Plasma and laser technologies led industrial research in 1987

by Robert Gallagher

In November 1987, Josef Tylko at the University of Minnesota reported impressive results in developing a plasma technology that would eliminate the United States' dependence on foreign sources of chromium. His experiments were perhaps the most exciting advance in developing efficient, labor-saving industrial applications of lasers and plasmas announced during the year. In addition:

- In February, Amoco Corporation announced invention of a laser process that will increase the yield of production of certain industrial bulk chemicals.
- Dramatic progress was made in developing materials that can conduct electricity without resistance at higher and higher temperatures. These superconducting materials will find industrial application in the mid-1990s.

Chromium extraction breakthrough

The progress in developing plasma technologies to reduce low-grade U.S. chromium ores, may succeed in extricating us from a threat to our national security. We import over 90% of the chromium we use, and we need it for everything from stainless steel to the MX missile. Tylko reported at a conference in Japan that the University of Minnesota team had been able to achieve 90% reduction (more precisely, "metalization") of low-grade Montana chromite ore in a device named the "Sustained Shockwave Plasma" reactor.

Chromite is a compound of iron oxide and chromium oxide. Since chromium is usually alloyed in relatively small proportions with other metals (such as iron), a good process of reducing chromite into ferro-chrome will satisfy most of our chromium needs. The low-grade Montana ore used in the experiments also contained significant amounts of aluminum and magnesium oxides. With this ore, the Minnesota process yielded tiny metallic spheres that were over 90% an alloy of four elements—chromium, iron, aluminum, and magnesium. These spheres were 68% ferrochrome, the remainder of their metallic weight taken up by aluminum, magnesium, and silicon.

Tylko also reports that the Sustained Shockwave Plasma reactor, has successfully separated the metals in "electric furnace dust," a by-product of electric furnace steel refining which is usually considered waste. Electric furnace dust contains iron, zinc, cadmium, and lead. So far, the SSP has been able to produce fractions greater than 90% iron, and greater than 80% zinc.

The Sustained Shockwave Plasma reactor uses an ordinary electric-arc plasma discharge between an anode and cathode in a very inventive way.

A plasma is a gas in which the electrons have been separated from their atoms. The gas used in the recent SSP experiments was argon. A base current of 25 amperes flows between the anode and the cathode. The plasma arc discharge is rotated to sweep out the surface of a cone at the rate of several hundred rotations per second.

This produces "a plasma arc front," which entrains ore particles as they descend from the top so that they descend in a spiral path instead of a straight line, with the result that the ore remains in the plasma for a longer period of time (see **Figure 1**).

The plasma arc discharge is also pulsed above the base current of 25 amperes by 60-80 amperes, 2,000 to 4,000 times per second depending on the rate of rotation of the discharge. The time for the current to switch from the base current to the pulse current or from the pulse current to the base current was estimated to be less than 10 millionths of a second, that is, nearly instantaneous. Therefore, the ore entrained in the plasma is subjected to thousands of nearly discontinuous changes or "shocks" in the current pulse, every second. From this, Tylko named the device the Sustained Shockwave Plasma reactor. According to Tylko, the pulsation increases the rate of the reduction reactions. (See *EIR Quarterly Economic Report*, Oct. 15, 1985, for a more complete description.)

The rate of rotation of the plasma arc and the ratio of the pulse current to the base current, are tuned to the specific ore being reduced through the reactor. In other words, the action of the arc is nonlinear. Tylko writes: "There appears to be also an [electromagnetic] resonance-like phenomenon, namely, the best results are obtained (judged by degree of metallization) for a given combination of orbital speed and base to pulse current ratio, rather than the energy flux itself."

In the recent chromite experiments, it was found that orbital speeds of about 330 cycles per second, with a pulse current of 70 amperes, pulsed 2,000 times per second, were most effective. With this choice of parameters, the Minnesota University group achieved 96.4% metallization of the low grade Montana chromite ore. The ore was 39% chromia, 23% various iron oxides, 15% alumina, 12% magnesia, 7% silica, and a trace of calcia.

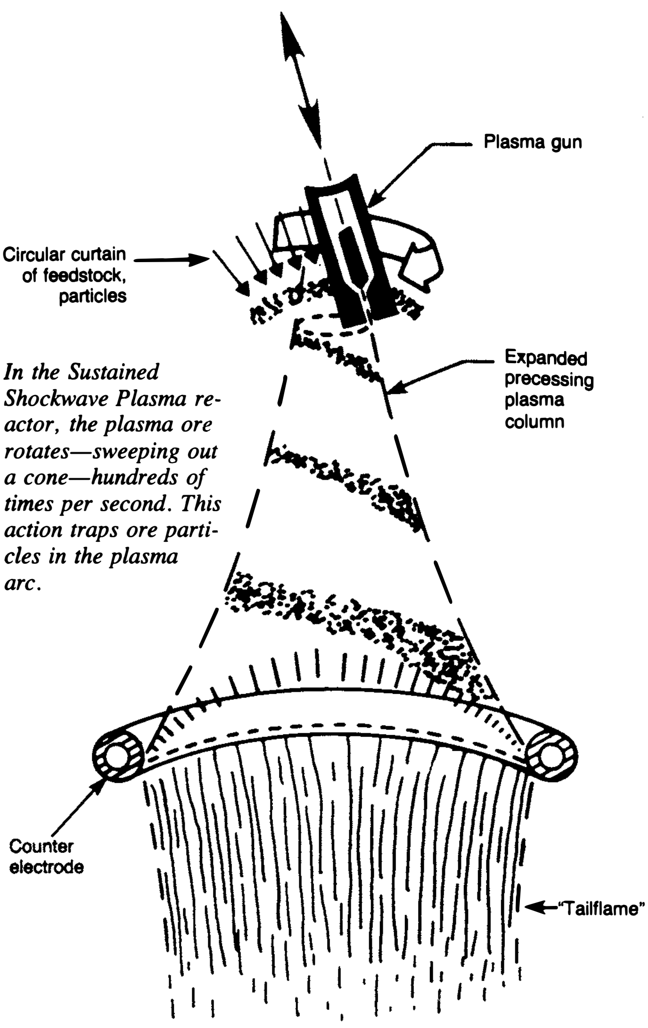
Laser applications

The U.S. Patent Office issued a patent on Feb. 17, 1987 to Joshua Zavelovich and Virupaksha Reddy of Amoco Corporation for invention of a process that will increase the yield of production of certain industrial bulk chemicals.

These processes are dependent for their speed and efficiency on production of highly reactive chemical "free radicals" (atoms or groups of atoms possessing an odd number of electrons, such as bromine) from the molecules in which they are found (for example, hydrogen bromine). The free radicals "link" the separate reactions in a chemical chain reaction so that it propagates.

Until recently, free radicals were produced with heat or flashlamps. Laser radiation is more selective than these processes. As a result, it is possible to increase the number of individual reactions linked in a chain by a single free radical.

FIGURE 1
Principle of the SSP Action



In the Sustained Shockwave Plasma reactor, the plasma ore rotates—sweeping out a cone—hundreds of times per second. This action traps ore particles in the plasma arc.

Zavelovich and Reddy developed a nonlinear "multiphoton" process of generating bromine radicals by photochemical dissociation of hydrogen bromide, to initiate chemical chain reactions that produce ethyl bromide from ethylene with a yield per photon of laser light greater than 10,000 product molecules. (See *EIR,* June 26, 1987 for a complete description of the process.)

Zavelovich and Reddy claim that their process will apply to hydrogen bromide reactions with any of the unsaturated hydrocarbons of which ethyline is the simplest. Even if the process is only applicable to ethyl bromide production, it will be economically viable. The Zavelovich-Reddy patent (No. 4,643,812) reports: "Ethyl bromide . . . is a commercially significant material which has found use as a refrigerant, as an ethylating agent in organic synthesis, and as a grain and fruit fumigant. . . .

"The commercial preparation of ethyl bromide by the hydrobromination of ethylene has been carried out photochemically using high energy ionizing radiation such as gamma radiation from a cobalt-60 radiation source. . . . Although this process has been commercially successful, it requires the use of extensive shielding and the use of a hazardous radiation source. In addition, the use of high energy ionizing radiation such as gamma radiation is undesirable because each photon carries about one million times the amount of energy actually required to dissociate a molecule of hydrogen bromide into atoms. This excess energy is converted into heat and results in an increase in the temperature of the reaction mixture, which is undesirable since the quantum yield of the reaction decreases as the temperature increases."

Superconductivity advances

Prior to 1987, reliable superconducting materials had to operate near the so-called Absolute Zero of temperature, −273°C. This necessitates cooling the materials in a liquid helium bath. Last year, materials were discovered that display superconducting properties at temperatures ranging from −196°C. to room temperature. Superconducting operation at ambient industrial temperatures is obviously the goal; that would require no special cooling technology.

The advance in superconducting materials that will lead to industrial applications soonest, is the development of metal-oxide ceramics that superconduct at −196°C. Materials can be cooled to that temperature with liquid nitrogen, an abundant element which is easier to condense than helium. Superconducting has been demonstrated with relatively small particles of material. The principal problem remaining before these materials can be applied to industrial and military uses, is the fabrication of larger pieces. Once this is solved over the next 5-10 years, we will see the new superconducting materials appear in magnet technology for accelerators, radio frequency weapons, and energy production.