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Using air curtain to control pollutant spreading for emergency management in a cleanroom

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ABSTRACT

The present investigation aims to examine the pollutant dispersion flowfield in an IQC cleanroom. Experimentally, the airflow velocities were measured using a TSI 8495 hot-wire anemometer to inspect the flow characteristics. Three ppbRAE PGM-7240 photoionization detectors were employed to concurrently measure the spatial and temporal distributions of ethanol concentration from a gas-pollutant leaking source. The computational analysis was based on the time-dependent three-dimensional conservation equations of mass, momentum and species concentration for the incompressible isothermal turbulent flow with a k-ε two-equation turbulent model adopted for turbulence closure. Considering a massive amount of gaseous ethanol released from a malfunction machine, we presented a novel application of using an air curtain to resolve the personnel safety concern for emergency management in a contaminated cleanroom. For the cases without and with activation of an air curtain device, the airflow and contaminant characteristics were explored to better understand the pollutant spreading process for contamination control purpose. Numerical simulations were extended to verify if the air curtain device can establish a satisfactory shield for constraint of pollutant dispersal and optimize the sealing performance by systematically varying the parameters of ejection velocity, ejection angle and installation height.

1. Introduction

Contamination control of cleanrooms is a focal issue for assurance of product reliability and personnel safety associated with the fabrication process in a variety of high-precision industries, for instance thin film transistor-liquid crystal display (TFT-LCD), semiconductor, microelectronics and biotechnology [1–3]. Pollutant organic gases, unintentionally emitted from certain solids or liquids during operations, may also cause the serious safety problems in cleanrooms [4,5]. Computational and experimental studies were conducted to examine the motions of the airflow and particles for improvement of contamination control in cleanrooms. The airflow around the physical obstructions could generate turbulence, and thereby draw airborne particles into circulation streams. Various operating conditions were also analyzed to assess the effects of the height/width of cleanroom, porosity of filter and inlet velocity profile on the uniformity of air velocity distribution for simultaneous pollution control of particles and volatile organic compound (VOC) in cleanrooms [6–10]. The influences of the porosity of access panel and damper tuning were inspected to probe the dynamic cross-contamination. The studied results indicated the sulfur hexafluoride (SF_6) concentration rapidly accumulated in the dead recirculation zone [11,12]. Recently, the SF_6 gas was artificially discharged to emulate the emission sources in the etching-thin film sector of a semiconductor fab [13]. An enhanced monitoring strategy is required to mitigate the adverse effects of indoor pollutant dispersal on facilities, products and personnel [14–16]. The proper CFD models were crucial to simulate the hazard events for crisis management in cleanrooms [17]. The performances of various minienvironments were also measured to assess their operating characteristics [18]. Countermeasures were conducted via reducing the air flowrate of exhaust fans and installing additional fan filter units (FFUs) for pollution control in a minienvironment [19].

An air curtain device has been commonly used in different fields to keep goods at a low temperature for appropriate storage as well as to control the access of flying insects, dust and pollutants. With the rapid advances of computational power in recent years, the use of CFD methods in this application has become more prevalent [20–23]. The fire dynamics simulator (FDS) was used to predict the fire-induced smoke spreading and carbon monoxide transport in

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