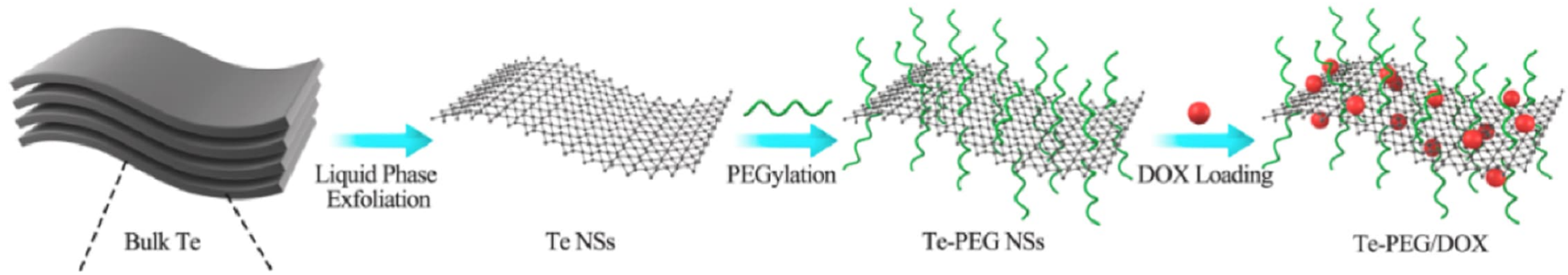


Fig. 9. Nanoindentation results for (a) AM-A and (b) AM-B samples. The parenthesized numbers in blue and black show the hardness values of coarse- and fine-grain regions, respectively (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

Biomedical application: Tellurium nanosheets in cancer treatment

- Before there have been done some research related to Te materials and if they could be used in biomedical applications.
- Te nanomaterials which have been studied before were for example Te nanodots and Te nanorods.
  - Active electrons/holes ⟶ Photothermal transformation
- Te based nanomaterials could be utilized in cancer treatment but there needs to be done more research.

W. Pan, C. Liu, Y. Li, Y. Yang, W. Li, C. Feng, L. Li, Ultrathin tellurium nanosheets for simultaneous cancer thermo-chemotherapy. *Bioactive Materials*, 2022, 13, 96-104. (10.1016/j.bioactmat.2021.11.010)



Biomedical application: Tellurium nanosheets in cancer treatment

- There was studied if tellurium nanosheets could be utilized in thermo-chemotherapy.
  - Thermochemotherapeutic anti-tumor platfrom
- Interaction between Te-PEG nanosheets and DOX:
  - Strong π-π stacking interaction

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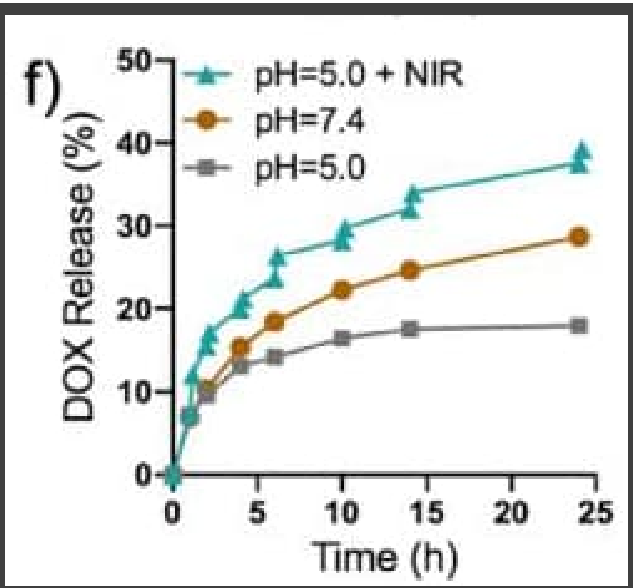
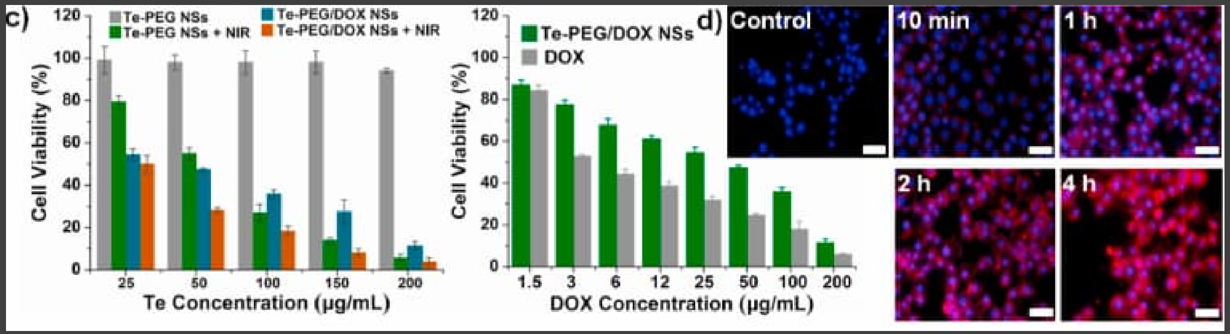
Biomedical application: Tellurium nanosheets in cancer treatment

- In vitro and in vivo experiments
    - Photothermal and chemotherapy
- Te-PEG nanosheets had several good properties:
    - Biocompatibility
    - Stability
    - Loading capacity
    - Photothermal conversion efficiency
- Tellurium nanosheets are used in this application because they had several good properties:
    - Optical response properties
    - Electronic characters
    - Surface





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