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SELENIUM AND TELLURIUM: STATE OF THE MARKETS, THE CRISIS, AND ITS CONSEQUENCES

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Selenium and tellurium are used as alloying additions in ferrous and nonferrous metallurgy. The current state of the international and Russian markets for selenium and tellurium is surveyed based on the literature data of the last several years.

Selenium. Selenium comprises $6 \cdot 10^{-5}$ mass % of the Earth's core and is classified as a trace element. It is encountered in sulfides (pyrite, chalcopyrite). The U.S. Geological Survey (USGS) estimates its reserves worldwide to be within the range 80,000–90,000 tons. Selenium is also present in coal and crude oil (0.5–12.0 ppm), which boosts its world reserves by a factor of 80–90. Sludge from the electrolytic cleaning of copper anodes serves as an industrial source of selenium. This sludge contains 5–25% selenium in the form of compounds with noble metals, so that the main objective of technologists is to first extract gold and silver in the sludge and only then extract its selenium and tellurium (in the present sludge processing technology, factories extract Se and Te first and then the Dore alloy: Au–Ag).

The available statistical data do not include all the selenium and tellurium production in the world, so the information given here will be approximate. Total selenium production is estimated to be about 3000 tons/yr, and of the 80 operating copper plants in the world only 20 provide data on whether or not they produce selenium or collect sludge for later recovery of this element.

The main selenium-producing companies

Japan. Mitsubishi Materials Corp., Nippon Mining and Metals Co., Shinko Kagaku Kogyo Co., and Sumitomo Metal Mining Co. – total production 600,000–750,000 tons/yr.

Canada. Noranda Inc. and Falconbridge – 240,000–250,000 tons. The Yukon Zinc Corporation, founded in 2004 and bought in 2008 by China's Jinduicheng Molybdenum Group and the Northwest Nonferrous International Investment Co., plans to produce 340,000 tons of selenium a year beginning in 2010.

Europe. Umicore S. A. (Belgium), Retorte Selenium Chemicals & Metals (Germany), MCP-Sidech (Great Britain – Belgium). Total European production of selenium is 700,000–750,000 tons/yr.

U.S. Phelps Dodge Refining Corp. and Rio Tinto Zinc sell sludge for recycling to Asian nations, but the exact prices are unknown. However, the U.S. accounts for about 20% of the world's production of selenium.

Philippines. The companies Umicore Specialty Chemicals and Pacific Rare Specialty Metals and Chemicals (PRM) produce up to 120 tons of selenium a year.

China. China is the largest consumer of selenium for the production of electrolytic manganese. China itself produces about 400 tons of selenium a year and is increasing its output by 7% annually. The main producers are Jiangxi Copper (120 tons), Yunnan Copper (80 tons), the Jinchuan Group (36 tons), Tongling Nonferrous (30 tons), Daye Nonferrous (20 tons), and Baiyin Nonferrous (15 tons). However, China's need for selenium is considerably greater than the amount it produces, and as of 2009 its imports of this element stood at roughly 1400 tons/yr.

KVAR Company, Moscow, Russia. Translated from Metallurg, No. 4, pp. 19–21, April, 2010.

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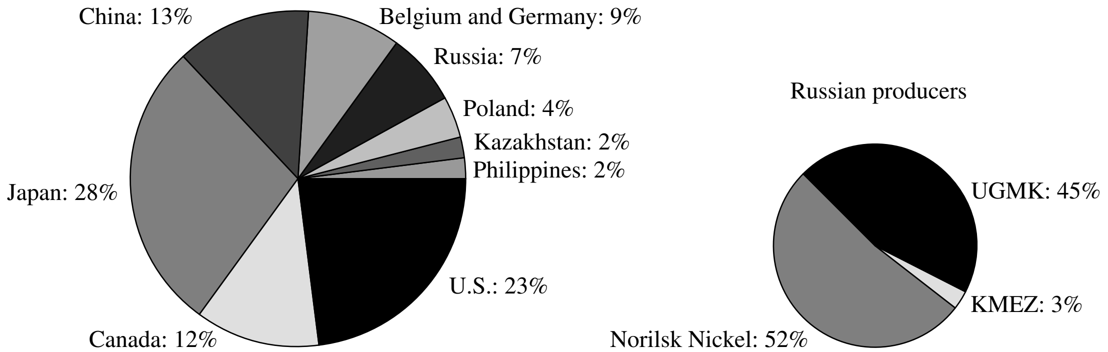

Fig. 1. Selenium production in the world (approximate, sources – USGS, company data).

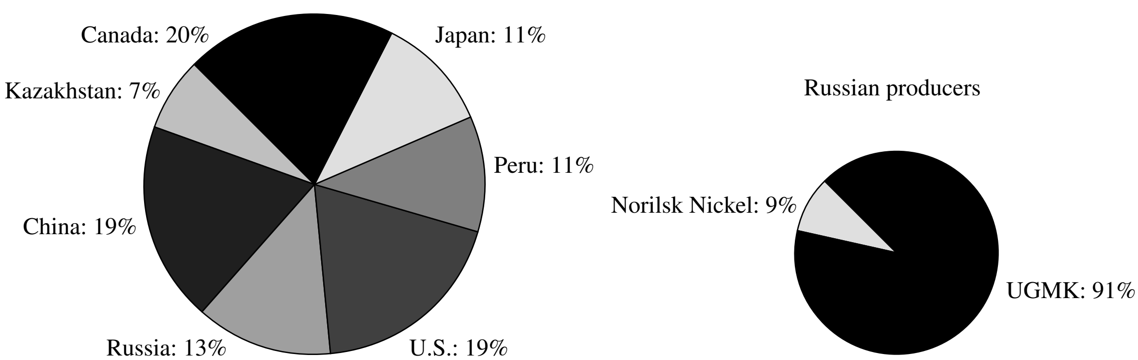

Fig. 2. Tellurium production in the world (approximate, sources – USGS, company data).

Russia. Norilsk Nickel (~80 tons/yr), the Ural Mining-Metallurgical Company (80–90 tons/yr), and the Kyshtym Copper Alloy Plant (4–5 tons/yr). Figure 1 depicts selenium production in the world as a whole and in Russia (the data are approximate).

Use of selenium. In *metallurgy*, selenium is added (in amounts up to 1%) to iron or copper alloys to improve their strength and ductility characteristics. Lead alloyed with selenium is used to make the cells of batteries. The addition of 0.3–0.5% selenium to magnesium-manganese alloys improves their resistance to corrosion. Another important area of application of selenium has become the production of electrolytic manganese in China: Se_2O_3 is added to the bath in the electrolysis of manganese.

In the *chemicals industry*, selenium is used as a catalyst or oxidant in organic synthesis processes, and the rubber industry employs it as a vulcanizing agent and a means of making rubber more durable. Selenium is used to obtain pigments ranging from yellow to dark red.

Electronics. Selenides (CdSe, ZnSe, HgSe, etc.) are used in the production of electrooptic devices – lasers, light diodes, and photodetectors. Solar cells composed of the compound $Cu(InGa)Se_2$ on a flexible polyamide base are widely produced.

Medicine. The population of regions where there is little selenium is at heightened risk to cardiovascular diseases and cancer. The Se content of the soil and water is low in the nations of China, Sweden, and Finland; and within Russia, in the Republic of Buryatiya and Chita oblast. Several countries in Western Europe, the U.S., and China have instituted federal programs to stimulate the production of food additives for humans and livestock, selenium-bearing fertilizers, etc.

Tellurium. Tellurium accounts for $1 \cdot 10^{-6}$ mass % of the Earth's core and is rarer than selenium. As selenium, tellurium is a chalcophile and is encountered in sulfide deposits of copper and polymetallic and gold-bearing ores. The oceans' reserves of tellurium are estimated to be 40,000–50,000 tons.

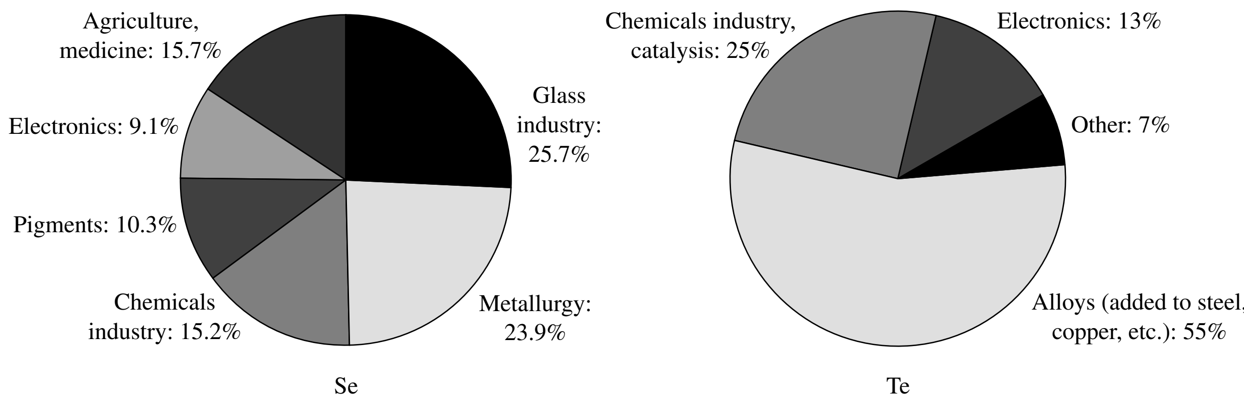

Fig. 3. Use of selenium and tellurium (source – USGS).

As in the case of selenium, the main industrial source of tellurium is sludge formed in the electrolytic cleaning of copper anodes.

The market for tellurium is extremely small, and according to various estimates the total commercial production of this element worldwide is just 400–700 tons a year.

The main tellurium-producing companies

Canada. The production of tellurium in Canada has declined in recent years, going from 100 tons in 1995 to 30–70 tons in recent years.

Japan produces 20–30 tons of tellurium annually and is also its largest consumer (for the metallurgical and chemical industries).

Peru – about 20–30 tons/yr.

U.S. – about 50 tons.

In *China*, tellurium is made by the Shenzhen Jiangton Southern Company and the Zhuzhou Smelter Group. Although no exact figures are published, it is apparent that total output is roughly 50–60 tons/yr. China consumes about 80–90 tons of tellurium annually, and the shortfall is made up by purchases from abroad.

Kazakhstan. Tellurium is produced in this country by the company Kaztsilnk (17–18 tons/yr).

Uzbekistan. Tellurium is made in Uzbekistan by the Almalykskii GMK (no exact figures are reported).

Russia. The company Norilsk Nickel (about 3 tons/yr) and the UGMK (more than 30 tons/yr) produce tellurium in Russia.

Figure 2 shows the total output of tellurium in the world and in Russia (these data are highly approximate).

Use of tellurium. *Metallurgy* consumes about 55% of the available tellurium, with 10% of this amount being used by nonferrous metallurgy and the rest being employed for the alloying of steel and cast iron. Tellurium decreases the amount of nitrogen absorbed by cast iron and steel, refines the grains in steel, and makes it stronger and more corrosion-resistant. In nonferrous metallurgy, tellurium is used to improve the machineability of copper alloys. Lead alloyed with tellurium is used to make durable sheathing for cables such as those used with submersible oil pumps. In the *chemicals industry*, tellurium is employed in catalysts, as a vulcanizing agent in the production of rubber, and as a means of making rubber more durable and elastic. Tellurium is used as a paint and a pigment for glazes, enamels, and plastics. *Electronic and electrooptic device*s – lasers, light diodes, and photodetectors that operate within the radiation range from infrared to ultraviolet – contain semiconductor elements of the groups A^2B^6 (tellurides: ZnTe, CdTe, HgTe, CdHgTe, etc.) and A^4B^6 (PbSnSeTe). Tellurides of lead, tin, mercury, and cadmium are sensitive to infrared radiation, so that the compounds PbSnTe and HgCdTe are extremely efficient as transducers in the IR region of the spectrum.

Solar cells are made of the compound CdTe and reach an efficiency on the order of 11–12%. Crystals of Bi_2Te_3–Bi_2Se_3 and Bi_2Te_3–Sb_2Te_3 are used in thermoelectric devices that are employed in semiconductor coolers, air-conditioning systems, and other types of equipment.

Attempt to predict the growth of the selenium and tellurium markets. In connection with the growth in the production of lasers, light diodes, and photodetectors, tellurium and selenium have become strategically important raw materials. This is borne out by the facts that in 2007 the American company II–VI Inc., which makes optical and thermal devices, bought the Philippine company PRM, and in 2008 the Chinese companies Jinduicheng Molybdenum Group and Northwest Nonferrous International Investment Co acquired Yukon Zinc Corporation.

Growth has recently also been seen in another sector of selenium and tellurium use. The production of electric power through solar cells (solar energy) has become one of the fastest-growing industries in the world and has not slowed even during the current recession. The average annual increase in the size of the market for solar energy was greater than 35% during the period 1999–2008. The industrially developed nations plan to further increase the power obtained from solar plants to 25–30% of total electric power generation by the decade of 2030–2040. In addition to silicon, solar cells are also made of cadmium telluride and the compound $Cu–In–Ga–Se_2$ or CIGS (which contains 10% Cu, 28% In, 10% Ga, and 52% Se). Thus, the demand for selenium and tellurium is rising sharply. In 2010, "solar" applications are expected to push demand to 250 tons/yr for selenium and 200 tons/yr for tellurium. These are very large quantities for such small markets.

However, in recent years – even during the period of economic growth – increases in the production of copper have not automatically signaled corresponding increases in selenium and tellurium production as they did previously. The new technology (the so-called SW-EW technology) that is now being used to leach copper from chalcopyrite ores and was developed at the beginning of the 1990s by Phelps Dodge Corp. (in the U.S.) and Placer Dome Inc. (Canada) is an alternative to the methods traditionally used to smelt copper and obtain it from copper cathodes. The new technology has several economic advantages, but it does not produce an electrolytic sludge that contains selenium and tellurium. While pre-recession estimates had copper production increasing by 3.8 million tons by 2011, roughly 2.3 million tons of this amount will be electrolytic copper and only 1.5 million tons will be electrochemical copper. In other words, in terms of relative units, the raw-materials base for the recovery of selenium and tellurium underwent a contraction even before the recession began.

Now if the worldwide recession leads to a reduction in the production of copper, that will signify an absolute reduction in the size of the raw-materials base for selenium and tellurium. While a greater demand for selenium or tellurium has developed in the scientifically advanced regions, it cannot be satisfied quickly because the growth in the raw-materials base will not be able to keep pace with the growth in demand. The prices for selenium and tellurium may undergo a sizable jump.

All this means that metallurgists may soon feel competition for selenium and tellurium from the "new" science-based regions and experience a shortage of these elements, which are used as alloying elements.