RJ Lee *Group*, Inc.

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April 25, 2001

Mr. John Yoakam
Applied Engineered Surfaces
591 Ternes Avenue
Elyria, OH 44035

RE: RJ Lee *Group* Project No.: MAC104012
Client Work Order No.: 6039

The analytical results for the tubing samples that you submitted are summarized in the following:

INTRODUCTION

The stainless steel samples were labeled as follows:

1. Sample 1
2. Sample 2
3. Sample 3
4. Sample 4

The above samples were submitted for analysis by Auger Electron Spectroscopy (AES), X-ray Photoelectron Spectroscopy (XPS), Scanning Electron Microscopy (SEM), Profilometry and Optical Emmission Spectroscopy.

EXPERIMENTAL

The method corresponds to SEMATECH Test Methods 91060573B (AES), 90120403B (XPS), 90120401B (SEM), and ISO 4288 (Profilometry).

AES quantitative atomic percent values were calculated using sensitivity factors for pure elements or compounds and reflect the concentrations that would be present if the components were present in the same form as the standard. These results may have systematic errors and should only be used to compare samples. Two sets of concentration values are presented in Table I. One set was calculated assuming silicon is present in an oxidized form and the other assuming it is present as elemental silicon.

AES etch depths are reported as silicon dioxide equivalent. The reported thickness values represent the thickness that would be present if the layers had the same etch rate as silicon dioxide.

The samples were analyzed as received.

RESULTS

The following observations can be made based on this analysis:

1. The AES analytical results are present in Spectra 1 – 12 and in Tables I and II. The oxide layer thicknesses (29 – 36 angstroms silicon dioxide equivalent) and chromium to iron ratios on the sample are similar to those generally found on stainless steel.

2. The surface contaminants are characteristic of those generally found on electropolished stainless steel. Various amounts of carbon, nitrogen, sulfur, silicon, chlorine and phosphorus; elements characteristic of stainless steel (iron, nickel and chromium); and oxygen were found on the surface of the samples. Phosphorus and nitrogen are common contaminants from the electropolish and passivation steps.

3. Results of analysis per SEMATECH Test Method 90120401B are presented in Table III and Micrograph file number 1 – 4.

   For the purpose of this analysis, only defects in the finish larger than 0.2 microns (2000 angstroms) were counted.

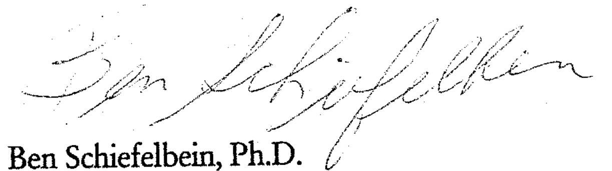
4. XPS results are presented in Spectra 13 – 20. The Cr-O/Fe-O and total Cr/Fe ratios are listed in Table IV.

5. Profilometry results are presented in Table V.

6. Optical Emission Spectroscopy is presented in Table VI.

Please feel free to contact me should you have any question regarding this analysis or if I can be of further assistance to you.

Sincerely,



Ben Schiefelbein, Ph.D.

BS/sjb

These results are submitted pursuant to RJ Lee Group's current terms and conditions of sale, including the company's standard warranty and limitation of liability provisions and no responsibility is assumed for the manner in which the results are used or interpreted.

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Table VI
RJ Lee Group Laboratory Results
Spectrochemical Results
(Reported as Wt. %)

Sample Name		Sample 1
Carbon	(C)	0.02
Maganese	(Mn)	0.01
Phosphorus	(P)	0.013
Sulfur	(S)	0.003
Silicon	(Si)	0.01
Chromium	(Cr)	16.85
Nickel	(Ni)	13.61
Molybdenum	(Mo)	2.23
Copper	(Cu)	0.13
Iron	(Fe)	Balance

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Table I
RJ Lee Group Laboratory Results
Calculated Surface Composition
Expressed as Atomic Percent

Sample Name		Sample 1	Sample 1	Sample 2	Sample 2
Element					
Carbon	(C)	23	23	24	24
Chromium	(Cr)	16	16	16	16
Iron	(Fe)	13	13	12	12
Nickel	(Ni)	6.6	6.6	6.5	6.5
Oxygen	(O)	39	39	40	40
Nitrogen	(N)	1.2	1.2	0.7	0.7
Chlorine	(Cl)	0.2	0.2	0.1	0.1
Sulfur	(S)	0.3	0.3	0.5	0.5
Phosphorus	(P)	0.1	0.1	0.1	0.1
Silicon	(Si)	0.3	~ ~	0.6	~ ~
Silicon Oxide	(Si(O))	~ ~	0.4	~ ~	0.9

Detection limits for most elements are approximately 0.1 atomic percent. These results are narmalized to total one hundred percent

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Table I
RJ Lee Group Laboratory Results
Calculated Surface Composition
Expressed as Atomic Percent

Sample Name		*Sample 3*	*Sample 3*	*Sample 4*	*Sample 4*
Element					
Carbon	*(C)*	22	22	28	28
Chromium	*(Cr)*	15	15	14	14
Iron	*(Fe)*	14	14	12	12
Nickel	*(Ni)*	6.0	6.0	6.2	6.2
Oxygen	*(O)*	42	42	38	38
Nitrogen	*(N)*	0.8	0.8	1.0	1.0
Chlorine	*(Cl)*	0.1	0.1	0.5	0.5
Sulfur	*(S)*	0.1	0.1	0.1	0.1
Phosphorus	*(P)*	0.2	0.2	0.1	0.1
Silicon	*(Si)*	0.4	~ ~	0.5	~ ~
Silicon Oxide	*(Si(O))*	~ ~	0.6	~ ~	0.8

*Note: '***' Below detection limit*

Detection limits for most elements are approximately 0.1 atomic percent. These results are narmalized to total one hundred percent

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Table II
RJ Lee Group Laboratory Results
Depth Profile Results

Sample Name		Sample 1	Sample 2	Sample 3	Sample 4
Oxide Thickness	(Ang.)	36	30	29.5	29
Corrected Oxide Layer ***	(Ang.)	31.5	25.5	25	24.5
Cr/Fe Ratio at 10 Ang.**		1.6	1.5	1.4	1.5
Max Cr/Fe Ratio		1.7	1.9	1.6	1.7
(Depth Ang.)		0	0	8.5	8.5
Carbon Layer Thickness	(Ang.)	4.5	4.5	4.5	4.5
Contaminants*		C, N, S, Si	C, N, S, Si	C, N, Si	C, N, Si

Note: '' = Only elements present at concentrations > 0.2 atomic percent are listed.*
*Note: '**' = Measurements taken at a depth equal to 10 angstroms plus the carbon layer thickness.*
*Note: '***' = Oxide layer corrected for carbon layer thickness.*

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Table III
RJ Lee Group Laboratory Results
Surface Morphology By SEM

Sample Name	Sample 1	Sample 2	Sample 3	Sample 4
Micrograph Number				
1	3	2	1	0
2	0	2	1	0
3	0	5	0	0
4	0	0	2	0
5	0	0	0	0
Average Number Per Micrograph	0.0	1.8	0.8	0.0
Maximum Number In Any Micrograph	0	5	2	0

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Table IV
RJ Lee Group Laboratory Results
ESCA Results

Sample Name	Sample 1	Sample 2	Sample 3	Sample 4
Cr/Fe	2.9	3.0	3.2	3.0
CrO/FeO	4.5	4.5	5.2	4.7

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Table V
RJ Lee Group Laboratory Results
Contact Profilometry Results
Expressed in Micro Inches

Sample Name	Sample 1	Sample 2	Sample 3	Sample 4
Site 1	2.25	2.50	2.75	2.25
Site 2	2.25	2.25	3.25	2.50
Site 3	2.50	2.25	2.75	2.00
Site 4	2.00	2.50	3.00	2.25
Average	2.25	2.38	2.94	2.25
Max	3.00	3.00	4.00	3.00