
Effects of Non-Aqueous Vapor Degreasing Solvent Cleaning on Ultra- High Molecular Weight Polyethylene (UHMWPE)

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Overview

- Provide a brief summary of the chemistry of HFEs and HFCs
- Summarize the results of laboratory tests evaluating the interactions of HFEs and HFCs with UHMWPE



Introduction

- Solvent degreasing operations have been historically used with great success
 - Mostly on metal and less so for polymeric components
- It had the advantages of:
 - Excellent cleaning power
 - Low surface tension solvents – small clearance cleaning
 - Low Boiling Point solvents – rapid drying
 - Simple equipment
- Historical degreaser solvents were ozone depleters
 - Fell out of popularity because of laws and costs of environmental controls
- New environmentally friendly solvents developed
- New solvent containment equipment designed

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Introduction

- Composition of 3M HFE-72DA
 - Ethyl Nonafluorobutyl Ether
 - Ethyl Nanofluoroisobutyl Ether
 - Methyl Nonafluorobutyl Ether
 - Methyl Nanofluoroisobutyl Ether
 - IPA
 - *trans*-1,2-Dichloroethene

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Introduction

- Composition of Micro Care Heavy Duty Degreasing Solvent
 - 1,1,1,2,3,4,4,5,5,5-Decafluoropentane
 - 1,1,1,3,3-Pentafluorobutane
 - *trans*-1,2-Dichloroethene

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Introduction

- Effects of Such Solvents on Metals vs. UHMWPE
 - Adsorption (unto) versus Absorption (into)
 - Absorption (into) versus Desorption (out of)

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Test Methods

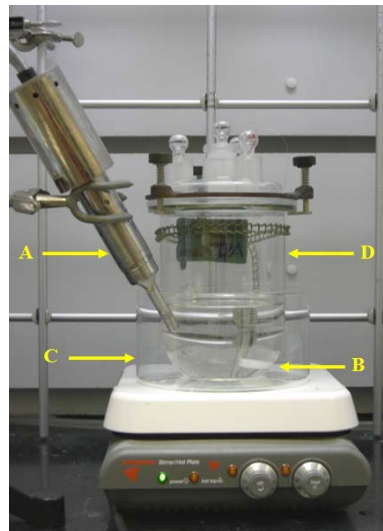
Material Processing Methods:

- Mimic Typical manufacturing processes Suggested by Solvent Suppliers
- UHMWPE Test Specimens:
 - 6 mm x 12 mm x 40 mm bars
 - GUR-1050 Compression Molded Slab Stock (Ticona)
- Typical Solvent Processing Cycle:
 - 1 minute soak in boiling solvent (HFE ~45 C, HFC ~41 C)
 - 2-5 minute agitated clean (with or without sonication)
 - 1 minute vapor phase rinse
 - 1 minute dry

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Test Methods



- A – Sonication probe
- B – Sample submerged in solvent
- C – Beaker with water for sonication energy transfer
- D – Processing vessel

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Test Methods

Material Post Cleaning Processing Methods:

- Out-gassing, solvent desorption (drying):
 - Ambient air drying
 - 80 C oven drying
 - 80 C vacuum oven drying

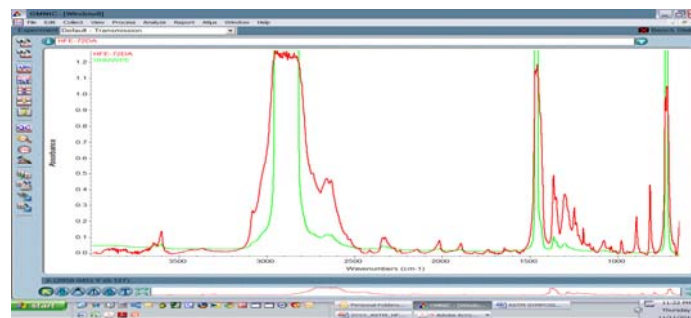
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Test Methods

Material Evaluation for Absorption/Desorption Characteristics:

- Weight differences are not very accurate
- FTIR is very efficient at identifying the presence of these materials within the UHMWPE
- HFE/HFCs have unique FTIR absorption peaks from UHMWPE
 - HFE-72DA vs. UHMWPE



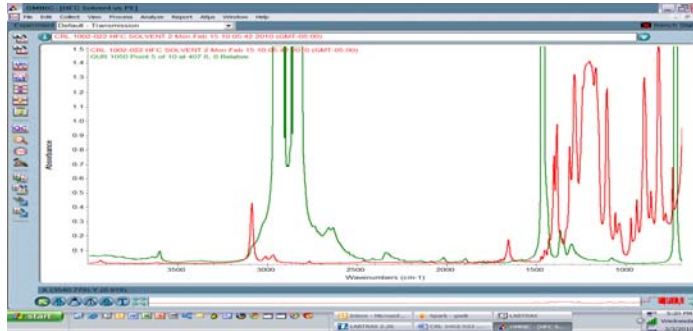
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Test Methods

HFE/HFC Monitoring Methods:

- HDDS vs. UHMWPE



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Test Methods

Material Evaluation for Absorption/Desorption Characteristics:

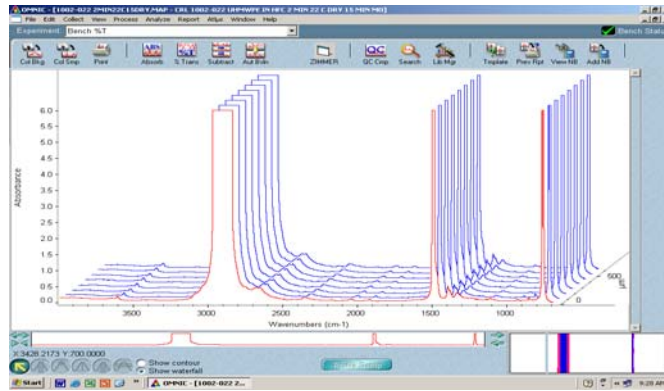
- FTIR Line-Mapping is very efficient at identifying the presence of these materials and their location within the UHMWPE
 - Processed UHMWPE bars are sectioned to obtain a fresh inner surface
 - ~150 Micron thick microtomed films are collected from this inner surface
 - FTIR transmission line-map spectra are collected every 200 microns starting from a solvent processed surface
 - Examination of individual line-map spectra allows one to determine the presence or absence of solvent and estimate its depth of absorption

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Test Methods

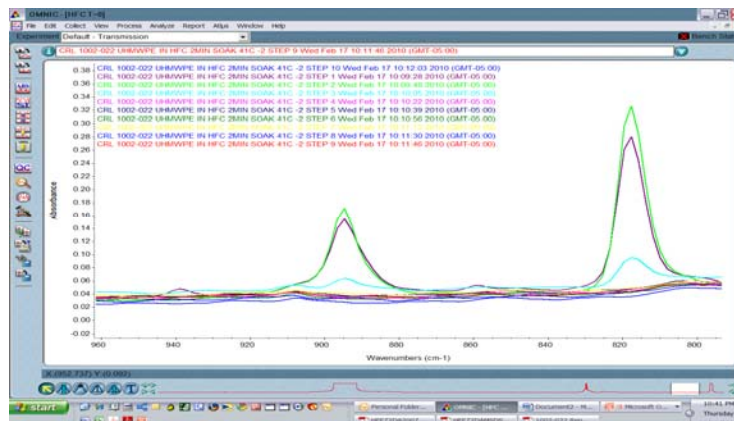
- Typical FTIR Line-Map spectra



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Results

- Typical depth profile of HDDS after 2-minute soak at 41 C



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Results

- Typical depth profile of HDDS after a 2-minute soak at 41 C and 2-hour oven drying



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Results Summary and comparison of HFE/HFCs

Samples of Tests and Results Using HFE-72DA and GUR 1050

Liquid Contact Time (Min.)	Vapor Contact Time (Min.)	Drying Time (Min.)	Drying Temperature (°C)	Drying Pressure (Atm.)	Solvent Absorbed (Y/N)	Maximum Depth (µm)
2	0	0	80/Oven	Ambient	Yes	250
2	0	15	80/Oven	Ambient	Yes	550
2	0	34	80/Oven	Ambient	Yes	750
2	0	50	80/Oven	Ambient	Yes	1100
2	0	90	80/Oven	Ambient	Yes	1300

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Results Summary and comparison of HFE/HFCs

Samples of Tests and Results Using HDDS and GUR 1050

Liquid Contact Time (Min.)	Vapor Contact Time (Min.)	Drying Time (Min.)	Drying Temperature (°C)	Drying Pressure (Atm.)	Solvent Absorbed (Y/N)	Maximum Depth (µm)
2	0	0	Ambient	Ambient	Yes	200
2	0	40	Ambient	Ambient	Yes	500
2	0	68	Ambient	Ambient	Yes	600
2	0	0	Ambient	Ambient	Yes	300
2	0	30	80/Oven	Ambient	Yes	1000
2	0	60	80/Oven	Ambient	Yes	1100
2	0	90	80/Oven	Ambient	No	N/A
2	0	120	80/Oven	Ambient	No	N/A

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Conclusions

- These HFE and HFC solvents tend to be rapidly absorbed into UHMWPE during degreasing cleaning operations but only slowly desorbed
- The *trans*-1,2-Dichlorethene component is the ‘culprit’
- HFC is desorbed more rapidly from UHMWPE than HFE
 - HFC was completely desorbed after 1.5 hours in an 80 C convection oven while HFE-72DA was still present
- Solvent components are absorbed to depths of ~1 mm with solvent contact times of about 2 minutes
 - Longer solvent contact times increases penetration depths
 - Sonication had little affect on penetration depths
- Elevated temperatures reduce desorption times
- Absorbed solvent moves deeper into material upon drying
- Vacuum oven had little affect on desorption times

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Conclusions

- The use of HFEs and HFCs to clean UHMWPE is complicated by their rapid absorption but slow desorption from this material
 - Although the cleaning cycles may be significantly shorter than other methods the much longer desorption (drying) times may make the overall manufacturing process longer
 - Additional testing and documentation may be necessary to insure such a cleaning process produces a product that is free or 'essentially free' of residual processing materials