ESD and Mechanical Design

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Abstract:

Automated Component Handling (ACH) and Automated Handling Equipment (AHEs) manufacturers have been aware of ESD and the damage it causes to devices for quite sometime. ESD damage to components through various failure modes such as Human Body Model, Charged Device Model, and Machine Model have been well documented and discussed with more research being done all the time. The need for component packaging to protect component and devices from Static Electricity has also been well documented, however, with new technologies emerging all the time allowing greater throughput and smaller area population, packaging is and will play even a greater roll in performance. ESD effects of automated component packaging such as carrier tapes can and will affect performance of high-speed equipment. In making decisions regarding packaging, ESD concerns in protecting sensitive components are no longer the only concerns but what ESD requirements are also needed to prevent reductions in system performance due to ESD. This paper discusses the ESD measurement and mechanical test methods, and results of completed tests on various qualities and configurations of chip packaging materials and the effects on various prototype equipment performances. As a result, conclusions and recommendations will be made regarding specific types of packaging for specific types of components used in various types of automated equipment. Included in the results is high-speed documentation displaying the effects of ESD charging on chips, packaging, and the effects on system performance.

Introduction:

Electrostatic Electricity (ESD) hazards to the reliability of electronic devices and assemblies have been well documented for quite some time. As devices become smaller, faster, and use less power, they are becoming more sensitive to ESD. The component manufactures have been challenged to find economical methods and packaging to safely store and transport sensitive components such as recommended in EIA-541. Users are constantly being challenged to provide static safe environments to process new technologies in an economical manner. Manufactures are also being challenged to design and manufacture assembly equipment that will process devices safely while doing so faster, more accurate, and at a lower cost.

Recently while performing system verifications on prototype equipment, it was observed at times, a large amount of missed picked parts. It was determined that the large number of missed picked parts were consistent with several factors, type of component, size of component, humidity, and packaging materials. In other words, the smaller chips such as 0603s and 0402s in some packaging did not perform as well. With automatic processing components such as 0603s, 0402s, 0201s, and some 0805s, the mechanics become more difficult. Also as the weights of these components continue to drop, the sensitivity to Coulombic Interaction (attraction and repelling) increases and proper ESD Packaging becomes more important not so much as to protect the devices but to insure a high degree of mechanical reliability and performance. Mechanical devices designed to process these types of components must also be more robust to maintain high performance. Also, as these charged components are being processed, what is happening to adjacent components already placed that may be ESD Sensitive. A study was initiated to evaluate the ESD results of processing various components with different styles of packaging.

When researching the Standards such as EIA/IS-726 and EIA-481-B for recommended taping characteristics, I was referred to Standard EIA-541 for ESD Descriptions and terminology. These standards address the mechanics of taping properties and packaging material requirements for handling and storing sensitive components, however, they fall short in describing and recommending materials for automated handling of sensitive components as well as packaging for optimized mechanical performance.

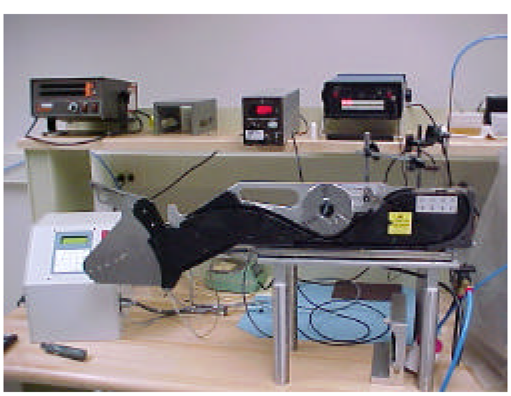
The Experiment:

Purpose:

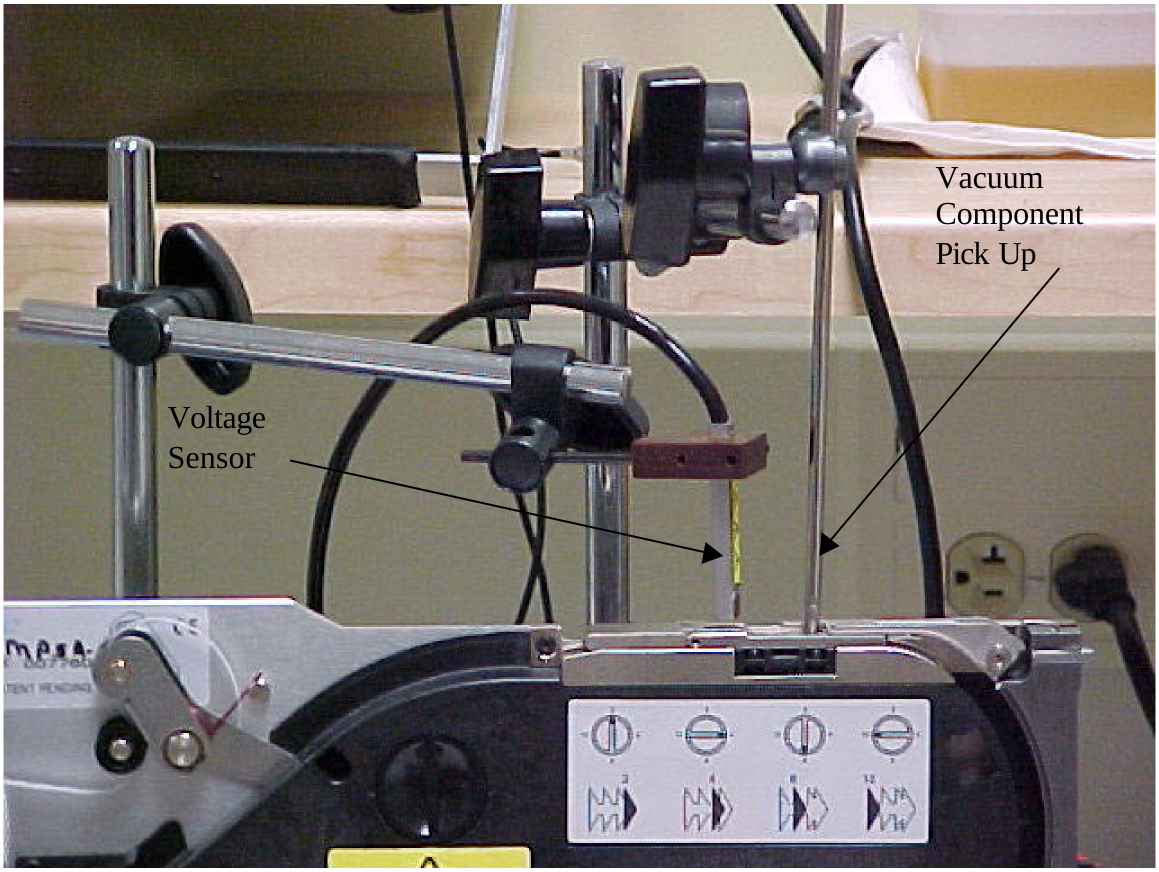
The purpose of the test was to evaluate the various packaging types and components to determine the overall ESD Characteristics and the effects on performance with prototype feeders.

Set Up:

The tests were conducted on the bench with a feeder set up as indicated by the following Photos and on a number of machines tracking Parts Per Million (PPM) Defect Rates. The bench testing used a feeder test controller capable of single cycle and continuous cycle that simulate the machine function.

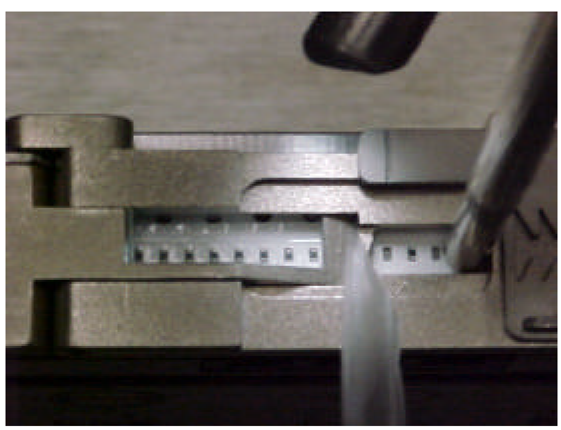


The Machine tests consisted of several machines using these products to populate test boards. Not all of the same manufactures and types were used for both studies due to time and availability; however, the different characteristics were represented in both types of tests.

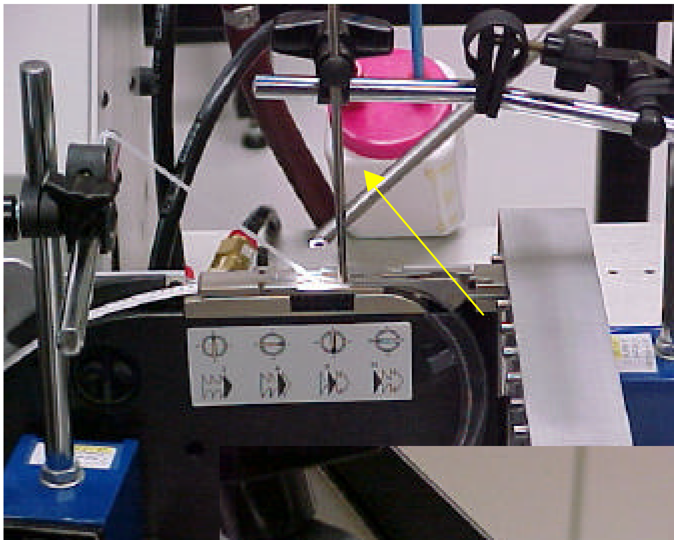


See arrows for Voltage Sensor and Component Pick Up

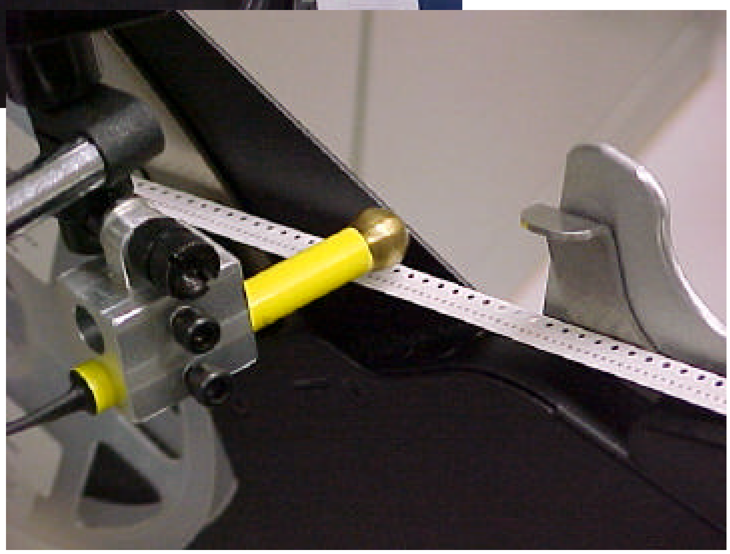
As the components are indexed, the cover tape is monitored and the components are picked up by vacuum to prevent jamming the feeder. The components measured were measured while in the pockets.



These photos are of the modified peeler used to view the components in the pockets prior to peeling the cover tape back. As one can see a section was removed from the peeler to gain viewing access and to allow for static voltage measurements at a close proximity to the peeling function. Correlations of the measurements indicate that these measurements made in this location will be somewhat less than if made off of the peeler entirely due to field absorption.



This Photo is one of the set ups for High Speed Motion analysis and was used to obtain the high speed AWIs from which the various pictures came from as still frames. They will be seen later under the results. Note that in this set up, the cover tape was held up to allow for viewing under the peeled cover. See the arrow for the high speed Bore Scope Lens.



This photo indicates the position of the voltage measurement probe while monitoring the voltage levels of the tape being unreeled.

Results:

The following Tables 1 and 2 are the results of the measurements made, the types of components and packaging used for processing, and comments specific to the performance.

Table 1 provides a list of component types, the average weight of each component in grams, the type of packaging, paper or plastic, stamped or thermo formed, and the voltage measurements of the packaging and resultant voltage on the component. Temperature was between 70 to 73 degrees F. and Humidity was as indicated.

Table 1

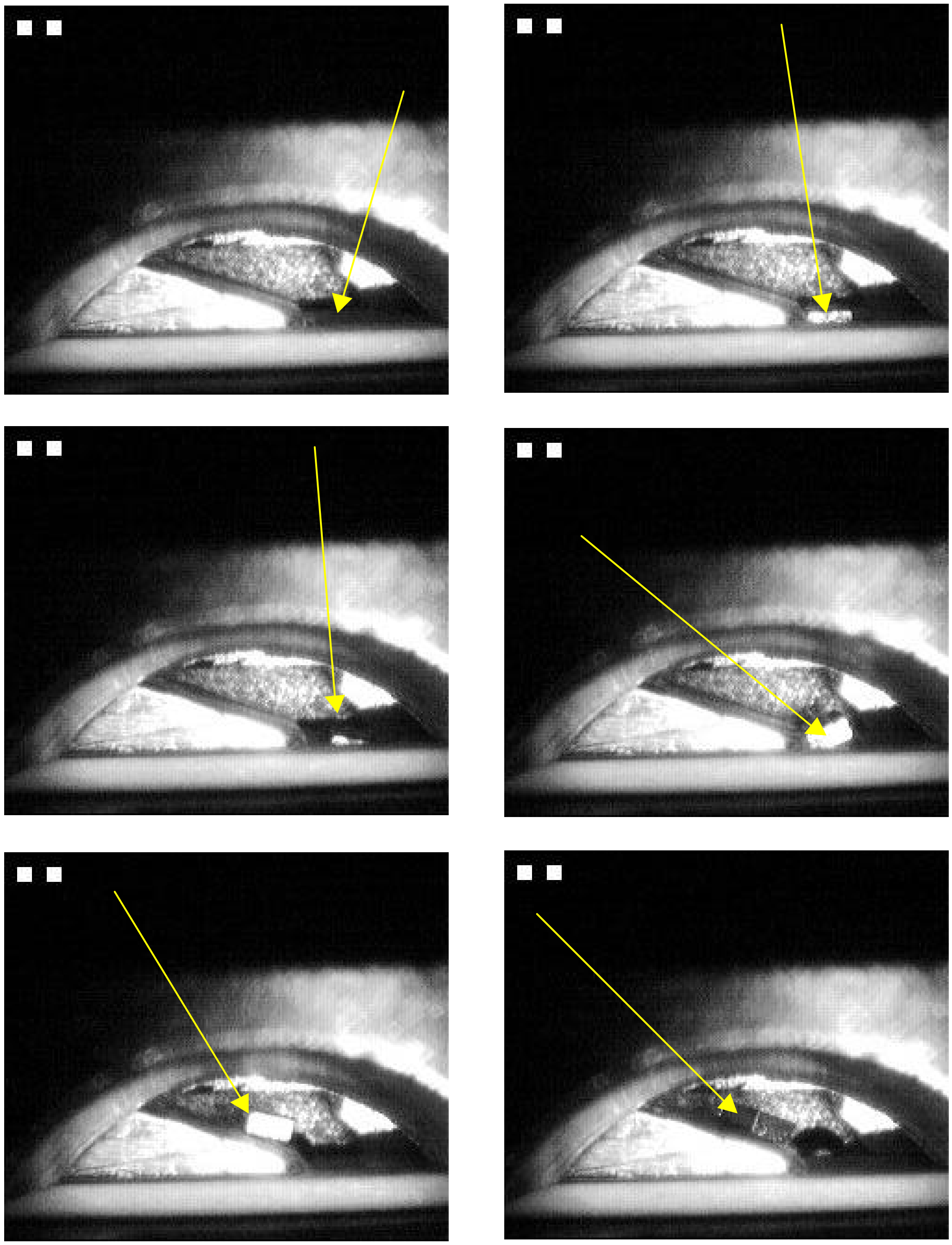
Relative Humidity RH %	Product Description				Charge Generation, Volts			
	Component Type	Weight Grams	Feeder	Tape Type	Cover Tape	Carrier Tape	Bottom Tape	Comp.
20.6	0201 - C	0.00031	8 mm	Paper stamped	-96	-2000	-3000	NA
19.9	0201 - R	0.00014	8 mm	Paper stamped	-50	-500	-400	30
19	0402 - C	0.00125	8 mm	Paper stamped	-200	-700	-700	50
19	0402 - C	0.00088	8 mm	Paper stamped	-60	-81	-81	25
19	0402 - C	0.0026	8 mm	Paper stamped	-30	25	20	10
21.5	0402 - C	0.0017	8 mm	Thermo Form	-26	30	30	0
21.2	0402 - R	0.0011	8 mm	Paper stamped	-300	-1000	-1000	50
20.8	0402 - R	0.00075	8 mm	Paper stamped	-850	-3000	-3000	75
21.7	0402 - R	0.0006	8 mm	Paper stamped	-2000	-800	-800	60
33	0603 - C	0.0056	8 mm	Paper stamped	-5	7		0
19	0603 - C	0.0058	8 mm	Paper stamped	-1000	750	800	50
21.6	0603 - C	0.0055	8 mm	Thermo Form	800	6000	3000	20
21.6	0603 - C	0.007	8 mm	Thermo Form	2000	-4700	-5700	50
20.6	0603 - C	0.0058	8 mm	Paper stamped	2000	-160	-150	-15
18.9	0603 - R	0.0025	8 mm	Paper stamped	-1050	900	840	30
19	0603 - R	0.0025	8 mm	Paper stamped	-1050	800	740	50
33	0603 - R	0.0029	8 mm	Paper stamped	-20	100	100	0
19	0603 - R	0.0035	8 mm	Paper stamped				
19	0805 - C	0.017	8 mm	Plastic stamped	-1000	3000	3000	100
18.9	0805 - C	0.0091	8 mm	Paper stamped	-100	170	140	0
20	0805 -R	0.005	8 mm	Plastic stamped	-1000	7000	7000	15
38 - 42	LEDs 0603s	0.002	8 mm	Thermo Form	-500	15	0	15
38 - 42	LEDs 0603s	0.002	8 mm	Thermo Form	-50	15	0	15
38 - 42	LEDs 0603s	0.002	8 mm	Thermo Form		-675	0	600
38 - 42	LEDs 0603s	0.002	8 mm	Thermo Form		15	0	15
38 - 42	LEDs 0603s	0.002	8 mm	Thermo Form	-200	-15	-200	15
38 - 42	LEDs 0603s	0.002	8 mm	Thermo Form	-1100	-1100		20
23.3	PLCC 44	NA	32 mm	Thermo Form	2000	0	0	150
22	SOIC 16	NA	16 mm	Thermo Form	3	0	0	0
23	SOIC 8	NA	12 mm	Thermo Form	-200	0	0	30

Table 2 provides a list of resultant voltages on the components and the resistance of the packaging and specific comments. The resistance for most of the packaging regardless of color (black, clear, or white), was 10e11 ohms with a few exceptions.

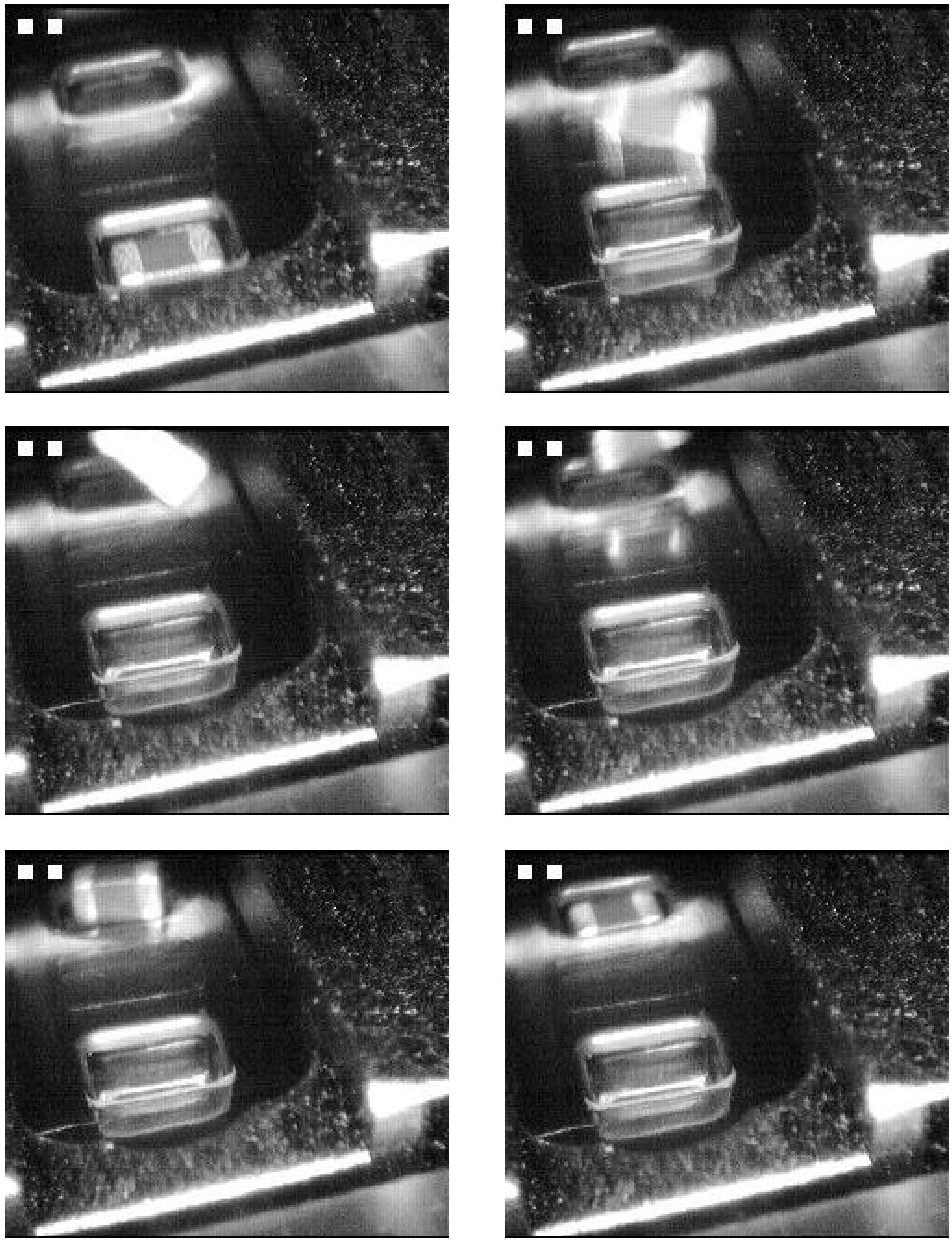
Comp. Voltage	Cover Tape	Carrier Tape	Bottom tape	Comments
NA	1.00E+12	1.00E+12	1.00E+12	
30	1.00E+12	1.00E+12	1.00E+12	Every other to every components was pulled from the pocket and traveled up the cover.
50	1.00E+12	1.00E+12	1.00E+12	Carrier Tape out of scrap chute at 1000 Volts
25	1.00E+12	1.00E+12	1.00E+12	Classified as problem, material appears to be low charging. Decay time is rapid
10	1.00E+12	1.00E+12	1.00E+12	
0	1.00E+11	50000	50000	Parts ran very good, even with old peeler.
50	1.00E+12	1.00E+12	1.00E+12	Classified as a problem, components are pulled from pockets by attraction to cover tape.
75	1.00E+11	1.00E+12	1.00E+12	Classified as a problem, components are pulled from pockets by attraction to cover tape.
60	1.00E+12	1.00E+12	1.00E+12	Classified as a problem, components are pulled from pockets by attraction to cover tape.
0	1.00E+12	1.00E+12	1.00E+12	
50	1.00E+12	1.00E+12	1.00E+12	Classified as a problem, components are pulled from pockets by attraction to cover tape.
20	1.00E+11	1.00E+12	1.00E+12	Tape is charged to several hundred volts as it is coming off the reel and before peeler.
50	1.00E+11	1.00E+11	1.00E+11	Parts stick in pocket, +comp with -tape, reverse attraction
-15	1.00E+11	1.00E+12	1.00E+12	Parts stayed in pockets, hard to remove.
30	1.00E+12	1.00E+12	1.00E+12	Large Amount of paper fuzz on cover tape, paper bottom. Parts are attracted to cover tape.
50	1.00E+12	1.00E+12	1.00E+12	+ 60 volts on tape as unreeled, Paper fuzz on cover tape increases charge and attraction, 200 V.
0	1.00E+12	1.00E+12	1.00E+12	
	1.00E+12	1.00E+12	1.00E+12	
100	1.00E+12	1.00E+12	1.00E+12	Classified as a problem, components are pulled from pockets by attraction to cover tape.
0	1.00E+12	1.00E+12	1.00E+12	Not listed as a problem, however, it appears the paper fuzz on the cover tape charges and attracts components.
15	1.00E+12	1.00E+12	1.00E+12	Highly chargeable materials used. If antistatic, properties have dissipated
15	1.00E+12	1.00E+07	NA	
15	1.00E+12	1.00E+07	NA	
600	1.00E+12	1.00E+07	NA	Components would attract to cover tape over 450 volts in 5 minutes run time and charge would last for 2 to 3 minutes
15	1.00E+12	1.00E+07	NA	
15	1.00E+12	1.00E+12	1.00E+12	Carrier Tape is low charging, cover tape is not
20	1.00E+12	1.00E+12	1.00E+12	Charge occurred in processing or indexing 10 components. Parts were attracted to cover tape.
150	1.00E+12	1.00E+06	1.00E+06	150 volts measured with field probe, 50 volts measured with High imp. Voltage probe. The rolled up cover tape was generating 6000 volts within .5 inches of the taped components without the benefit of static shielding.
0	1.00E+11	1.00E+07	1.00E+07	There was no apparent charge to measure.
30	1.00E+11	1.00E+06	1.00E+07	Components lead frame was charged to 30 volts.

Table 2

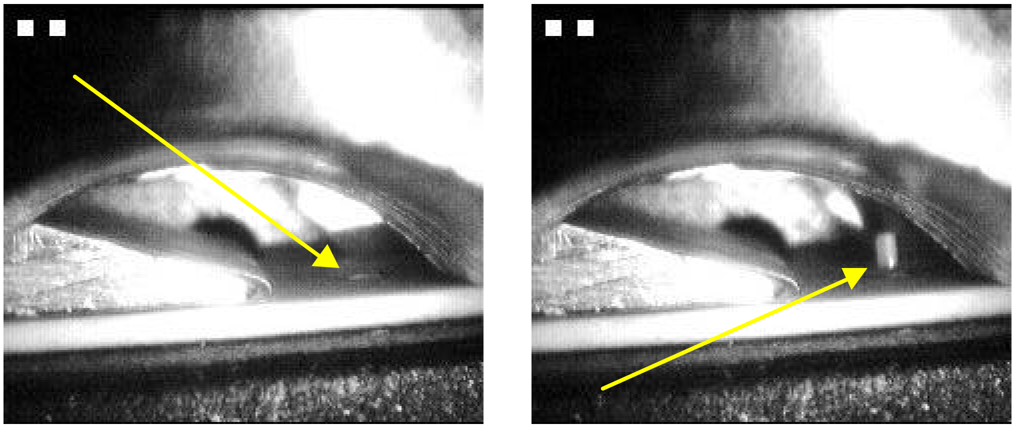
The following are consequences of charged 0603 components and degradation of performance. They are single frames taken from high speed motion analysis videos and saved as single frames.



These are high-speed photos of consecutive positive charged 603 capacitor pulled out of the pockets by attraction to the negative charged cover tape. The tape was -100 volts while the component was 50 volts.



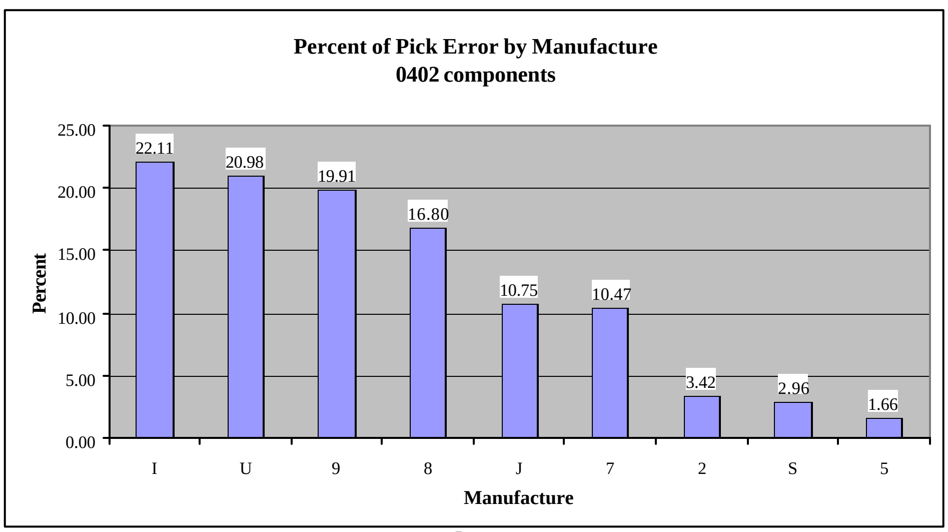
The 0603 capacitor was lifted in the pocket as it came out from under the peeler, it was then like a big spring and as soon as it was free, it launched. The next few photos show the trajectory as it lands into the next pocket. That part may be hard to explain in real time.



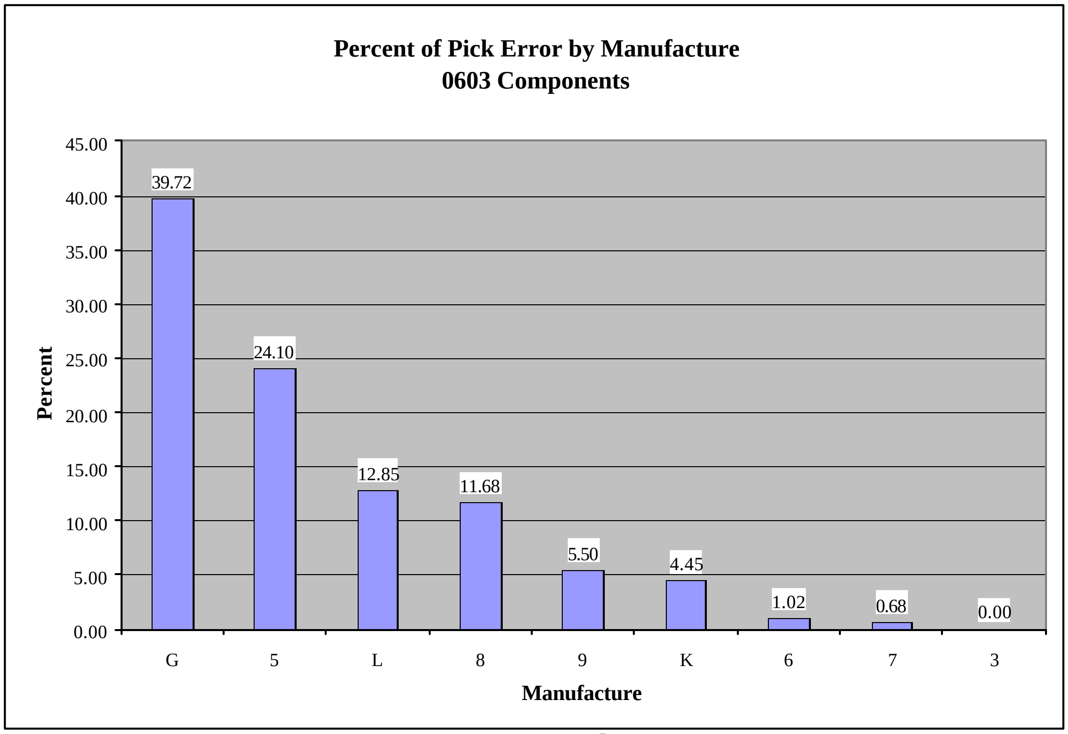
In these photos the part is advanced in the first photo (see arrow) and in the second photo, the nozzle attempts to pick up the part with a part still on the nozzle (see arrow). The part had to be physically removed from the nozzle.

Average Weight	Grams
0201	0.0002
0402-R	0.0008
0402-C	0.0016
0603-R	0.0029
0603-C	0.0059
0603-LEDs	0.0020

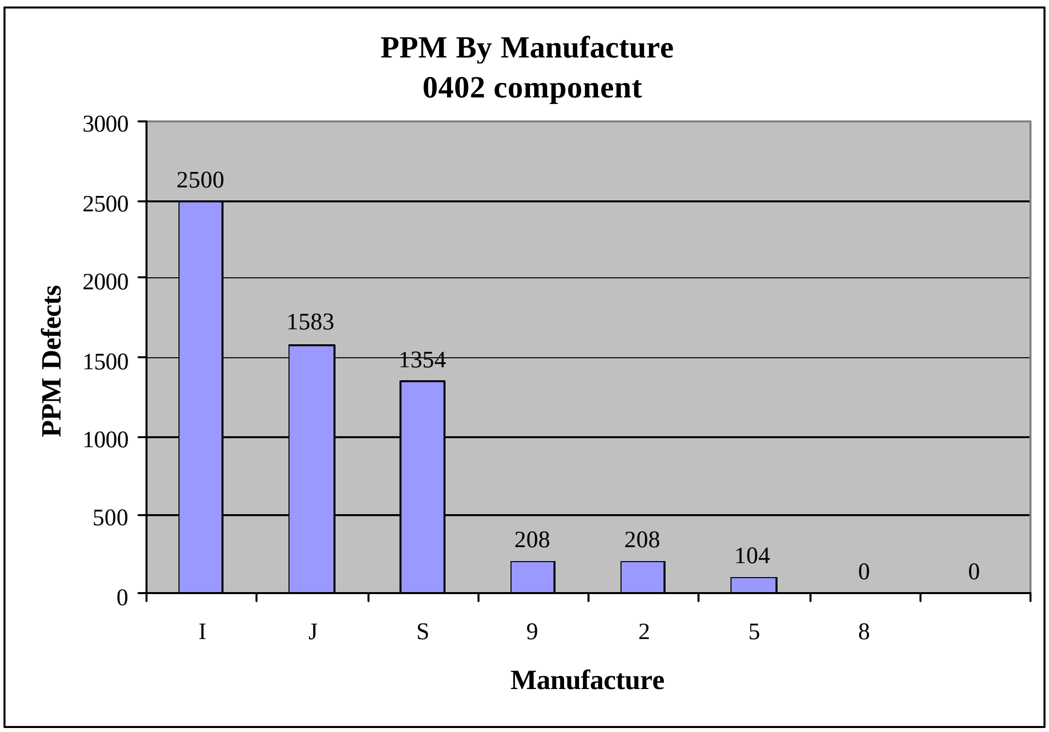
Table 3
Average weights of components obtained from weighing 30to 100 components.



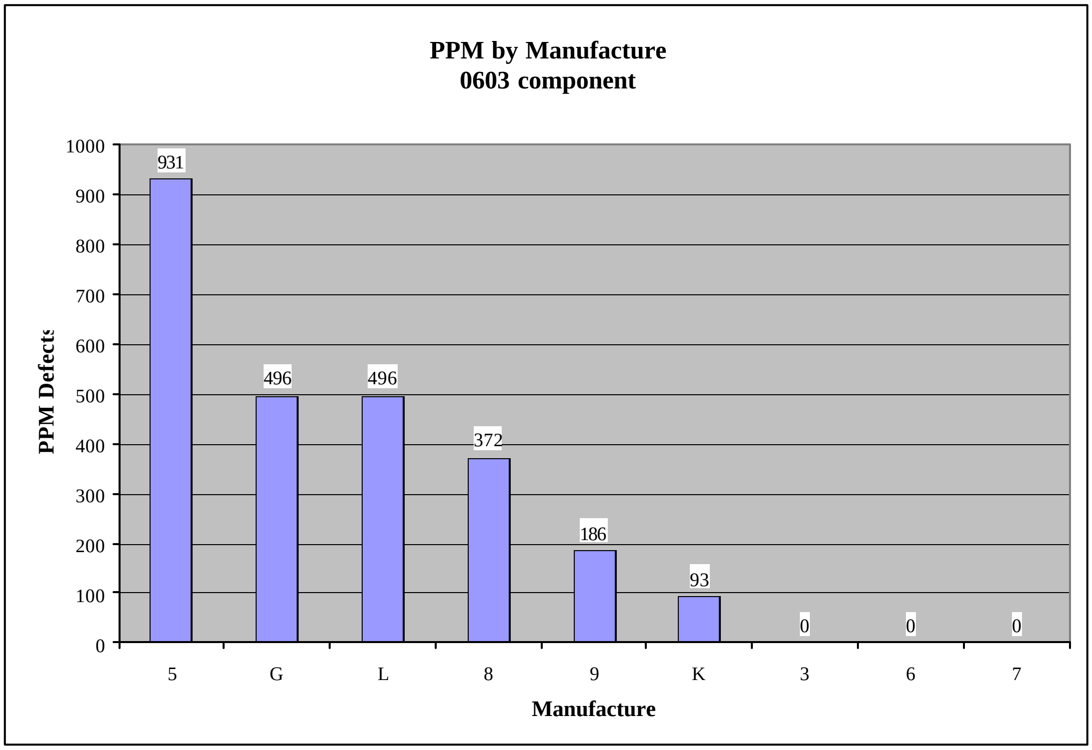
Graph 1



Graph 2



Graph 3



Graph 4

Conclusions:

1. With an average weight of .0016 grams for 0402 capacitors, (Tables 2 and 3) coulombic interaction (attraction and repelling) can result with as little as 50 volts on the cover tape.
2. With an average weight of .0002 grams for 0201s, (Tables 2 and 3) coulombic interaction can result with as little as 25 volts on the cover tape.
3. Based on tables 1 and 2, the packaging materials tested ranged from static dissipative to low charging (anti-static) materials. Low charging is the preferred term in the ESD industry. Since resistance properties are usually not tied to low charging materials, it is difficult to determine. However, some cover tapes charged up very easily to 1000 to 2000 volts while other did not. While some tapes charged up, the charged decayed rapidly. Most low charging materials of these types have a shelf life and some packaging may have expired since the low charging properties were inconsistent between the same manufacture.
4. There is another factor referred to as wind up tension that causes an inconsistent charging through out the same reel. The winding up of the carrier tape places the cover tape under tension that causes the low charging surfactant to degrade or break down in spots. At one point the voltage level could be an order of magnitude higher than another point on the same reel. Consequently, the act of reeling up the carrier and cover tapes must cause an inconsistent low charging characteristic.

5. Based on Tables 1 and 2, and Graphs 1 through 4, there is a correlation between poor packaging and higher defects rates. The higher the charge on the component and carrier system, the higher the defect rate. While not all manufactures were tested in each set of tests, the types and characteristics of the packaging was represented in both tests.
6. Handling devices have to be robust enough to handle these types of issues, however, as the components get smaller, see Table 3, for example, a 0201 component weighs .0002 grams, ESD issues will become an even greater factor. The packaging materials of these components may need to be dissipative or conductive to prevent charging of the component and thereby reduce ESDA defects. Work will have to continue in this area.
7. End users need to be aware of the differences in packaging materials. Anti-Static or low charging materials do not necessarily mean the problems are solved. As seen in Tables 1 and 2, there is a significant difference between them. There are self-life, tension wind up, and quality issues affecting the packaging. The amount of charge measured on the components, please see Table 1, LEDs and PLCCs charged up to 600 volts and 150 volts respectively, cannot be good for the process. A side note is that while the PLCCs were packaged in dissipative carrier tape, the cover tape was a low charging material, consequently, the components saw very little or no benefits of static shielding.
8. End Users, Equipment, and Component Manufactures have to work very close together to provide greater protection to sensitive assemblies and insure the optimum process performance at the lowest cost. It all becomes a business decision regarding the cost of components, cost of packaging, and the cost of additional robustness of the handling devices.
9. Low Charging materials are no longer sufficient for many of these types of components. Static Dissipative materials may be required to improve and insure handling performance.
10. Standards EIA/IS-726 and EIA-481-B need to have an appendix or a section briefly describing various ESD related terms and applications where such materials may be used. Standards are intended to be helpful, to provide education specific to an application or process, and to provide guidance for consistent processes. One should not have to read one standard and be referred to other standards unless greater detail is desired.

Test Equipment Used:

Trek Model 368 Electrostatic Voltmeter	Trek Miniature Probe
3 M Megohm meter	Feeder Test Controller
Trek 152P-2P Surface Resistance Probe	GSM Platform

References:

ESD Association ESD STM4.1-1997
ESD Association ESD SP10.1-2000
ESD Association ESD STM11.11-2001
ESD Association ESD STM11.12-2001
ESD Association ESD-ADV-1.0-1994
EIA-541, June 1988
EIA / IS-726, October 1997
ANSI/ EIA-481-B-2001

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