

# 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  $\text{AuTe}_2$  and Petzite  $\text{Ag}_3\text{AuTe}_2$ .
- 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

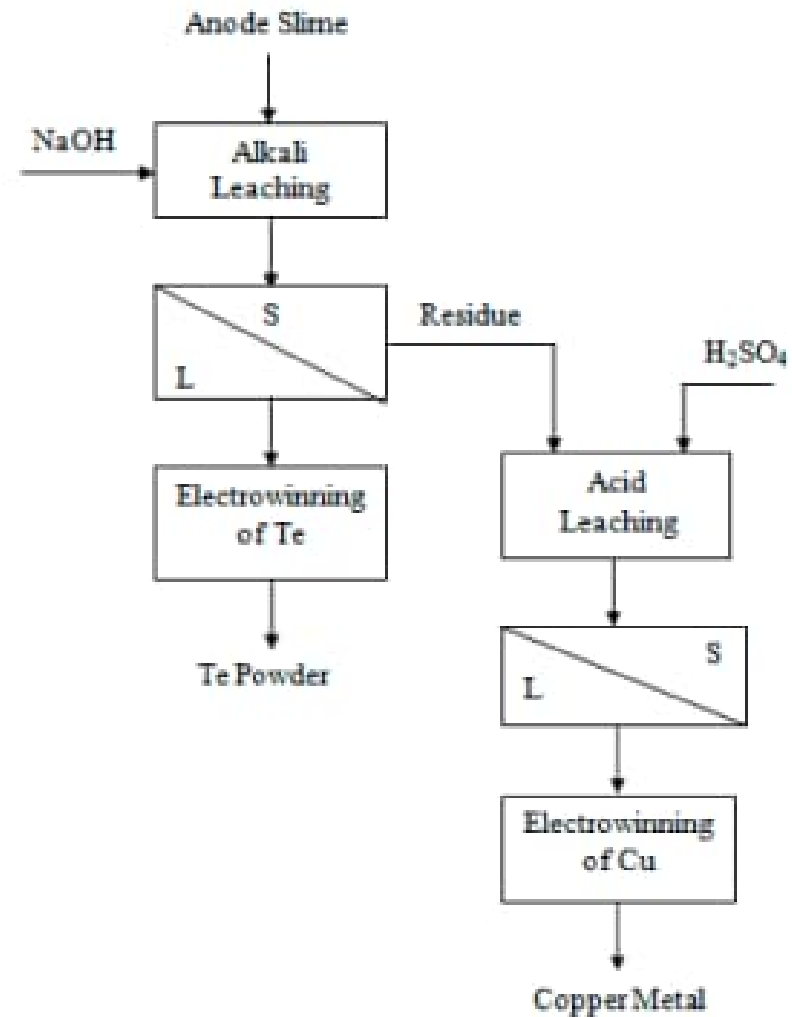
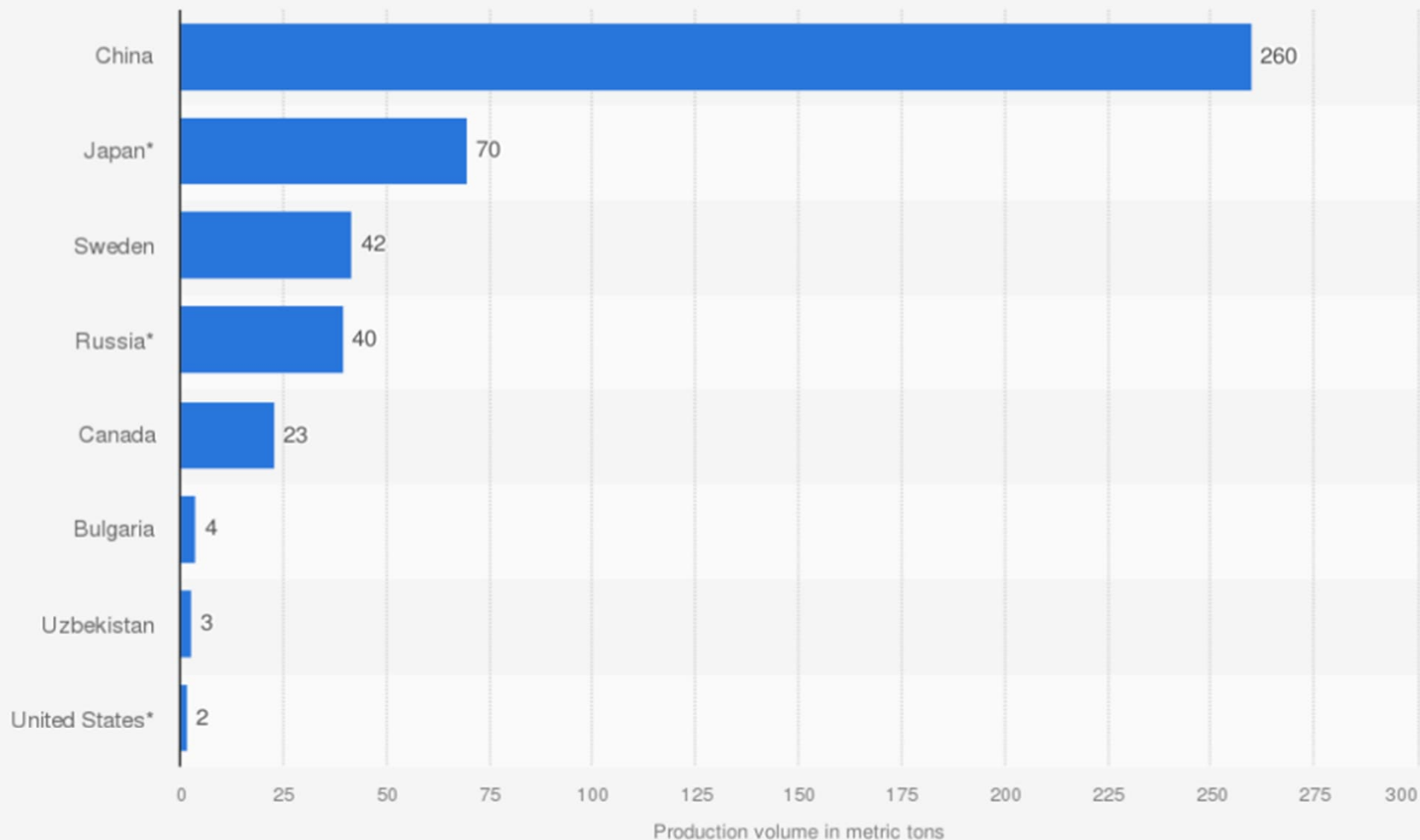


Figure 4. Process flowsheet for production of Te and Cu from anode slime.

### Production volume of tellurium worldwide in 2020, by country (in metric tons)



Source  
BMLRT (Österreich)  
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Additional Information:  
Worldwide; 2020

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<sup>3</sup>
- 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<sub>2</sub>.
- Tellurium is the heaviest element which is known to form a double bond with Boron.

52

127.6

Te

Tellurium

[Kr] 4d<sup>10</sup>5s<sup>2</sup>5p<sup>4</sup>

Metalloid



# Chemistry of tellurium

- Group 16, period 5
- Electronic configuration:  $[\text{Kr}] 5s^2 4d^{10} 5p^4$
- 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

**Periodic Table of the Elements**

1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.63	33 As Arsenic 74.92	34 Se Selenium 78.97	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium [208.98]	85 At Astatine 209.98	86 Rn Radon 222.02
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]
57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 144.91	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.06	71 Lu Lutetium 174.97			
89 Ac Actinium 227.03	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.05	94 Pu Plutonium 244.06	95 Am Americium 243.06	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.08	99 Es Einsteinium [254]	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium [262]			

Alkali Metal
Alkaline Earth
Transition Metal
Basic Metal
Metalloid
Nonmetal
Halogen
Noble Gas
Lanthanide
Actinide



# 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:
  - $3 \text{ Te} + 4 \text{ HNO}_3 + \text{H}_2\text{O} \longrightarrow 3 \text{ H}_2\text{TeO}_3 + 4 \text{ NO}$
- Reaction in air when there are used high temperatures:
  - $\text{Te}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{TeO}_2(\text{s})$

# Compounds

Tellurium forms both inorganic and organic compounds.

## Inorganic

- Tellurides ( $\text{AuTe}_2$ )
- Telluriumoxides ( $\text{TeO}_2$ )
- Telluriumacids ( $\text{H}_2\text{TeO}_3$ )
- Tellurium nitrides ( $\text{Te}_4\text{N}_4$ )
- Tellurium sulfates

## Organic

- Dimethyl telluride:  $\text{Te}(\text{CH}_3)_2$
- Diphenyl telluride:  $\text{Te}(\text{Ph})_2$





# Bismuth telluride

## Bi<sub>2</sub>Te<sub>3</sub>

- 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<sub>2</sub>Te<sub>3</sub> can increase the speed of microchips, and this has brought the basis of next generation technology called “Spintronics”.

# Tellurium dioxide

## TeO<sub>2</sub>

- Oxidation state of Te +IV
- Two forms  $\alpha$ -TeO<sub>2</sub> white powder like and  $\beta$ -TeO<sub>2</sub> which is rare yellowish mineral
- Under pressure  $\alpha$ -TeO<sub>2</sub> is slowly converting to  $\beta$ -TeO<sub>2</sub>.
- TeO<sub>2</sub> 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



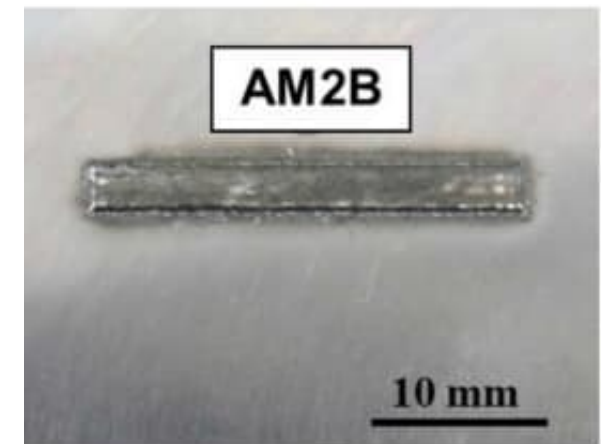
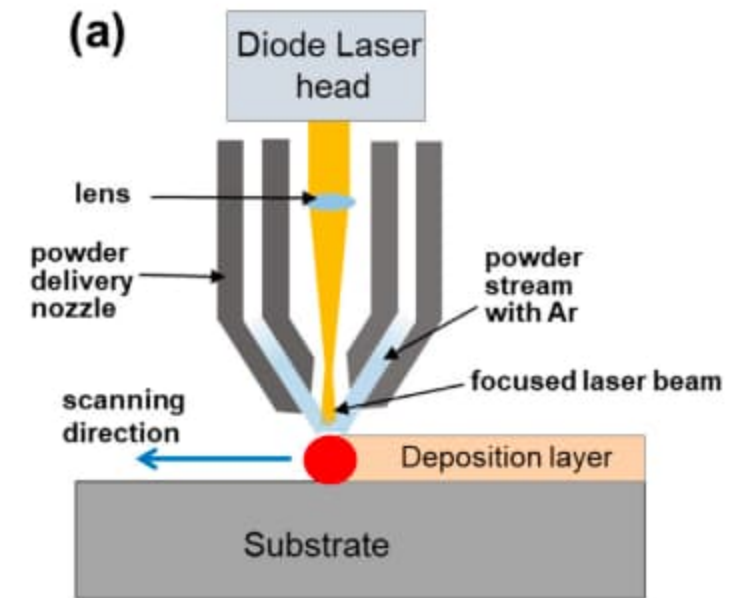
# Applications

- 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.

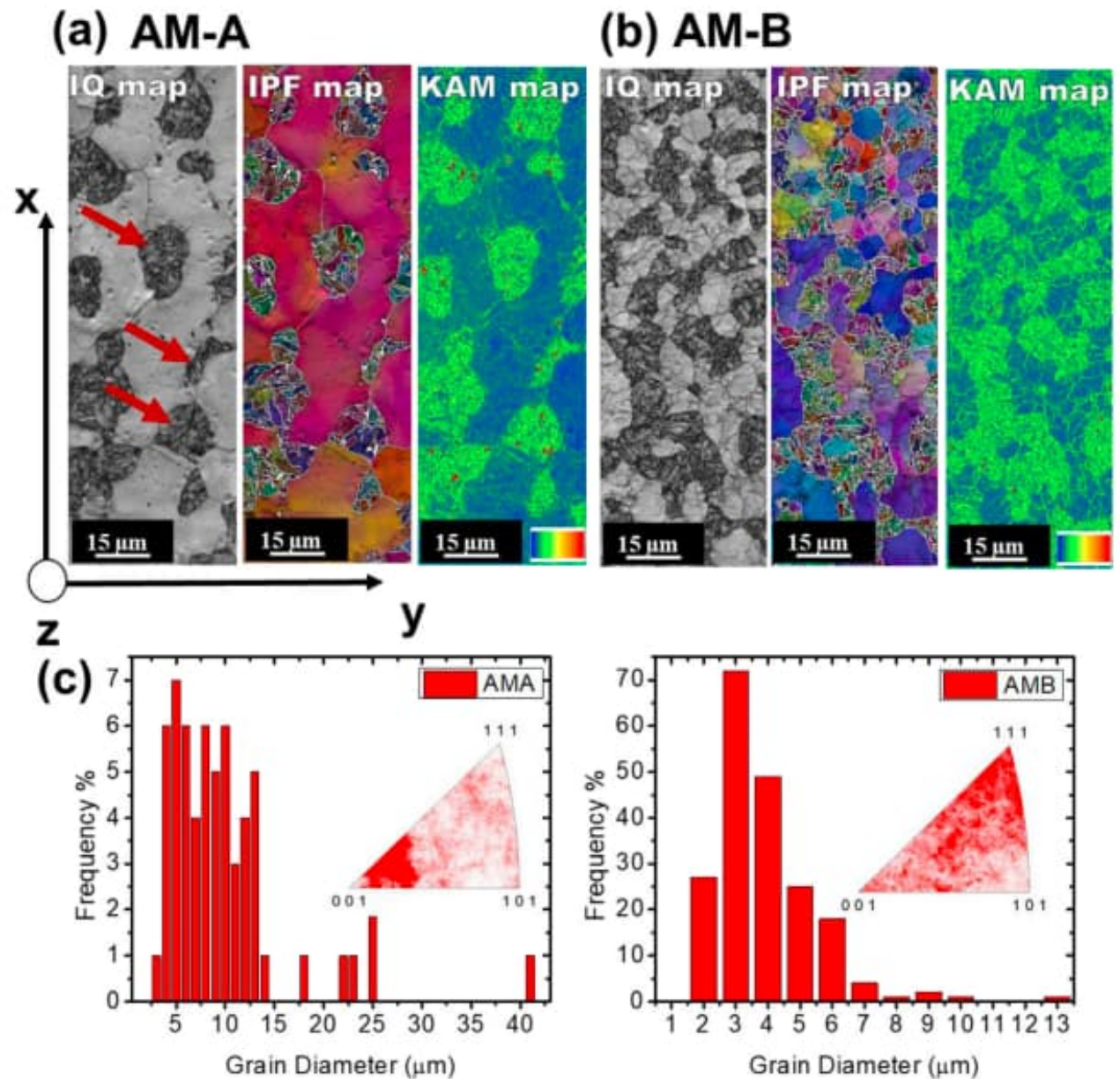


# Effect of tellurium on the microstructure and mechanical properties of Fe-14Cr oxide-dispersion-strengthened steels produced by additive manufacturing

- 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 atmosphere.
- Process parameters were same for both samples.



- The microstructure and the mechanical 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  $\mu\text{m}$
- Without added Te 9,4  $\mu\text{m}$ .



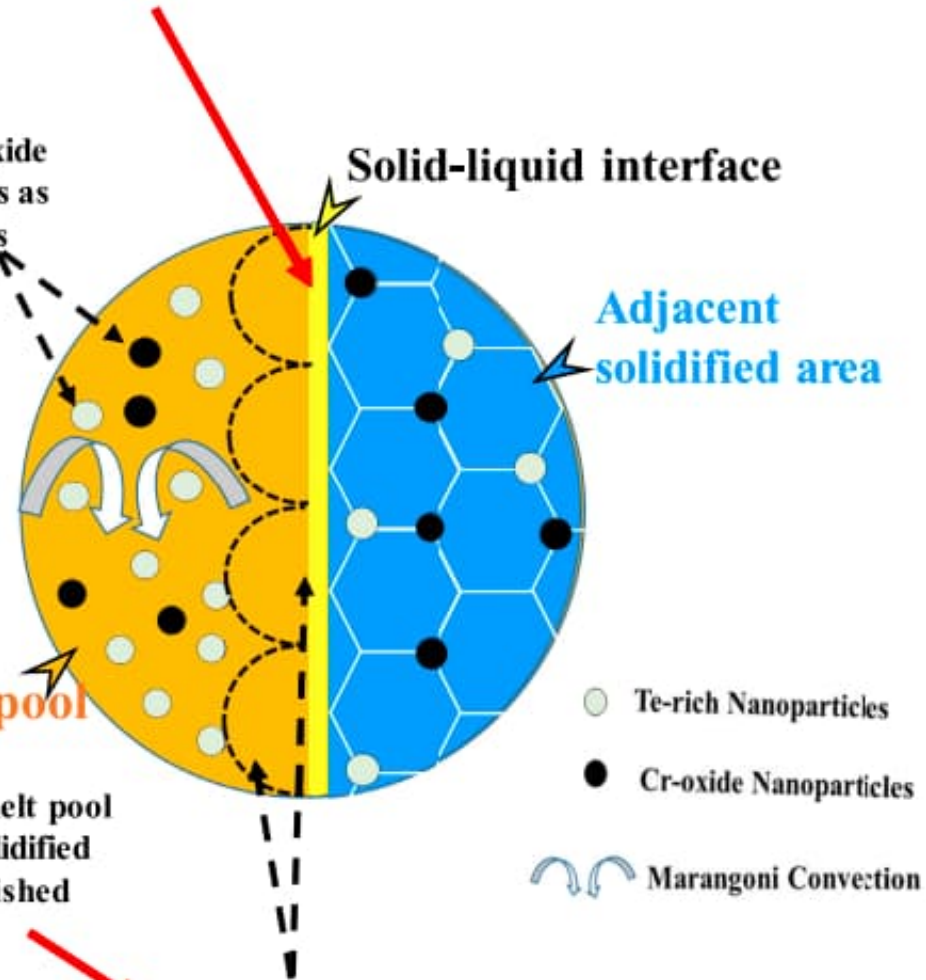
① Temperature gradient and difference in chemical composition generates surface tension and Marangoni convection within melt pool .

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



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

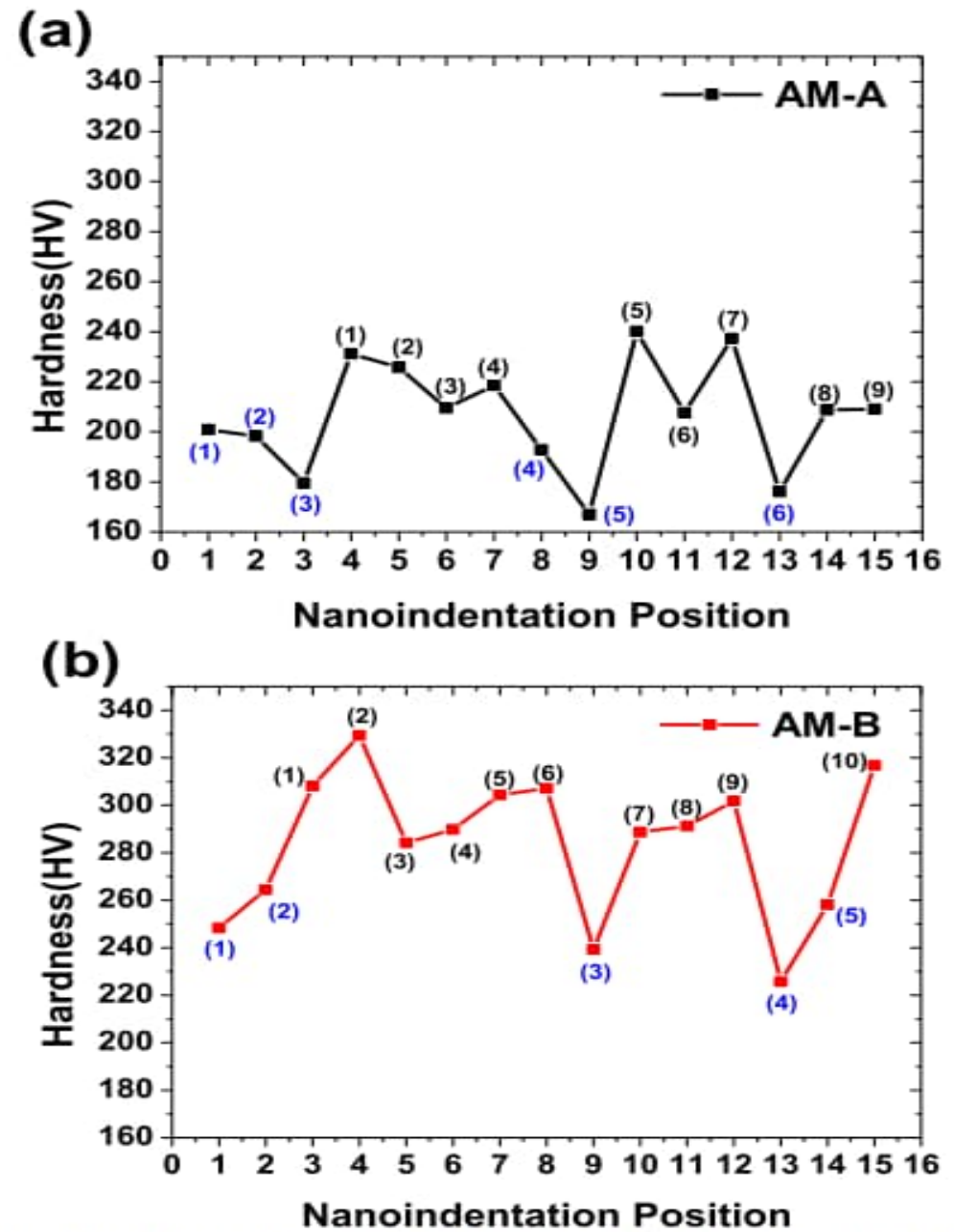
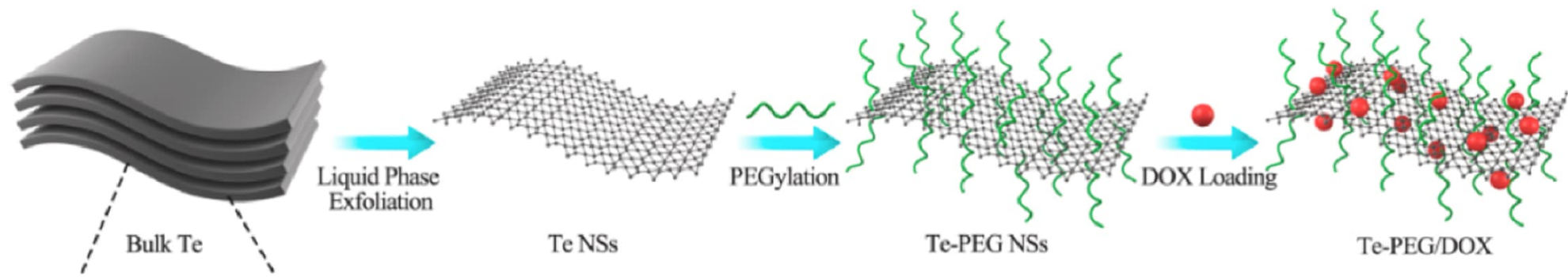


Fig. 9. Nanoindentation results for (a) AM-A and (b) AM-B samples. The parenthesized numbers in blue and black show the hardness values of coarse- and fine-grain regions, respectively (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this 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  $\longrightarrow$  Photothermal transformation
- Te based nanomaterials could be utilized in cancer treatment but there needs to be done more research.



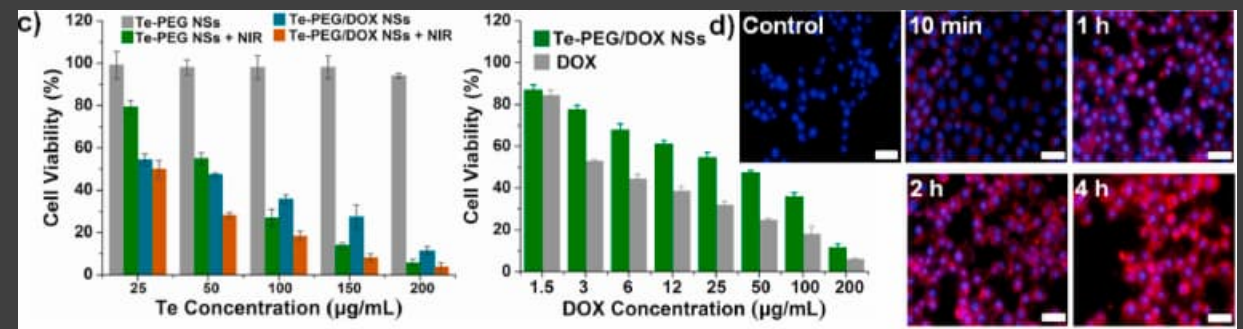
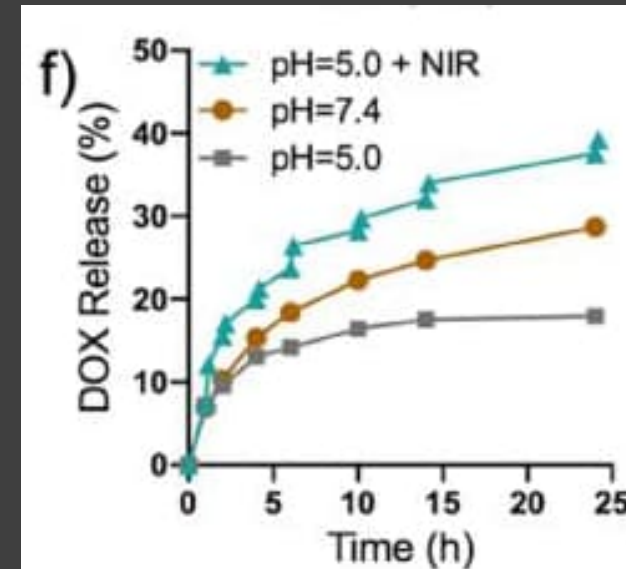


# Biomedical application: Tellurium nanosheets in cancer treatment

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

# 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



# References

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[1] Royal Society of Chemistry. Tellurium. [Online] [Tellurium - Element information, properties and uses | Periodic Table \(rsc.org\)](https://www.rsc.org/periodic-table/element/52-tellurium)

[2] Statista. Production volume of tellurium worldwide in 2020, by country. [Online] [Tellurium global production volume by country | Statista](https://www.statista.com/statistics/1111111/tellurium-global-production-volume-by-country/)

[3] D.M. Flanagan. Mineral Commodity Summaries 2023. Tellurium. U.S. Geological Survey, 2023.

[4] Jović, V. (1998). Tellurium . In: Geochemistry. Encyclopedia of Earth Science. Springer, Dordrecht. [https://doi.org/10.1007/1-4020-4496-8\\_316](https://doi.org/10.1007/1-4020-4496-8_316)

# References

2/3

[5] Umicore. Tellurium. [Online] [Tellurium | Umicore](#)

[6] M. A. Barton, H. B. Jee, Y. N. Min, J. C. Hye, G. K. Hyun, H. K. II, 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.

[7] D. Medina-Cruz, W. Tien-Street, A. Vernet-Crua, B. Zhang, X. Huang, A. Murali, J. Chen, Y. Liu, J. M. Garcia-Martin, J. L. Cholula-Díaz & T. Webster, " Tellurium, the Forgotten Element: A Review of the Properties, Processes, and Biomedical Applications of the Bulk and Nanoscale Metalloid," in *Racing for the Surface: : Antimicrobial and Interface Tissue Engineering*, 1<sup>st</sup> ed., Moriarty, T., Webster, T., Xing, Ed. Springer Cham, 2020, pp. 723-783.

[8] Aurubis. Tellurium Dioxide. [Online] [Tellurium Dioxide \(aurubis.com\)](#)

[9] C. Sarangi, A. Sheik, B. Marandi, V. Ponnamp, M. Ghosh, K. Sanjay, M. Minakshi, T. Subbaiah, " Recovery of Tellurium from Waste Anode Slime Containing High Copper and High Tellurium of Copper Refineries, " *Sustainability*, vol. 15, 2023.

# References

3/3

- [10] Red Optronics. Crystals. [Online] [TeO2 crystal tellurium dioxide - quality crystals supplied by RedOptronics](#)
- [11] Hq Graphene. Bi<sub>2</sub>Te<sub>3</sub> (Bismuth Telluride). [Online] [Bi<sub>2</sub>Te<sub>3</sub> - Bismuth Telluride \(hqgraphene.com\)](#)
- [12] S. Liu, M-A. Légaré, D. Auerhammer, H. Braunschweig, "The First Boron–Tellurium Double Bond: Direct Insertion of Heavy Chalcogens into a Mn=B Double Bond," *Angewandte Chemie.*, 2017, Vol.56(49), p.15760-15763
- [13] T. Helmenstine, Science notes, Periodic table for kids with 118 elements, 2017. Available: <https://sciencenotes.org/periodic-table-for-kids-118-elements/>
- [14] 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](https://doi.org/10.1016/j.bioactmat.2021.11.010))