CONTAMINATION RISKS RELATED TO ESD GLOVES AND FINGER COTS

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ABSTRACT
ESD gloves and finger cots are found at nearly every electronic manufacturing facility at assembly, rework, and repair stations, worldwide. The reason for using hand coverings is twofold: to reduce the risk of transferring detrimental skin oils and salts to the PCBA; to reduce the risk of electrical shock due to static electricity buildup from clothing and the environment. There are many different glove material types, having different advantages, as well as disadvantages. Some gloves and cots are treated with powders or chemicals to help the user fit or tactile feel; however, these can be transferred to the PCBA. The transferred materials may be detrimental to the PCBA by setting up electrical leakage and/or electrochemical migration-related issues in normal field service environments. This study will look at the possible glove-related effects in normal use of introducing known contamination, using ion chromatography.

Key words: Gloves**,** Contamination, Handling

INTRODUCTION
The effects of active flux residues are very well documented around the industry so this paper will not address the transfer of any single process chemistry but only what can be transferred from different type of virgin glove material. Knowing the base line effect of basic hand oils and contaminants is critical and the main reason for wearing gloves or finger cots in the first place. If there were no concerns about transfer of hand contaminants there would be no need for gloves or finger cots. The IPC A-610F 3.3.3 states [1] "Many times product is contaminated during the manufacturing process due to careless or poor handling practices causing soldering and coating problems; body salts and oils, and unauthorized hand creams are typical contaminants. Body oils and acids can reduce solderability, promote corrosion and dendritic growth. They can also cause poor adhesion of subsequent coating or encapsulants. Normal cleaning procedures may not remove all contaminants. Therefore it is important to minimize the opportunities for contamination. The best solution is prevention. Frequent washing of ones hands and handling boards only by the edges without touch the lands or pads will aid in reducing contamination. When required the use of pallets and carriers will also aid in reducing contamination during processing. The use of gloves or finger cots many times creates a false sense of protection and within a short time can become more contaminated than bare hands. When gloves or finger cots are used they should be discarded and replaced often. Gloves and finger cots need to be carefully chosen and properly utilized.

The main take away from 3.3.3 is the fact that the use of gloves themselves can create a false sense of security that as long as the operator is wearing gloves or finger cots then they are impervious to inducing contamination to the assembly they are working on. This is especially true when wearing cotton gloves as they are much easier to remove. When using a tighter fitting vinyl, nitrile, or latex glove they are usually taken off inside out and discarded as they are much harder to put back on if they are correctly sized to add the tactile feel necessary for handling small parts like during secondary operations. Some operators will use a set of cotton gloves during normal production and when not using them they go back into their ESD smock pockets to wait the next exposure to a myriad of chemistries used across every electronics manufacturer. This cycle will continue for weeks or months with the collection of ionics growing. At that point it takes much less direct contact to transfer contamination to the surface of the assembly. Beyond the ionic content cotton gloves will also deposit fibers on the board surface. As these are not conductive or particularly corrosive they are certainly not desired and if using conformal coating or some other epoxy they will impede proper adhesion. It is not to say that cotton gloves shouldn't be used at all but it is important to remember to change them anytime they are exposed to wet chemistries in particular they must be examined at a minimum and consider immediate replacement if the area at the fingertips is contaminated with a conductive or corrosion residue. Any material that is designed to be removed from the assembly before shipping is cause for replacement of the glove. That is true no matter the glove material.

ESD and Cleanroom considerations are also important factors when determining the best option for each specific application. IPC-A-610F 3.3.6 Handling Considerations Handling Consideration Gloves and Finger Cots states [1] "Any assembly related component if handled without EOS/ESD protection may damage electrostatic sensitive components. This damage could be in the form of latent failures, or product degradation not detectable during initial test of catastrophic failures found at initial test." This means that several factors must be considered to determine the right glove for your facility. As described in the abstract there are three main glove/finger cot material choices in the market that are latex, vinyl, and nitrile. In another presentation presented in the ESD Journal, Evaluation of

Materials for Cleanliness and ESD Protective Properties [2] “ESD protective materials are desirable too since they have at least one of the following properties: they prevent the generation of static, dissipate electrostatic charges, or provide shielding from electrostatic fields/ESD. Moreover, an ESD protective material attracts less particulate contamination to its surface than an insulative material since fewer charges are generated and accumulated on its surface”. In some cases this is as important as any other consideration, especially when working with wafer level fabrication. Even the smallest bit of foreign debris can be detrimental to some processes. The gloves tested in this study show varying levels of resistance to attract foreign, fibrous material according to the paper in ESD Journal. The gloves in this study are focusing on only ionic contamination levels.

TEST AREAS AND SAMPLING TECHNIQUE

I have noticed during normal operation on an assembly floor that direct contact with power and ground pads is not impossible but also isn’t always easily achieved. The way the boards were tested for this study would represent mishandling at a bare board level that can impact the cleanliness going forward. If this is a no-clean flux process, that isn’t being washed, there will be no way to remove the residues from the surface. These salts and oils will remain hydroscopic and act as a barrier for epoxy/coating adhesion. If the process includes an effective wash process there is a chance that the residues will be removed but the idea is to process the assemblies with the least amount of contamination added as you go along in case there are issues with cleaning process. Samples were produced using new latex, vinyl, and nitrile gloves in a dry state as well as after an application of IPA to simulate a rework/repair bench that uses solvent based cleaners. Each glove was worn fresh and then pressed against a comb pattern on an Umpire 2 test board, see Fig. 1, ten times for one second per touch. Each board also has one pattern with bare thumb contact as a control and uses the same ten touch method. A total of 10 replicates were processed for each condition and the IC tables show the average of all the data. The analysis method used was ion chromatography that will determine the exact type and amount of ionic contamination transferred from glove to board. The risk of human skin salts and oils has been researched by many sources and most have the same general result, it isn’t ideal and can be detrimental. The natural sodium chloride and oils that are present can induce electrical leakage and issues with adhesion. You also have to consider the presence of lotions, hand sanitizers, and other unknown foreign materials as they can have the same if not more exaggerated symptoms as the natural salts/oils. For this test no special consideration was taken when performing the bare skin test. This was considered a normal scenario when mimicking a production floor on any given work day. The analytical technique used was ion chromatography per IPC-TM-650 2.3.28b utilizing automated localized extraction. I.C. results yield results that can be traced back to specific material signatures from each surface tested, in this case the glove/thumb contamination on the bare copper pad sites. The main anion and cation species tested for include what are considered some of the most detrimental such as chloride, sulfate, and sodium for their conductive properties as well as calcium for the insulative properties that will affect adhesion. Chloride is one of the more detrimental materials found on printed circuit assemblies. Chlorides can come from a variety of sources, but is most often attributable to flux residues. Chlorides will generally initiate and propagate electrochemical failure mechanisms, such as metal migration and electrolytic corrosion, when combined with water vapor and an electrical potential. The amount of allowable chloride on a bare board is difficult to assess. If the board enters an assembly process that incorporates cleaning, then a higher level of chloride can be tolerated. If the bare board enters an assembly process void of cleaning (no-clean), then a more stringent level of acceptable chloride is necessary. Sulfate, when present in sufficient quantity, can be harmful to electronic assemblies. Sulfates can come from a variety of sources, such as contact with sulfur-bearing papers or plastics, acid processes in fabrication. However, most often these residues come from tap water rinsing / cleaning processes. When sulfate levels start rising appreciably above 3.0 $\mu g/in^2$, we look for a sulfate-bearing chemical in the process, such as sodium/ammonium per sulfate or sulfuric acid. In electronics manufacturing, sodium is found in some fluxes, as the counter ion to the acid activator such as sodium succinate. It is also found in solder mask as absorbed residues and can be conductive through or on top of the mask. Levels less than 3.0 $\mu g/in^2$ have shown good field performance and good SIR test results. Calcium is typically found in the solder mask as fillers and rarely come into solution or cause electrical leakage and corrosion problems. For the purpose of this study the calcium can be from gloves that are powdered on the inside. All ion chromatography testing is performed using a Dionex ICS 3000 system with Chromeleon software. Reference control and blank tests are performed before the start of testing and controls are run after every 10 test samples. The system is calibrated using NIST-traceable standards utilizing six-point calibration. A 1.5mL sample of each extracted solution is analyzed using a sodium bicarbonate and sodium carbonate eluent.

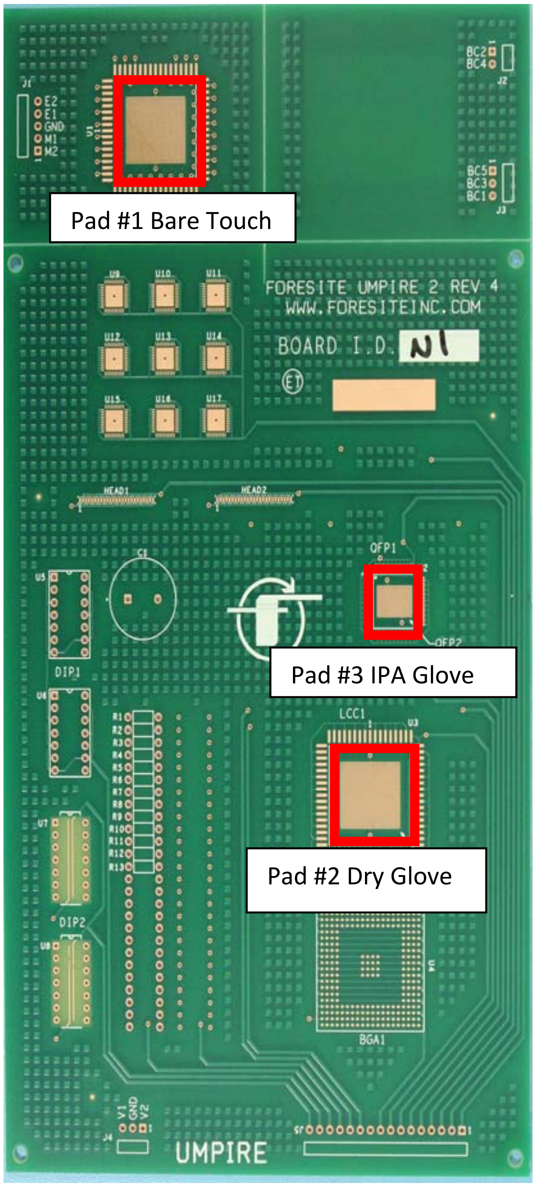


Figure 1. Umpire 2 Test Board Test

Figure 2. Latex Glove

Figure 3. Nitrile Glove

Figure 4. Vinyl Glove

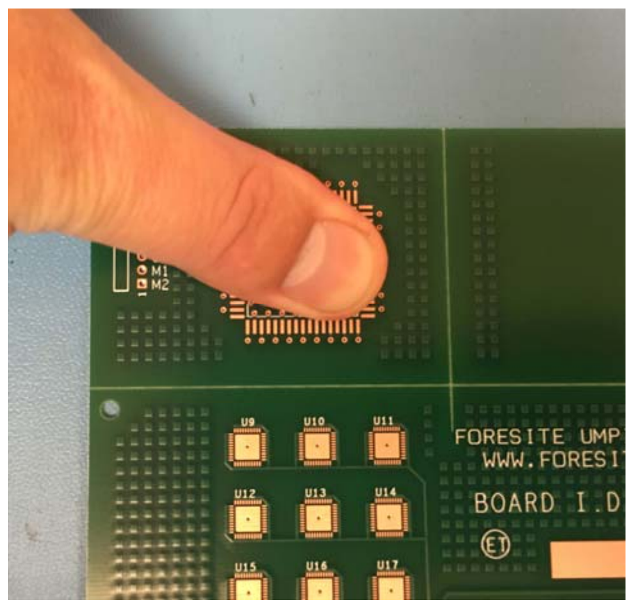


Figure 5. Bare thumb application for all control samples on Pad #1

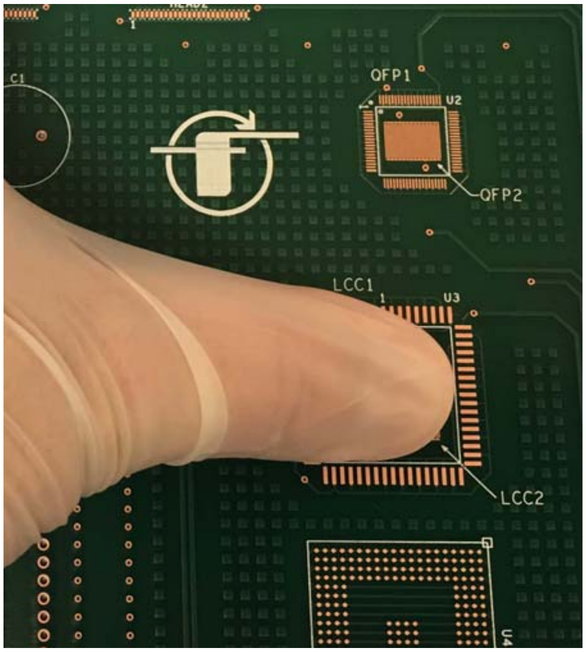


Figure 6. Dry glove application for all samples on Pad #2

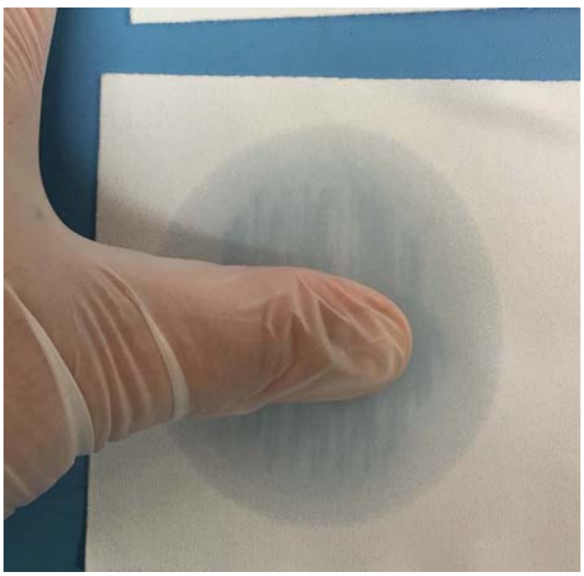


Figure 7. IPA glove application process with clean wipe soaked with IPA.

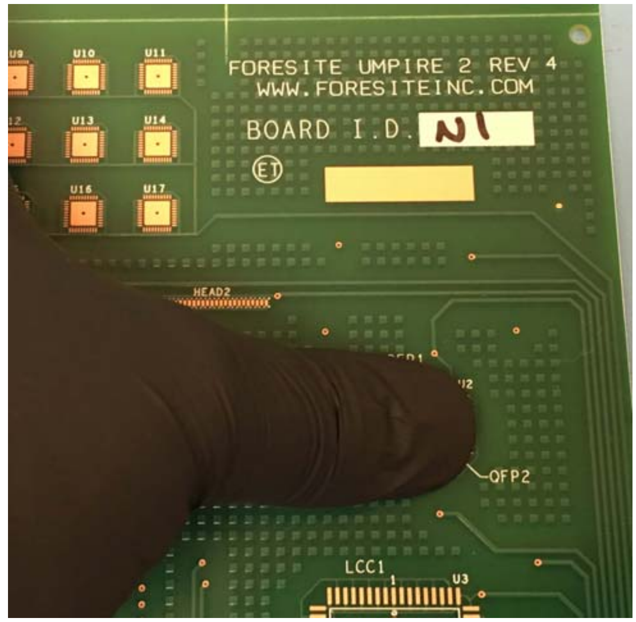


Figure 8. IPA glove process on pad #3

Figure 2 shows the latex glove, figure 3 shows the nitrile glove, and figure 4 shows the vinyl glove used for the study. Figure 5 shows the bare thumb process. Figure 6 shows the dry glove transfer test. Figure 7 shows the IPA to glove application with figure 8 showing the IPA exposed glove to pad application. The photos taken show the different glove types but so apply to all types individually as well. Test pad 1 is the bare thumb contact, test pad 2 is the dry glove contact, and test pad 3 is the IPA gloved contact. The IPA contact consist of rolling a gloved thumb on a clean room wipe, Figure 3, that has been soaked in lab grade IPA similar to what is found in the bottle top IPA/solvent dispenser. This was done between each one second touch to pad 3.

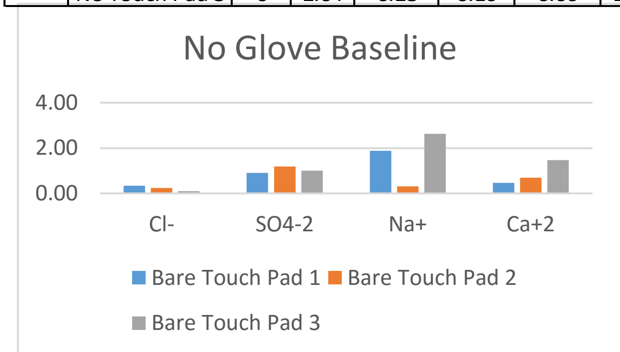
Sample one results, Tables 1 and 2, consist of an Umpire 2 test board without being subjected to any touching from either bare or gloved finger. This is the baseline data and has been subtracted from the I.C. results on each conditioned sample. All results are the average of 10 sample replicated processed for each sample type.

Table 1. Bare Copper Pad Baseline Anions

	all values in ug/in^2	Ion Chromatography (Dionex ICS 3000 at Foresite) n/a = no							
	Sample Description	Fluoride	Acetate	Formate	Chloride	Bromide	Nitrate	Sulfate	WOA
Foresite recommended limits for Bare Boards-Anions		3	2.5	2.5	2.0	2.5	2.5	3.0	n/a
ID									
1	No Touch Pad 1	0.08	0.04	0.04	0.34	0.06	0.24	0.91	1.19
2	No Touch Pad 2	0.18	0.45	0.04	0.24	0.09	0.26	1.19	1.38
3	No Touch Pad 3	0.37	0.40	0.22	0.10	0.19	0.12	1.00	0.26

Table 2. Bare Copper Pad Baseline Cations

all values in ug/in²							
	Sample Descriptio	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
Foresite recommended limits for Bare Boards-Cation		2	2	2.5	2	n/a	n/a
ID							
1	No Touch Pad 1	0	1.88	0.67	0.29	0.36	0.46
2	No Touch Pad 2	0	0.31	0.08	0.07	0.33	0.69
3	No Touch Pad 3	0	2.64	0.28	0.16	0.06	1.47



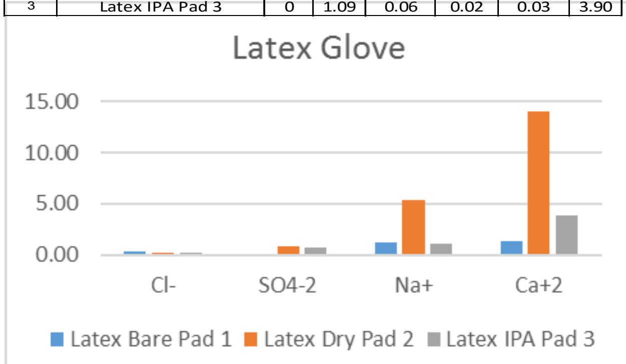
The first conditioned test board is the latex sample. Test pads 1, 2, and 3 were all conditioned as mentioned before. The IC test results are shown in Tables.

Table 3. Latex Anion Results

all values in ug/in²		Ion Chromatography (Dionex ICS 3000 a							
	Sample Descriptio	Fluoride	Acetate	Formate	Chloride	Bromide	Nitrate	Sulfate	WOA
Foresite recommended limits for Bare Boards-Anions		3	2.5	2.5	2.0	2.5	2.5	3.0	n/a
ID									
1	Latex Bare Pad 1	0.34	0.78	0.13	0.32	0.08	0.12	0.06	0.03
2	Latex Dry Pad 2	0.13	0.05	0.02	0.20	0.23	2.76	0.77	0.02
3	Latex IPA Pad 3	0.19	0.43	0.85	0.18	0.18	0.84	0.69	0.72

Table 4. Latex Cation Results

all values in ug/in²							
	Sample Description	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
Foresite recommended limits for Bare Boards-Cation		2	2	2.5	2	n/a	n/a
ID							
1	Latex Bare Pad 1	0	1.26	0.11	0.54	0.14	1.30
2	Latex Dry Pad 2	0	5.29	0.54	0.13	0.56	14.01
3	Latex IPA Pad 3	0	1.09	0.06	0.02	0.03	3.90



The latex glove samples show some elevated averages of sodium and calcium on the dry pad sample and not on the IPA sample. This is a function of material being present on the as received glove samples transferring some contamination that is being wiped off of the glove with the wiping of the IPA soaked clean room wipe. As the material was not transferred in greater amounts after the IPA application shows that the material is not soluble.

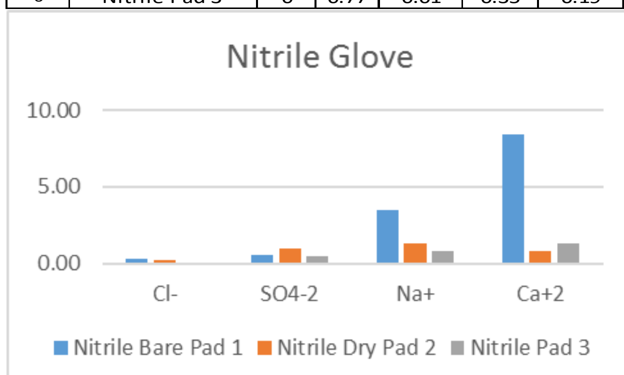
The second glove type is the nitrile material. The black nitrile gloves were all processed the same and used fresh from the packaging.

Table 5. Nitrile Anion Results

all values in ug/in²		Ion Chromatography (Dionex ICS 3000 a							
	Sample Description	Fluoride	Acetate	Formate	Chloride	Bromide	Nitrate	Sulfate	WOA
Foresite recommended limits for Bare Boards-Anions		3	2.5	2.5	2.0	2.5	2.5	3.0	n/a
ID									
1	Nitrile Bare Pad 1	0.54	0.75	0.07	0.30	0.20	0.13	0.56	0.19
2	Nitrile Dry Pad 2	0.09	0.02	0.12	0.22	0.01	0.28	0.98	0.13
3	Nitrile Pad 3	0.25	0.11	0.69	0.03	0.13	0.33	0.49	0.37

Table 6. Nitrile Cation Results

all values in ug/in²							
	Sample Description	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
Foresite recommended limits for Bare Boards-Cation		2	2	2.5	2	n/a	n/a
ID							
1	Nitrile Bare Pad 1	0	3.49	0.30	0.32	0.52	8.41
2	Nitrile Dry Pad 2	0	1.34	0.03	0.18	0.23	0.76
3	Nitrile Pad 3	0	0.77	0.01	0.35	0.19	1.26



The results of the nitrile samples show low levels of ionics on pads 2 and 3 when averaged over 10 samples of each condition. There is very little contamination transferred as with the latex samples.

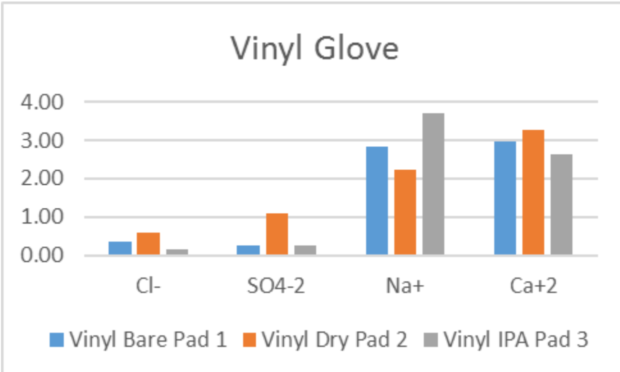
The final glove material choice tested is vinyl. One major difference in vinyl is that it does not stretch as much as nitrile and latex which lessens the tactile quality of a good laboratory glove.

Table 7. Vinyl Anion Results

all values in ug/in²		Ion Chromatography (Dionex ICS 3000 a							
	Sample Description	Fluoride	Acetate	Formate	Chloride	Bromide	Nitrate	Sulfate	WOA
Foresite recommended limits for Bare Boards-Anions		3	2.5	2.5	2.0	2.5	2.5	3.0	n/a
ID									
1	Vinyl Bare Pad 1	0.42	0.65	0.18	0.35	0.07	0.11	0.26	0.21
2	Vinyl Dry Pad 2	0.40	0.64	0.67	0.58	0.17	0.10	1.10	1.00
3	Vinyl IPA Pad 3	0.13	0.16	0.41	0.14	0.07	0.13	0.24	1.06

Table 8. Vinyl Cations Results

	all values in ug/in^2						
	Sample Description	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
Foresite recommended limits for Bare Boards-Cation		2	2	2.5	2	n/a	n/a
ID							
1	Vinyl Bare Pad 1	0	2.82	0.96	0.30	0.20	2.98
2	Vinyl Dry Pad 2	0	2.24	1.21	0.38	1.32	3.27
3	Vinyl IPA Pad 3	0	3.70	0.19	0.35	0.30	2.64



The total averages of the vinyl samples show elevated levels of sodium and ammonium. The level of calcium is also elevated more so with the dry touch than the IPA application touch due to the IPA clean wipe cleaning the glove. At the same time that means that the contact with the IPA does not degrade any of the glove materials to the point where the ionics are greatly increased after exposure and application on the PCB surface.

CONCLUSIONS

Choosing a protective glove for the production floor is a critical decision and all variable need to be considered. If ESD is not a special consideration, for PCB manufacturing, then all you need to consider is cleanliness as salts and oils can induce an insulative barrier that may inhibit proper solder flow. If they are to be used in an assembly house there needs to be a balance between ESD protection and cleanliness. The results of this study suggest that overall the vinyl gloves have the least total amount of ionic content. All three are at a low risk of introducing enough contamination to facilitate electrical leakage and/or electrochemical migration. The study was a worst case scenario with repeated exposure of various gloves to a single area. In normal production the risk for causing detrimental damage comes from handling of chemistries and then handling assemblies. When process chemistries come into contact with gloves it takes very little to transfer those residues to the surface of an assembly. The IPC-A-610F [1] states in 3.3.1 "Touch only the edges away from any edge connector tabs. Where a firm grip on the board is required due to any mechanical assembly procedure, gloves meeting EOS/ESD requirements may be required. These principles are especially critical when no-clean processes are employed" This should always be part of any employee training for handling of PCBs/PCBAs. One best practice is to train employees to properly handle the samples as if they were not going to be wearing gloves, and then wear gloves. Handling is a very real threat to the cleanliness and reliability but it isn't from the glove itself but more likely the manner in which they are being worn.

Future Work

Surface insulation resistance testing was to be done with this paper but due to a myriad of errors the data was not useable. Reproducing those samples for SIR/ECM should be added to this report. More finishes than bare copper should also be considered to determine if the effect of the glove materials on different surface finishes is vastly different. Conformal coating can still be added to the current samples as tested to determine effect on adhesion.

REFERENCES

[1] IPC-A-610F Acceptability of Electronic Assemblies 3.3.3 Handling Consideration -Contamination and 3.3.6 Handling Consideration-Gloves and Finger Cots

[2] ESD Journal- Evaluation of Material for Cleanliness and ESD Protective Properties Tom Lesniewksi and Kenn Yates