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Lasers will optimize control of chemical processes in industry

by Delia Arajo de Lozano

Lasers will soon become a powerful tool for the chemical industry. Laser chemistry is the science of selective initiation and control of chemical reactions. Nothing mysterious is involved. Chemical reactions respond to different kind of stimuli, including temperature, pressure, concentration of the reactants, electronic excitation, as well as the use of some catalysts which speed up the reaction. The handling of these stimuli by the chemist provides the means to influence the progress of the chemical reaction. Through the use of lasers, chemists can influence these parameters much more accurately than ever before and in some cases in a revolutionary way. Thus they will achieve better control over chemical processes in industry.

Many laser applications on chemical reactions are being tested at the laboratory or pilot plant level by both governmental and private company scientists. These applications will be available at industrial scale before the turn of this decade, provided that they prove to be economically feasible.

There is no question that lasers can been used as a useful tool in biological as well as in medical research. Brookhaven National Laboratory's scientists have been using lasers as tools to understand many basic biological processes such as photosynthesis, and analogous work is being done in many other research laboratories.

In terms of the industrial level applications, the most obvious and immediate ones are reaction diagnosis, chemical analysis, and process control. That is to say, the use of lasers as sensors (using laser spectroscopy), in order to determine what chemical and physical parameters should be changed in industrial processes so that the ongoing chemical reaction be placed in optimal conditions. For instance, Exxon Research and Engineering Co.'s scientists, located at Linden, New Jersey, are working on a very accurate laser-based thermometer for controlling industrial pyrolysis (specifically cracking) processes which require a very high temperature at which most other thermometers are ordinarily not able to function. The very fact that temperature can be controlled means that cracking yield can be increased by a factor of two or three.

We will not discuss here in detail these immediate process control applications, which are now generally acknowledged. Rather, we will discuss laser-induced chemistry, i.e., the use of tuned lasers to selectively couple energy into a chemical process. Depending upon the nature of the excitation, the specific reaction conditions, and the nature of the process being triggered, a broad diversity of chemical reactions may follow laser activation.

Laser techniques can accomplish the following:

- Laser techniques can selectively separate isotopes much more efficiently than currently used separation techniques, lowering cost while saving energy. Laser isotope separation could cheapen by many millions of dollars the process of enriching crude uranium to produce the fissionable isotope U235, assuring an inexpensive supply of fuel for nuclear fission plants. The current uranium enrichment process, gaseous diffusion, costs $87 per separative work unit (SWU), not taking into account the capital cost of the plant. The Advance Vapor Laser Isotope Separation costs approximately $21 per SWU, and will be even cheaper when laser equipment is produced industrially. Lawrence Livermore National Laboratory is working on this technology using visible lasers.

The process could also be used to isolate hazardous radioactive isotopes from nuclear waste, for example rare earth metal isotopes, making the useful radioisotopes available, and reducing vastly the amount of disposed waste. This range of newly available isotopes could supply useful new chemicals for basic research in biology and medicine. AVCO Everett Research Laboratory, located in Everett, Massachusetts, is developing laser-induced photo-ionization of atoms of one isotope followed by electrostatic collection. The vice president of that laboratory's isotope research told *Chemical and Engineering News* in 1982 that the cost of building a pilot plant for that process would be $2 million.

- Lasers can selectively purify expensive materials such as rare earth metals. Having these rare metals available could make possible the creation of new materials and metal alloys that would be impenetrable to fast neutrons produced in the fission and fussion reaction, allowing development of more advanced energy-dense reactor design. For instance, a steel company located in Pittsburgh is producing Europium, a very scarce (and therefore very expensive) rare earth metal, using ultraviolet laser photochemistry. They are making, at the experimental level, new alloys of steel-Europium (0.5 percent to 2 percent Europium), which have proven to be stronger than ordinary steel. Dr. G. Mittal at the Bhabha Research Institute in India is also working on this technique.

- Novel materials can be produced by laser. The principle used here is to activate specific species in a mixture. For instance, CO_2 laser-induced production of refractory solid particles such as: silicon (Si), from gas phase silane (SiH_4); silicon nitride (Si_3N_4), from silane and ammonia ($SiH_4 + NH_3$); and silicon carbide (SiC), from silane and ethene ($SiH_4 + C_2H_4$). These refractory solid particles are formed as polycrystalline or amorphous particles depending on reaction conditions. The particle size distribution is relatively narrow, which should allow the particles to be more effectively agglutinated, leading to ceramics with superior properties, which could then be used in new industrial processes.
- Laser-initiated chain products such as polymers, plastics, rubbers, etc. could be more cheaply produced. Many conventional synthetic reactions involve free radical chain-reactions that, once initiated, propagate readily, producing many product molecules per single radical initially formed. Radical reaction usually requires much more energy to initiate than to propagate; in fact, in a thermal process, the temperature which is high enough to initiate the reaction is generally much higher than what is required to assure the production of sufficient free radicals. Laser initiation of the chain reaction produces the desired free radical by means of selective excitation of the desired radical through the laser's high energy density. It provides a means by which the operating temperature can be lowered to that required for propagation, improving thermal stability and helping eliminate undesirable side chain-reactions. Thus, lasers could cheapen industrial processes not just by lowering temperature requirements, but also by avoiding purification steps. This very reduction of power cost and of production time is very attractive in itself.
- Production of catalytically active species by laser in the reacting medium itself could double, triple, or quintuple the efficiency of the chemical process. A number of experiments have been done on the production of organo-metallic complexes with high reactivity because of vacant binding sites around the metal atom. These active sites produce considerable catalytic activity. For example, iron pentacarbonyl ($FeCO_5$) in solution has been converted by ultraviolet lasers into iron tricarbonyl ($FeCO_3$), which subsequently induces reactions such as olefin isomerization, hydrogenation, and hydrolyzation.

At present, there are no examples of the use of lasers to produce catalysts in industrial processes; however, it is clear that lasers can use to cleanly produce high concentration of catalytic species *in situ* at desirable points in a real reactor on an almost arbitrarily short timescale and that the subsequent reactions of the catalyst may be produced with electronic equipment, thus automating the whole process.

- Laser techniques used for pyrolysis could provide in the near future homogenous processes, in which a single product could be produced, eliminating expensive purification steps. Pyrolysis has been used to obtain valuable organic products such as aniline, phenol, and light hydrocarbons from cracked pyrolysis. Scientists in SRI International's chemical kinetics department have been worked with infrared lasers to produce nitro-benzene pyrolysis by means of laser-powered homogenous pyrolysis (LPHP), which has proven to be succesful on a number of low-molecular-weight model substrates. LPHP utilizes an unreactive bath gas (in this case N_2) to absorb the infrared radiation and to transfer this energy by collision to substrate molecules, since if pressure is high enough, thermal distribution of energy take place faster than the chemical reaction. Their results show that laser pyrolysis is almost purely homogenous, in contrast to conventional (hot-wall) pyrolysis, which leads to compounds generated heterogenously and thus to impurities. Moreover, laser homogeneous pyrolysis overcomes three crucial problems of the currently used pyrolysis: 1) the laser technique eliminates hot wall problems because of homogenous heating; 2) the maximum temperature achieved by the laser technique is more than twice that achieved by the current process (2000 versus 900 degrees Celsius); and 3) the heating rate is 10 billion degrees Celsius per second using laser pyrolysis, compared with 100 degrees Celsius per second from the current process.

- Lasers would make possible massive production of vitamins, proteins, and antibiotics, among other biochemical products. In biochemical synthesis, the critical point is the selective excitation of the reacting molecule. In the case of Vitamin D production, the production itself is through the photo-induced change in the ergosterol molecule (Vitamin D precursor), at present produced by arc lamps, with a yield of approximately 35 per cent. The use of ultraviolet lasers will improve the yield to 80 per cent. Several private companies are working on these process at a pilot plant level, for example, Dow Chemical and the Batelle Columbus Laboratory.

The advantages of laser technology in this field are enormous, speeding up production time, decreasing operational cost, increasing the level of production, and reducing the equipment necessary for production.

- Modification of surfaces and production of surface films or coatings by laser-induced chemistry are already considered economically feasible processes. Processing is confined to the near-surface region and the bulk material is not disturbed. Thus lasers can be applied to annealing, alloying, and curing processes. For instance, Mobil Chemical company has worked with very good results on the application of electron beam radiation to curable materials, such as resins. Their economical analysis shows that electron beam radiation coating costs from $1.50 to $2.50 per pound.

Part II: Malaysia Survey

Crackdown on the drug traffickers

by Paul Zykofsky

Every day the leading newspapers in Malaysia publish a special section highlighted by a drawing of a skull titled "*Dadah* watch."

Dadah is the name given to dangerous drugs in Malaysia and the *Dadah* watch column is part of the government's campaign to stamp out drugs launched by Prime Minister Mahathir on Feb. 19. As Deputy Prime Minister and Home Minister Datuk Musa Hitam explained to *EIR* in an exclusive interview, Malaysia "considers the drug menace as a security threat." Dangerous drugs, he added, "are killing the young people, which is the biggest potential that the country has in order to develop."

The government campaign involves tougher anti-drug laws, expanded rehabilitation facilities for addicts, and a nation-wide publicity campaign involving all sectors of the society.

A national task force

In the recent period, since Deputy Prime Minister Musa took over the Home Ministry, a nationwide anti-*dadah* task force has been established to centralize and coordinate the fight against drugs. Several members of the task force explained the problem faced by Malaysia to this correspondent. Although no dangerous drugs are grown within the country, Malaysia is a transit point for heroin and opium produced in the nearby Golden Triangle region covering northern Thailand, Burma, Laos, and China. Drugs passing through Malaysia make their way to both Europe and Hong Kong.

Local consumption of drugs first emerged a problem in the late 1960s and early 1970s when American soldiers on leave from Vietnam and hippies from the United States and Europe began visiting Malaysia and creating a local demand for hard drugs.

The situation worsened considerably in 1975-76 when young Malaysians themselves increasingly began to take drugs. At present there are some 79,000 drug addicts who have been caught or who have voluntarily registered with the