Cold Plasma for Air Purification: A Technical Report Based on Patent Literature

Abstract (Summary)

This report synthesizes information from a collection of patent documents concerning the application of cold plasma technology for air purification. The inventions described address various challenges in air quality management, including the removal of volatile organic compounds (VOCs), halogenated volatile organic compounds (HVOCs), particulate matter, odors, and biological contaminants. The core technologies involve non-thermal plasma (NTP) generation, often using dielectric barrier discharge (DBD), to produce reactive species that decompose or deactivate pollutants. The inventions span diverse applications, from industrial exhaust treatment to indoor air purification and self-disinfecting fabrics.

Background and Challenges

Air pollution, both indoors and outdoors, poses significant environmental and health risks. Traditional air purification methods, such as filtration and chemical scrubbing, have limitations in terms of efficiency, cost, and the generation of secondary pollutants. Many of the patents address these limitations by employing cold plasma technology. Cold plasma, a non-equilibrium ionized gas, generates reactive species like ozone, hydroxyl radicals, and excited atoms, which can effectively oxidize and decompose a wide range of air pollutants. However, challenges remain in optimizing plasma generation efficiency, minimizing harmful byproducts like ozone and nitrogen oxides, and ensuring the long-term stability and cost-effectiveness of plasma-based air purification systems.

Technical Fields of Invention

The inventions discussed in this report fall into several interconnected technological areas:

- **Plasma Generation:** Devices and methods for generating non-thermal plasma, including dielectric barrier discharge (DBD) reactors (US8105546B2, US7767167B2, WO2020158967A1, WO2009105072A1),

corona discharge reactors (US6811757B2), and related power supply and control systems (EP4159246A4).

- **Air Purification Systems:** Integration of plasma generators with other components like filters, absorbers, and reactors to create complete air purification systems (US8003058B2, WO2021029471A1, WO2017152694A1, US11448409B2).
- **Materials Science:** Development of novel materials for electrodes and dielectrics in plasma generators, including catalytically active materials (US8105546B2) and cermet dielectrics (WO2009105072A1).
- **VOC Decomposition:** Apparatuses and methods specifically designed for the decomposition of volatile organic compounds (VOCs) using plasma technology (WO2019132539A1, US8105546B2).
- **Sterilization and Decontamination:** Systems for sterilizing air streams and decontaminating surfaces using plasma-generated reactive species (EP1441774A2, US20080063577A1, EP4153808A4).

Inventions Related to Cold Plasma for Air Purification

The patent documents describe a variety of inventions related to cold plasma for air purification. Key inventions, their novelty, and objectives are detailed below:

- **Dielectric Barrier Discharge (DBD) with Catalytically Active Electrodes (US8105546B2):** This invention focuses on a DBD-based NTP system for destroying VOCs, HVOCs, and organic particulate contaminants. The novelty lies in the use of catalytically active materials for the electrodes and dielectrics. The objective is to enhance the oxidation and reduction of pollutants into simpler, non-polluting compounds. The improvement is achieved by the synergistic effect of plasma and catalysis. (Relevant)

- **Plasma Generator with Porous Metal Electrode (WO2020158967A1):** This invention presents a plasma generator utilizing dielectric barrier discharge, designed for improved indoor air quality. The novelty is in the easily assembled electrode structure that enables high-efficiency discharge and easy replacement of the outer electrode. The objective is to provide a plasma generator with an electrode structure that is easy to assemble, allows for separate

replacement of the outer electrode, and achieves high-efficiency discharge. (Relevant)

- **Hermetically Sealed Electrodes in DBD Cells (US7767167B2):** This invention addresses the problem of electrical shorts in DBD cells caused by contaminant buildup. The novelty is the hermetic sealing of the hot electrodes with a rubber material. The objective is to prevent contaminants from contacting and building up on the electrodes, thereby extending the cell's lifespan. (Relevant)
- **VOC Decomposition Apparatus with Ozone and Oxidation Catalyst (WO2019132539A1):** This invention describes a VOC decomposition apparatus and method that reduces energy consumption. The novelty is the combination of ozone introduction, plasma generation, and an oxidation catalyst in a single reactor. The objective is to decompose VOCs with low energy consumption without separating the VOC and the decomposition apparatus. (Relevant)
- **Air Purification Device with Plasma, Electrostatic Filter, and Absorptive Material (US8003058B2):** This invention presents an air purification device with a combination of a plasma chamber, an electrostatic filter, and an absorptive material. The novelty is the synergistic use of these three components. The objective is to provide improved air purification and filtering for aerosol particulates and VOCs. (Relevant)
- **Air Purification with Separation-Type Electric Discharge Chamber (WO2021029471A1):** This invention focuses on an air purification device and method that avoids the generation of harmful byproducts like ozone and nitrogen oxides. The novelty is the separation of the electric discharge area from the air processing area, using a hydrogen/oxygen mixture gas to form plasma. The objective is to provide faster deodorization, sterilization, and smoke removal while removing fine particles without a filter. (Relevant)
- **Air-Purifying Electric Fan with Dual-Layer Blades (WO2017152694A1):** This invention combines an electric fan with air purification capabilities. The novelty is the use of dual-layer blades and a plasma high-voltage generator. The objective is to provide an electric fan that not only blows air but also efficiently removes solid and gaseous pollutants. (Relevant)

- **Self-Disinfecting Fabric using Fabric Dielectric Barrier Discharge (DBD) (EP4153808A4):** This invention presents a self-disinfecting fabric that generates cold homogenous plasma in the air gaps between the fibers. The novelty is the use of interconnected insulated conductive fibers to create a DBD device within the fabric itself. The objective is to provide a self-disinfecting fabric that does not rely on chemical additives. (Not Relevant)
- **Air Purification System with Electromagnetic Resonance (EP4159246A4):** This invention describes an air purification system that generates plasma using voltage. The novelty is the use of a controller to adjust the frequency and position of power supplied to a linear electrode to maximize the electric field intensity. The objective is to decompose bacteria and viruses in the air by efficiently generating plasma while reducing input power. (Relevant)
- **Plasma Generation Device with Enhanced Electromagnetic Wave Utilization (WO2023149305A1):** This invention addresses the problem of insufficient ultraviolet reflectance in conventional air purification devices. The novelty is a plasma generator comprising a first electrode, a second electrode, a first glass layer, and a first metal film layer, arranged in a specific configuration to enhance electromagnetic wave utilization. The objective is to efficiently use electromagnetic waves, including ultraviolet rays, produced by plasma generated through dielectric barrier discharge. (Relevant)

Applicability and Uses

The inventions described have a wide range of potential applications in air purification:

- **Industrial Emission Control:** Treatment of exhaust gases from industrial processes to remove VOCs, HVOCs, and particulate matter (US8105546B2, WO2019132539A1). (Relevant)
- **Indoor Air Quality Improvement:** Air purifiers for homes, offices, hospitals, and other indoor environments (WO2020158967A1, US8003058B2, WO2021029471A1, WO2017152694A1). (Relevant)
- **HVAC Systems:** Integration of plasma-based air purification into heating, ventilation, and air conditioning (HVAC) systems (US8003058B2, US11448409B2). (Relevant)

- **Sterilization and Disinfection:** Sterilization of air streams and decontamination of surfaces in medical facilities, food processing plants, and other environments where hygiene is critical (EP1441774A2, US20080063577A1, EP4153808A4). (Relevant)
- **Protective Clothing:** Incorporation of plasma technology into protective clothing for use in environments with prevalent bacteria and viruses (EP4159246A4). (Relevant)
- **Waste Treatment:** Sanitization of waste materials using non-thermal plasma to reduce bacterial loads, decompose VOCs, and remove odors (EP3938168B1). (Relevant)

Conclusion

The patent documents reviewed highlight the diverse and evolving landscape of cold plasma technology for air purification. The inventions address critical challenges in air quality management by offering solutions for removing a wide range of pollutants, improving energy efficiency, minimizing harmful byproducts, and expanding the applicability of plasma-based air purification systems. The ongoing research and development in this field promise to deliver more effective, sustainable, and versatile air purification technologies for a variety of applications.

Citations

- US8105546B2 (Relevant)
- WO2020158967A1(Relevant)
- US7767167B2 (Relevant)
- WO2019132539A1 (Relevant)
- US8003058B2 (Relevant)
- WO2021029471A1 (Relevant)
- WO2017152694A1 (Relevant)
- EP4153808A4(Not Relevant)
- EP4159246A4(Relevant)
- US6811757B2 (Relevant)
- WO2023149305A1(Relevant)
- WO2009105072A1 (Relevant)
- US20080063577A1(Relevant)

- EP1441774A2 (Relevant)
- US11448409B2 (Relevant)
- EP3938168B1 (Relevant)