Fraunhofer IST

Diamond-based generation of ozonated water

Disinfection and pollutant reduction of water and surfaces without the addition of chemicals

Water purification by means of diamond electrodes.

Whether for the reduction of micropollutants in drinking water for the fight against germs on surfaces, the prevention of biofilms in ultrapure water systems, cooling devices and equipment used in food processing, or the reduction of pests in soil and plants: In many applications, pollutants must be reduced or removed efficiently and, wherever possible, without the addition of chemicals such as anti-scalants or biocides. All of these applications therefore require powerful oxidants such as ozone, hydrogen peroxide or hydroxyl radicals that can destroy the pollutants.

Electrochemical oxidation with diamond electrodes (EAOP®)

One solution approach are electrochemical advanced oxidation processes (EAOP®), which have already been the subject of research and development at the Fraunhofer IST for many years. The oxidants are thereby formed directly from the water molecules. The significant advantage of this technology is that no chemicals have to be added.

The EAOP® processes are based on the utilization of diamond as an electrode material: With diamond, particularly high voltages can be applied to the electrodes without the water first splitting into hydrogen and oxygen. As a result, diamond electrodes can be used to produce ozonated water in a very energy-efficient and low-maintenance procedure.

Disinfection and pollutant degradation in water cycles

With the aid of electrochemical oxidation, diverse challenges can be solved in both natural and industrial water cycles in order to obtain contaminant-free and germ-free water. In this context, the Fraunhofer IST offers various systems and solutions which have already been developed for specific customers:

Decentralized drinking-water supply
For the decentralized and energy-autonomous supply of drinking water to rural areas, the Fraunhofer IST, in collaboration with partners, has developed a multi-stage treatment technology for drinking water, during the final stage of which EAOP® processes with diamond electrodes are utilized for germ reduction. Two of the plants, which were developed as container solutions and which are operated with the aid of solar energy, have been set up in Mozambique and South Africa and have demonstrated their ability to provide drinking water in compliance with WHO standards (further information at https://safewaterafrica.eu).

Electrochemical CIP process for ultrafiltration
Ultrafiltration (UF) is a commonly used process for water purification and the treatment of drinking water. The cleaning of UF modules by means of electrochemical oxidation during continuous UF operation can also be carried out in the case of natural surface water or well water – thereby avoiding river decline caused by biofouling – without the need to use external cleaning-in-place (CIP) chemicals.

Groundwater remediation
Groundwater is often polluted as a result of contaminated sites. By means of diamond electrodes and EAOP® processes, organic pollutants such as solvents, lead organics or cyanides can be degraded without the necessity of adding chemicals. Upstream membrane filters concentrate the pollutant stream and increase the energy efficiency.

Cold sanitization of ultrapure water plants
In modern water treatment, pure and ultrapure water systems are preferentially used in the pharmaceutical industry, healthcare, biotechnology, energy technology and semiconductor production. These installations require special and complex measures during maintenance in order to minimize contamination through microorganisms and to prevent the formation of biofilms. Once a biofilm has formed, it can, in the worst case, render the entire installation completely unusable. Through the utilization of the cold-sanitization process on the basis of diamond electrodes, the direct electrochemical production of ozone in the water can prevent the proliferation of microorganisms in the ultrapure water system and sustainably degrade existing biofilms.

Disinfection in agriculture, plant cultivation and food processing

Irrigation
As a result of increasing drought, there is a growing global need for new sources of water for the irrigation of crops. Both heavily contaminated river water and municipal wastewater which has been treated by wastewater treatment plants can be subjected to EAOP® processes in order to reduce micropollutants and germs to such an extent that it can be safely utilized for irrigation.

Agricultural and food hygiene
Microorganisms can form on food or on the surfaces of food-processing equipment, such as large-scale peeling or sorting plants, thereby not only causing spoilage but possibly also leading to foodborne infections that are hazardous to health. In order to reduce germ counts during the processing stage and ensure low-germ cleaning of operating equipment in accordance with national food hygiene regulations, mobile or stationary disinfection systems with EAOP® technology can be deployed.

Environmentally friendly control of soil and plant diseases
The possibilities for controlling soil diseases and plant pests are often not suitable in fruit-growing centers or tree-nursery areas. As an alternative to the current practice of soil disinfection via fumigation or the use of pesticides, the short-term and residue-free treatment with ozonated water is suitable. Ozone functions by splitting off an oxygen atom when it comes into contact with organic compounds and leads to oxidation, i.e. cell walls, membranes and virus shells are dissolved. Compared to other disinfection measures, the utilization of ozonated water therefore represents a cost-effective and ecologically compatible solution for reducing the economic damage caused by soil disease or pest infestation.

Demonstrator systems

Among the common disinfectants, ozone in dissolved form in water enables safe and efficient application, in particular in indoor areas. Ozone dissolved in water rapidly decomposes again and therefore has to be produced on site immediately prior to its utilization. For this purpose, the Fraunhofer IST has developed two mobile demonstrator systems with which the effectiveness of ozonated water can be tested in real applications directly on site.

Portable spray system
The mobile backpack sprayer is a variant for generating ozone quickly and efficiently directly in the water with the aid of the diamond electrodes developed at the Fraunhofer IST. It is used in order to spray the ozonated water specifically onto surfaces or to "fog" them. Areas of application include the disinfection of handrails, door handles and surfaces in offices and clinics as well as in the field of passenger transport or in agricultural, plant and food hygiene for the reduction of germs or pests.

Mobile backpack sprayer for efficient production of ozonated water for surface disinfection.

Mobile DiaDis unit
For the treatment of larger quantities of (waste) water with ozone, the Fraunhofer IST DiaDis system can be utilized. The mobile electrochemical disinfection system on the basis of diamond electrodes can also be operated directly on site. Typical applications in which pollutants have to be reduced without additional chemicals include the reduction of micropollutants or germs in drinking and waste water or the prevention of biofilms in ultrapure water, cooling and humidification systems or food-processing facilities.

Mobile ozone generator "DiaDis" on the basis of diamond electrodes for on-site generation of ozonated water.

Your collaboration with us

For an economical application of electrochemical oxidation using diamond electrodes, the electrochemical cells must be optimally adapted to the customer's specific conditions. For this purpose, the Fraunhofer IST develops specific electrode geometries and treats them with various diamond modifications by means of highly productive coating technology. In addition, the use of simulation and modeling at the institute enables the flow conditions and the reaction kinetics of the electrochemical cells to be designed and optimized for their respective application.

Our portfolio encompasses the development of prototypes as well as economic production scenarios and the up-scaling to industrial scales – all under the proviso of closed material and substance cycles.

Take advantage of our many years of experience in the field of diamond-coated electrodes and our comprehensive expertise in multiscale simulation, and benefit from our contacts to cell manufacturers.

#WeKnowSolutions

- System for the generation of very strong oxidants: ozone (O_3), hydrogen peroxide (H_2O_2) and hydroxyl radicals ($OH^{\bullet}$)
- Disinfection without addition of chemicals
- Application-specific design of diamond electrodes and electrochemical cells

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