

# Point of Use (POU) Filtration for Optical Elements in Semiconductor Lithography Tools

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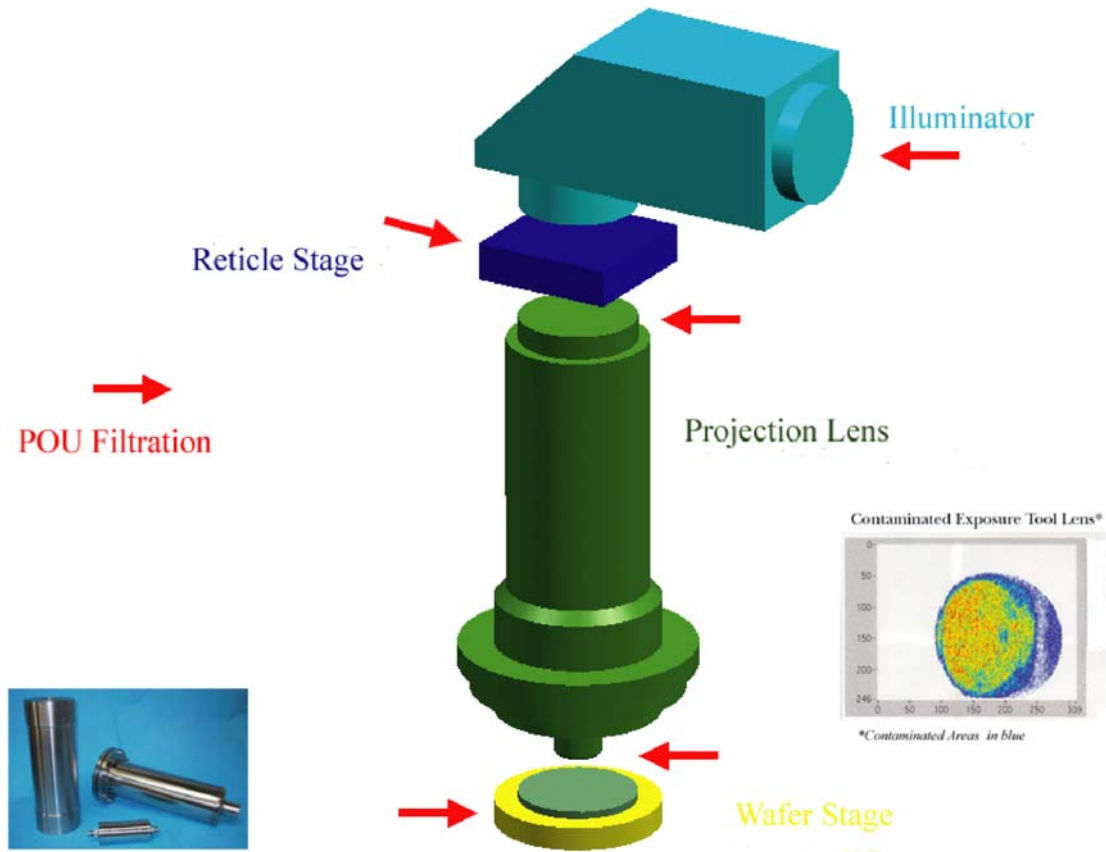
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## **ABSTRACT**

The optimal medium in which DUV resists are exposed is becoming increasingly under investigation by lithography tool manufacturers. These medium requirements have created even more design restrictions for effective filtration methods. Traditional airborne molecular contamination control in tracks and exposure tools has focused on the removal of weak bases that poison the resist. Newer concerns, including the degradation of optics, changes in resist sensitivity, the index of refraction and the demands of tighter geometries, all contribute to the need for quantification and control of gas-phase contamination within exposure tools. As a result, filter manufacturers are required not only to remove a broader spectrum of contaminants (e.g. organic and acid gases), but to supply removal efficiency data, under a variety of conditions such as variable challenge concentrations, mixed stream contamination, dew points, etc. This paper addresses these new concerns, focusing on the efficiency effects of relative humidity for various contaminant streams using a variety of filter media. In addition, the removal of hydrophilic compounds such as ammonia and sulfur dioxide when drying an air stream are also considered.

This ongoing study has contributed to the design of Donaldson's point-of-use air-shower filter used to protect lithography lenses. Preliminary field tests by a major manufacturer indicate that the removal of the specified bases, acids and total organics is below detection limits of <0.1 ppb.



## The Point-of-Use Application Dictates the Filter Design

The environmental conditions of a chemical filter application can dictate the overall performance of the filter; consequently, these conditions can also dictate the choice of filter media and the filter's overall design. The process of adapting the filter media to match the application has never been as critical as it is for deep ultraviolet (DUV) exposure tools.

Various locations within an exposure tool have different controlled environment requirements and, as a result, dictate the filter design. In addition to standard considerations such as airflow, pressure and size, the filter manufacturer must also consider the removal efficiency of the filter for any set of contaminants under the given conditions of temperature, relative humidity, and contaminant concentration.

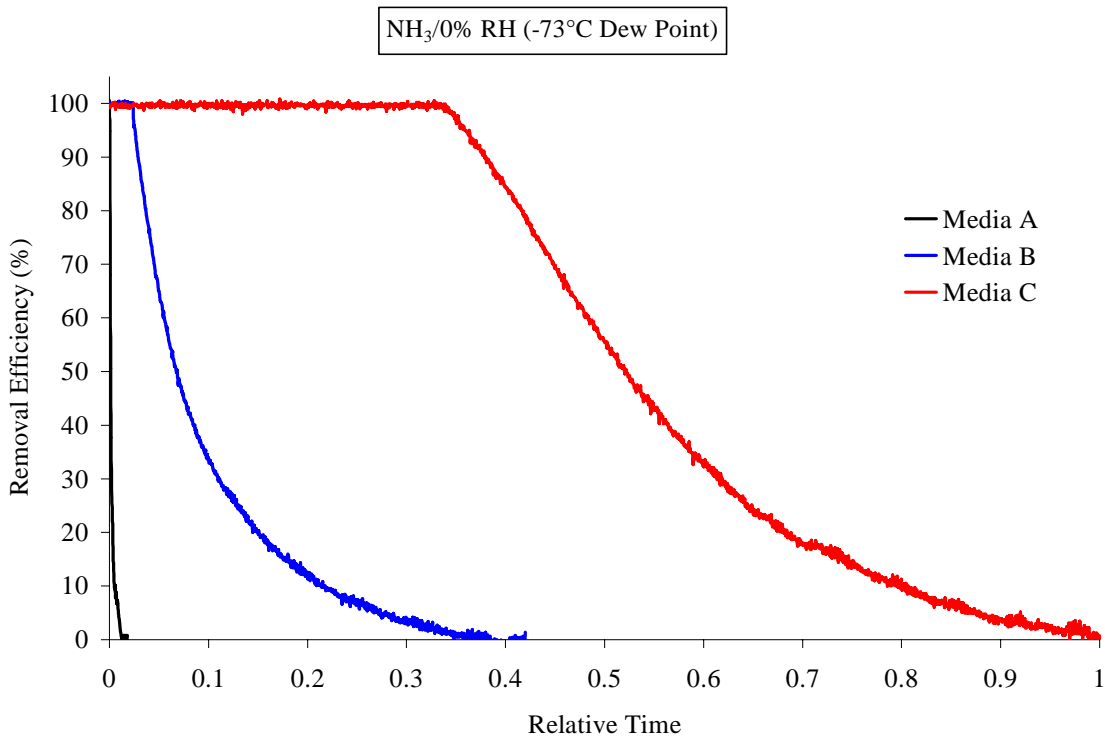
A cost-effective way to achieve these controlled conditions within an exposure tool is with point-of-use (POU) chemical filtration. The major POU applications currently addressed in the tool include the wafer and reticle stages, as well as the illuminator system. It has been proven that well designed POU filters can meet the less than parts-per-billion contamination levels requirements at these locations, while being a relatively inexpensive solution that is easily incorporated into new and existing tools.

Within the wafer stage, a low level of moisture, acidic, basic and organic contaminants is required in order to both protect optical coatings and allow maximum light transmission.

However, some resist coatings also require the presence of moisture in order for the image to print. Conversely, at the reticle stage, the presence of moisture is usually not critical and often requires that the filter operate in a dry air or gas stream. The extreme difference in the environmental conditions of these two examples illustrates the need to completely understand the appropriate mechanism of filtration that will meet the end user's requirements.

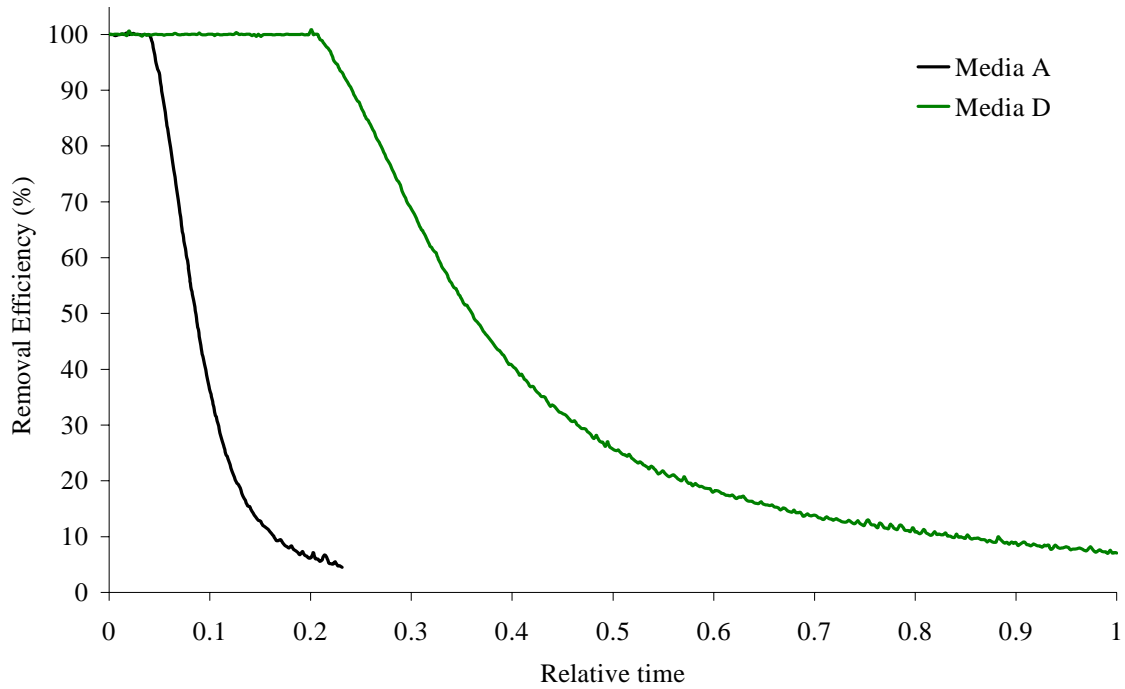
In this work we have evaluated over 200 commercially available and internally developed chemical filtration media under a wide variety of conditions. However, for brevity we have chosen to only compare four of these materials. To this end, we present a series of experimental breakthrough curves that compare the performance of 4 chemical filtration media for the removal of basic ( $\text{NH}_3$ , ammonia), acidic ( $\text{SO}_2$ , sulfur dioxide), and organic ( $\text{C}_6\text{H}_5\text{CH}_3$ , toluene) contaminants. In figures 1-3 below we compare these media under dry conditions (0% RH,  $-73^\circ\text{C}$  dew point at  $25^\circ\text{C}$  dry bulb), and figures 4-6 are under humid conditions (50% RH,  $14^\circ\text{C}$  dew point at  $25^\circ\text{C}$  dry bulb). In some cases we do not compare all four media since some were deemed to be inappropriate for the specific conditions being considered.

**Figure 1: Contaminant Breakthrough Curves at 0% RH ( $-73^\circ\text{C}$  Dew Point)**



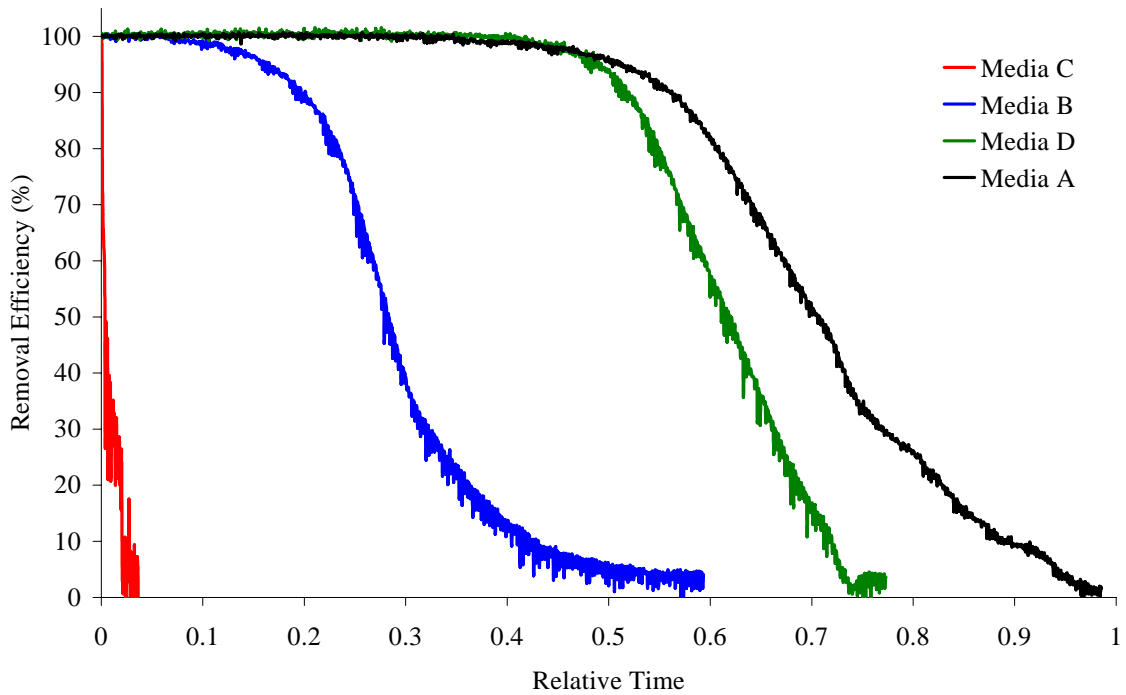
**Figure 2**

SO<sub>2</sub>/0%RH (-73°C Dew Point)



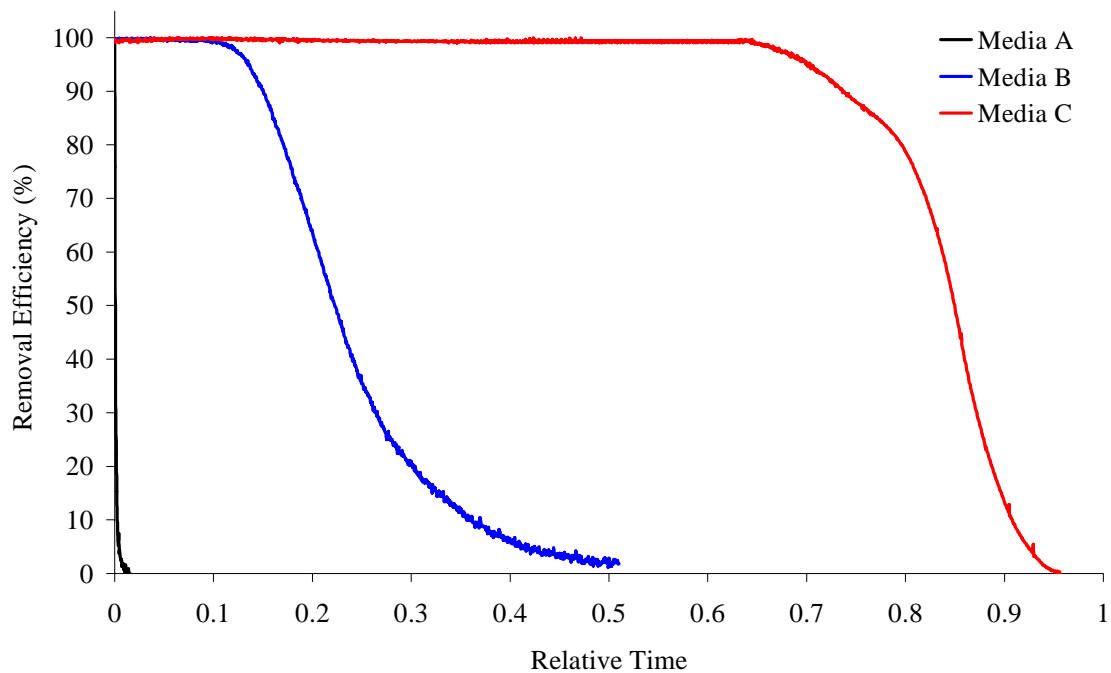
**Figure 3: Contaminant Breakthrough Curves at 50% RH (14°C Dew Point)**

Toluene/0%rh (-73°C Dew Point)



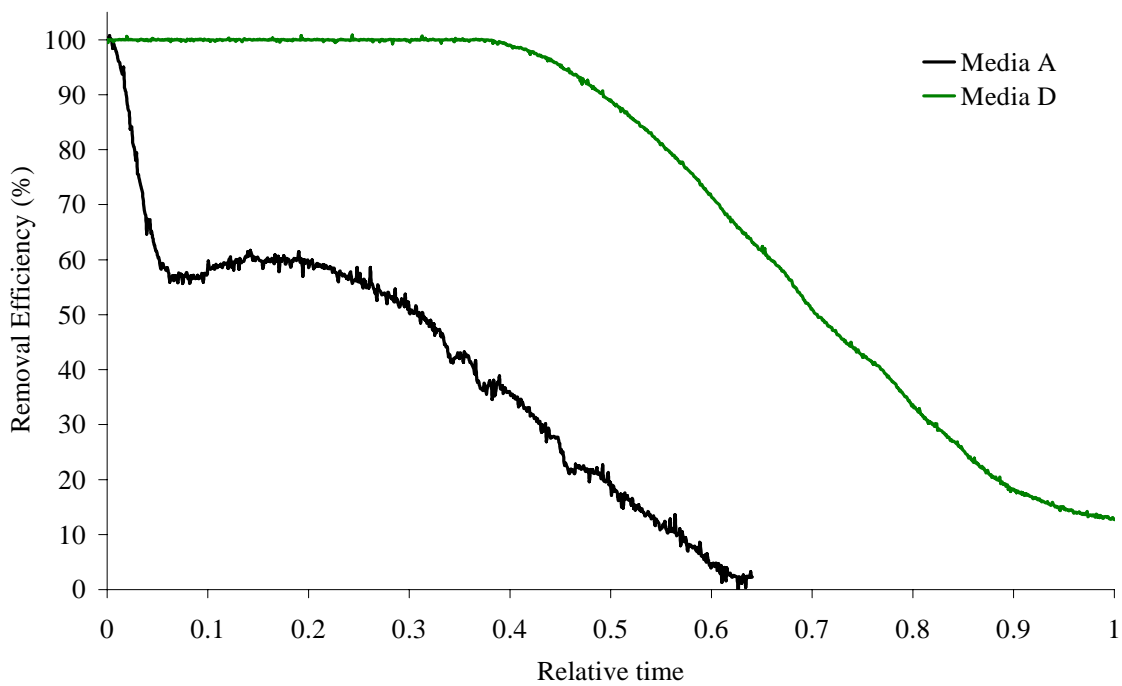
**Figure 4**

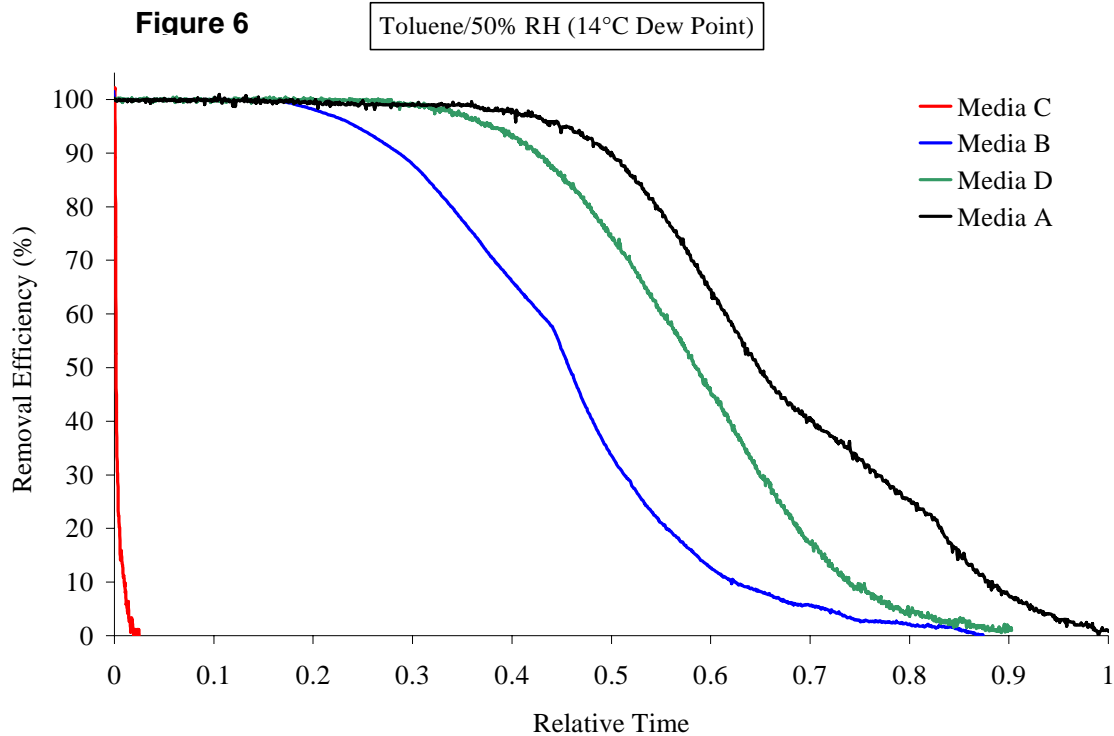
NH<sub>3</sub>/50% RH (14°C Dew Point)



**Figure 5**

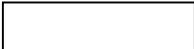
SO<sub>2</sub>/50% RH (14°C Dew Point)



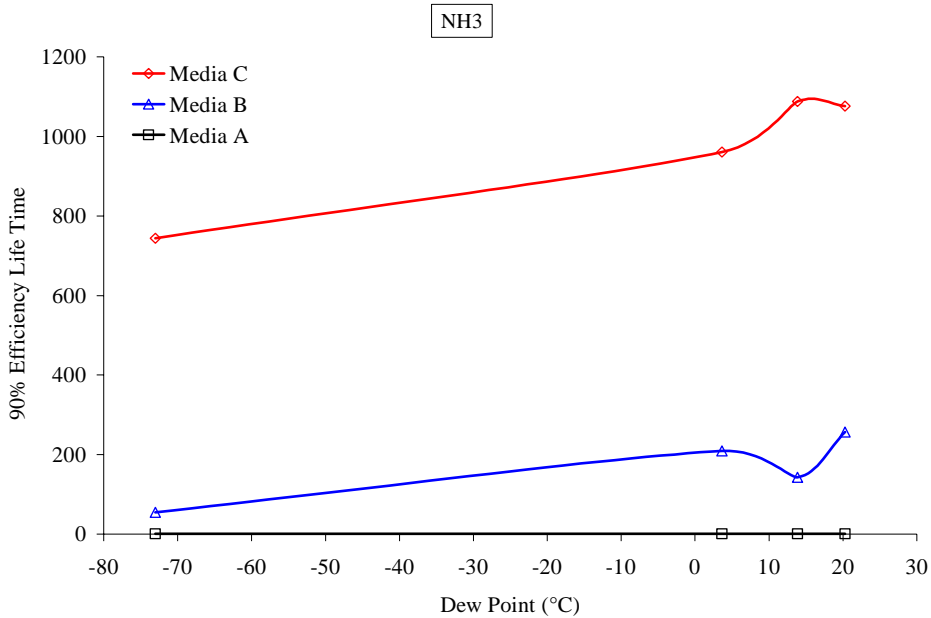


At both 0% RH and 50% RH the best performing media are Media C for basic contaminants, Media D for acidic contaminants, and Media A for organic contaminants. These three media maintain greater than 99% removal efficiencies for periods of time that meet, or exceed, the tool manufacturer's current requirements.

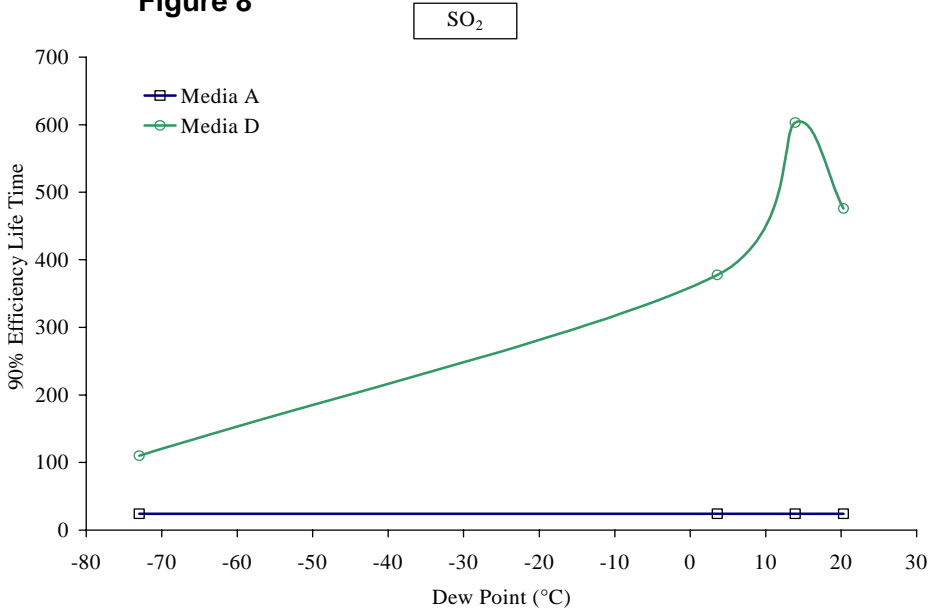
As a result of considering such a large range in humidity, it is evident that the presence, or absence, of moisture has a significant impact on the performance of these media. For some media the presence of moisture adversely affects its performance, whereas for others it enhances its performance. These effects can easily be observed in the series of filter efficiency curves presented below (figures 7-9) as a function of dew point. Over the dew point range of 21°C to -73°C, the removal efficiency life of Media B for basic contaminants drops by approximately 80 %, but it only drops by approximately 30% for Media C. For acidic contaminants over the same humidity range, the removal efficiency life of Media D drops by approximately 75%, but Media A is unaffected. Conversely, for the removal of organic contaminants over the dew point range of 14°C to -73°C, the removal efficiency life of Media A and D increase by approximately 57% and 65%, respectively.



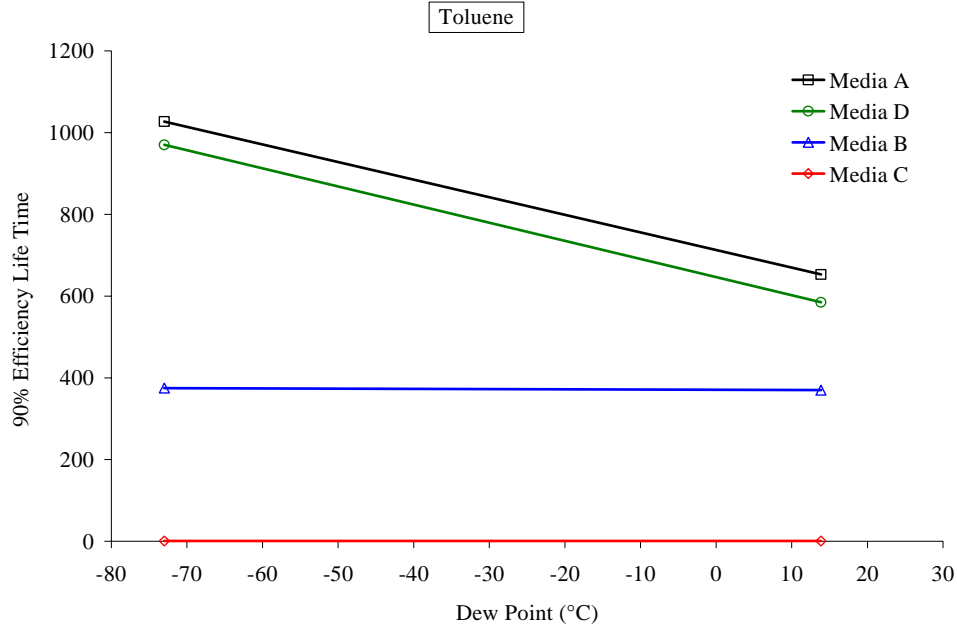
**Figure 7: Effect of Dew Point on Chemical Filter Media Removal Efficiency**



**Figure 8**



**Figure 9**



**SUMMARY**

Minor changes in environmental conditions (e.g. humidity) have shown to significantly affect the performance of filter media. Consequently, various point-of-use (POU) designs were considered for specific filter designs. Two prototype POU filters were developed using the test results of this work as a guideline to meet the critical environment requirements within an exposure tool. These prototype filters were designed to effectively remove basic, acidic, and organic airborne contaminants at the wafer and reticle stages, as well as in the illuminator system. In addition to the media performance results, actual exposure tool requirements for construction material off-gassing, size restrictions, pressure drop and flow rates were considered in designing these filters. The filter life estimates at 0% RH and 50% RH for known exposure tool challenge contaminant concentrations are given in the two tables below. As intentionally designed, the table summary shows that base contaminants breakthrough first, possibly resulting in "T-Topping." Although undesirable, such an event may be considered an inexpensive "end of filter life indicator" when compared to the costs associated with repairing damaged optical elements following organic and acid contamination exposure. A more desirable filter change out method is to generate a preventative maintenance schedule, drawn up in accordance with filter life estimation models using validated fab ambient conditions and filter media performance results.

**Prototype Filter Life Estimates for NH<sub>3</sub>, SO<sub>2</sub>, & Organics When RH 0%**

Challenge Contaminant	Challenge Concentration. (ppb)	Filter Life Estimate (years)	Estimated Filter Efficiency (%)
Base*	100	2.18	>99
Acid*	5	>4	>99
Organic*	100	9.01	>99

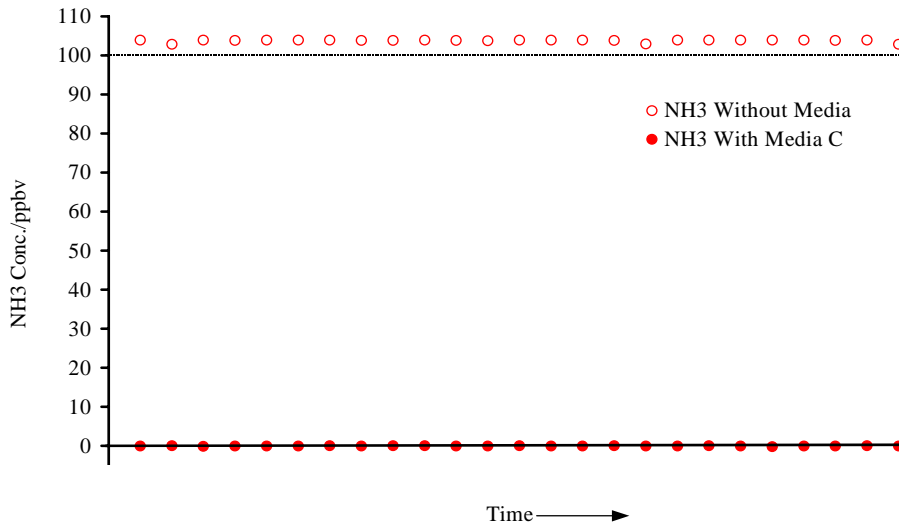
\* **Challenge compounds: Bases = NH<sub>3</sub>, Acids = SO<sub>2</sub> & Organics = Toluene**

**Table : Prototype Filter Life Estimates for NH<sub>3</sub>, SO<sub>2</sub>, & Organics When RH 50%**

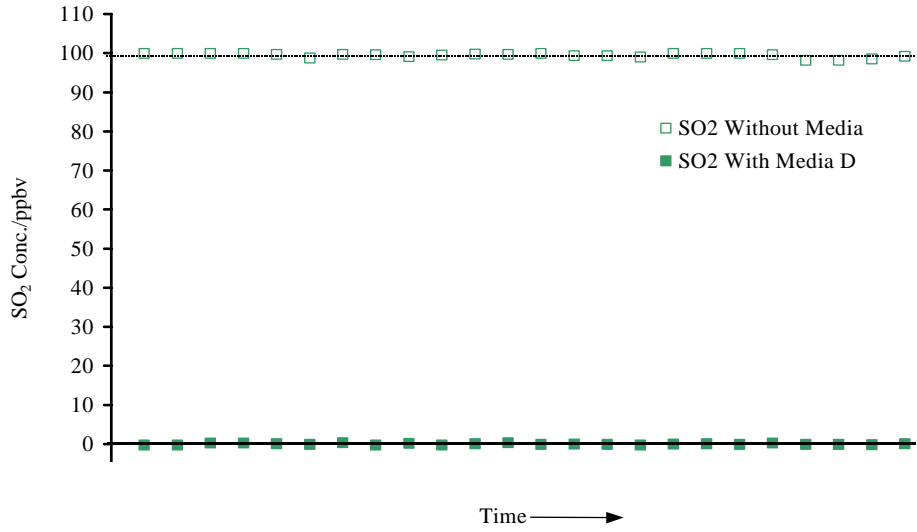
Challenge Contaminant	Challenge Concentration. (ppb)	Filter Life Estimate (years)	Estimated Filter Efficiency (%)
Base*	100	2.49	>99
Acid*	5	>4	>99
Organic*	100	4.56	>99

\* **Challenge compounds: Bases = NH<sub>3</sub>, Acids = SO<sub>2</sub> & Organics = Toluene**

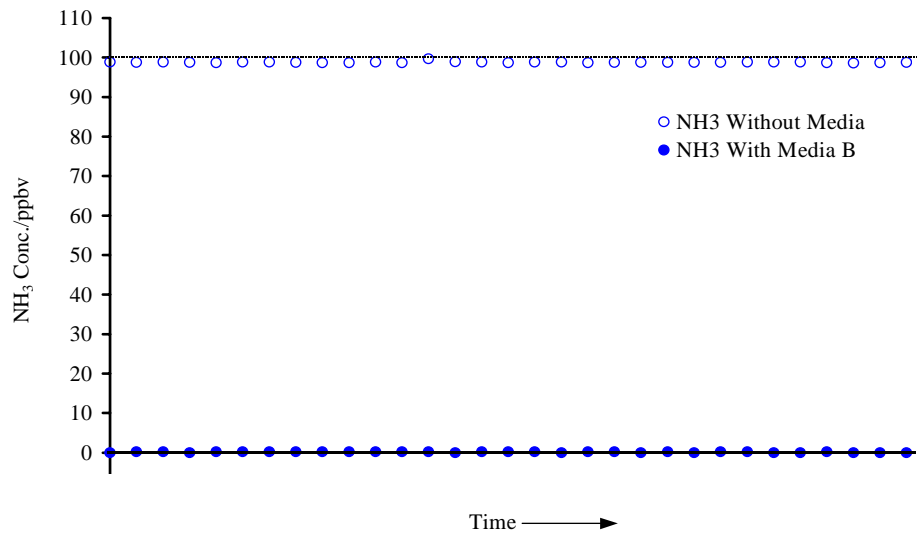
**Removal Efficiency at 0% RH**



### Removal Efficiency at 0% RH



### Removal Efficiency at 50% RH



### Removal Efficiency at 50% RH

