



SEMI Europe

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SEMI Assessment of Proposed Alternative Fluoroelastomers for Sealing

Many semiconductor manufacturing processes are very complex, with most utilising elevated temperatures as well as aggressive and potentially hazardous chemistries that Kumagai (1990) notes require special system design considerations. Semiconductor manufacturing processes therefore require high performance seal materials that have high operating temperature range capabilities and that are also resistive to the aggressive chemistry used as process media as well as system cleaning solutions between process steps (Wang & Legare 2007).

As noted by Goto et al. (2020), perfluoroelastomers (FFKM) and fluoroelastomers (FKM) have been reliable seal materials used in semiconductor manufacturing processes because of their excellent performance under these aggressive temperature and chemical conditions. Alternative materials such as EPDM and other hydrocarbon elastomers, Nitrile, as well as Silicone lack the combined acid resistivity, solvent resistivity and the high temperature performance characteristics needed in semiconductor process applications compared to perfluoroelastomers and fluoroelastomers Foggiano et al. (2007). This is a position broadly supported by material compatibility recommendations in Pruett (2005). As a result, EPDM, Silicone, and hydrocarbon elastomer materials are not technically viable substitutable sealing materials for perfluoroelastomer and fluoroelastomer in semiconductor manufacturing processes.

This position is further supported by a review of non-PFAS alternatives suggested by the Dossier Submitter for several specific semiconductor processes shown below:

Table: List of non-PFAS alternatives suggested for Fluoroelastomer's sealing applications in
Appendix E2 to the Annex XV Report

#	Substance name	CAS no	EC no
1	Ethylene propylene diene monomer (EPDM)	308064-28-0	920-736-4
2	Silicone rubbers		
3	Aryl Ketone polymer (PEEK)	29658-26-2	608-392-0
4	Hydrocarbon elastomers		

EPDM (#1) and Hydrocarbon elastomers (#4)

- For wet environments typically seen in semiconductor manufacturing equipment for wafer surface cleaning/preparation, photolithographic material coating/developing, chemical mechanical polishing (CMP), and electrochemical deposition processes, EPDM or other hydrocarbon elastomers (such as IIR, NBR, SBR as defined in DIN/ISO 1629) cannot substitute fluoroelastomer O-rings and gaskets for the following reasons;
 - Wafer contamination: Cleanliness level of material is low, leaching out metals and other elements from the elastomer will result in metal contamination on the wafer, making chips unusable.
 - Chemical incompatibility: EPDM and other Hydrocarbon elastomers are not compatible with some of the chemicals used in wet applications including strong acids such as, nitric, sulfuric, and hydrofluoric acids, oxidizers and solvents. This is publicly known information that can easily be found in manufacturer's literature (handbooks, datasheets, etc., for example "Parker O-Ring Handbook") and also supported by material compatibility recommendations in Pruett (2005).
 - Safety/environment protection: their lack of chemical compatibility can result in leaks, increasing the risk of human exposure and environmental release of hazardous chemicals.
 - Impact to production: Use of EPDM or other hydrocarbon elastomers as seals would make it impossible to manufacture chips due to wafer contamination and lack of chemical compatibility.
- For vacuum processes' environment typically seen in types of semiconductor manufacturing equipment used for plasma etching, chemical/physical vapor deposition, and thermal processes, EPDM or other hydrocarbon elastomers cannot substitute fluoroelastomer O-rings and gaskets for the following reasons;
 - Wafer contamination: Cleanliness level of material is low and some hydrocarbons' outgassing drastically increase at high temperatures, so transfer of contaminants from seal to wafer will result in contamination of the wafer, making chips unusable. Also due

to poor chemical compatibility, reaction products generated upon exposure to process gases and reactive species will result in wafer contamination, making chips unusable.

- Incompatibility with reactive gases, high temperature (for instance, maximum operating temperature of EPDM is up to 175°C, which is more than 150°C lower than FFKM's), and plasma: EPDM and other hydrocarbon elastomers are not compatible reactive gases and plasma, so reaction products generated upon exposure to process gases/plasma will result in wafer contamination, making chips unusable.
- Safety/environment protection: their lack of chemical compatibility can result in leaks, increasing the risk of human exposure and environmental release of hazardous chemicals.
- Impact to production: Use of EPDM or other hydrocarbon elastomers as seals would make it impossible to manufacture chips due to wafer contamination and lack of chemical compatibility.

Silicone rubbers (#2)

- For wet environments silicone rubbers cannot substitute fluoroelastomer O-rings and gaskets because of;
 - a. Wafer contamination: Cleanliness level of material is low, leaching out metals and other elements from the rubber will result in contamination on the wafer, making chips unusable.
 - Chemical incompatibility: Silicone rubbers are not compatible with strong acids, bases, oxidizers and solvents. This is publicly known information that can easily be found in manufacturer's literature and also supported by material compatibility recommendations in Pruett (2005).
 - Safety/environment protection: Silicone rubber's lack of chemical compatibility can result in leaks, increasing the risk of human exposure and environmental release of hazardous chemicals.
 - Impact to production: Use of silicone rubbers as seals would make it impossible to manufacture chips due to wafer contamination and lack of chemical compatibility.

- For vacuum processes' environment silicone rubbers cannot substitute fluoroelastomer seals because of;
 - Wafer contamination: Cleanliness level of material is low, so transfer of contaminants from seal to wafer will result in metal contamination of the wafer, and silicone rubber is known to outgas volatile organic compounds (e.g., siloxanes), which results in organic contamination of the wafer, making chips unusable.
 - Incompatibility with reactive gases and plasma: silicone rubber is more resistant to reactive gas than hydrocarbons but still eroded much faster than FFKM. Both characteristics result in shorter maintenance intervals and reduced productivity.
 - Safety/environment protection: their lack of chemical compatibility can result in leaks, increased risk of human exposure and environmental release of hazardous chemicals. Silicone rubber's porous structure allows unwanted permeation of reactive gases to adjacent higher vacuum chamber, resulting in elevated safety risks as high vacuum chamber may not be designed to accept reactive gases.
 - Impact to production: Use of silicone rubber as seals would make it impossible to manufacture chips due to wafer contamination and operability issues such as gas permeation.

PEEK (#3)

- While PEEK is known to be used for sealing viscous and abrasive materials in some industries, its very low elasticity and flexibility is not suitable for sealing off less viscous fluids or sealing between differential pressure (e.g., sealing between vacuum and atmosphere, pressurised fluid at mechanical joints of piping), which are the case for most of sealing applications in semiconductor manufacturing uses. In addition, PEEK being a rigid material, it is not always possible to retrofit into the hardware designed for elastomers.

Additional information on fluoroelastomer performance requirements can be found throughout the SIA PFAS Consortium White Paper: [PFAS-Containing Articles used in Semiconductor Manufacturing](#) and Table 3 in Appendix III of the White Paper in:

<https://www.semiconductors.org/pfas/>

References

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