EUROCORR Paris 2024
EUROPEAN CORROSION CONGRESS

Vapor Phase Corrosion Inhibiting Biodegradable And Compostable Packaging For The Electronic Industry

Antonia Durin, Snjezana Mikolic, Boris A. Miksic, Ivana Radic Borsic

Environmental issues

- <u>Packaging Waste:</u>

Major contributor to solid waste.

Significant environmental challenge.

- <u>Sustainable Strategies:</u>

Reuse

Recycling

Packaging waste recovery methods for sustainable disposal.

EUROCORR Paris 2024 EUROPEAN CORROSION CONGRESS

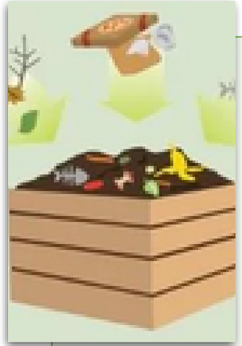
- **<u>Biodegradable Packaging:</u>**

✓ Environmentally friendly alternative with no negative impact.
✓ Made from materials like paper and blown film.
✓ Can include corrosion-inhibiting properties.

Green packaging materials

Recycling - process of extracting material from waste and its reuse.

Biodegradability - the capability of a material to be broken down by living organisms.



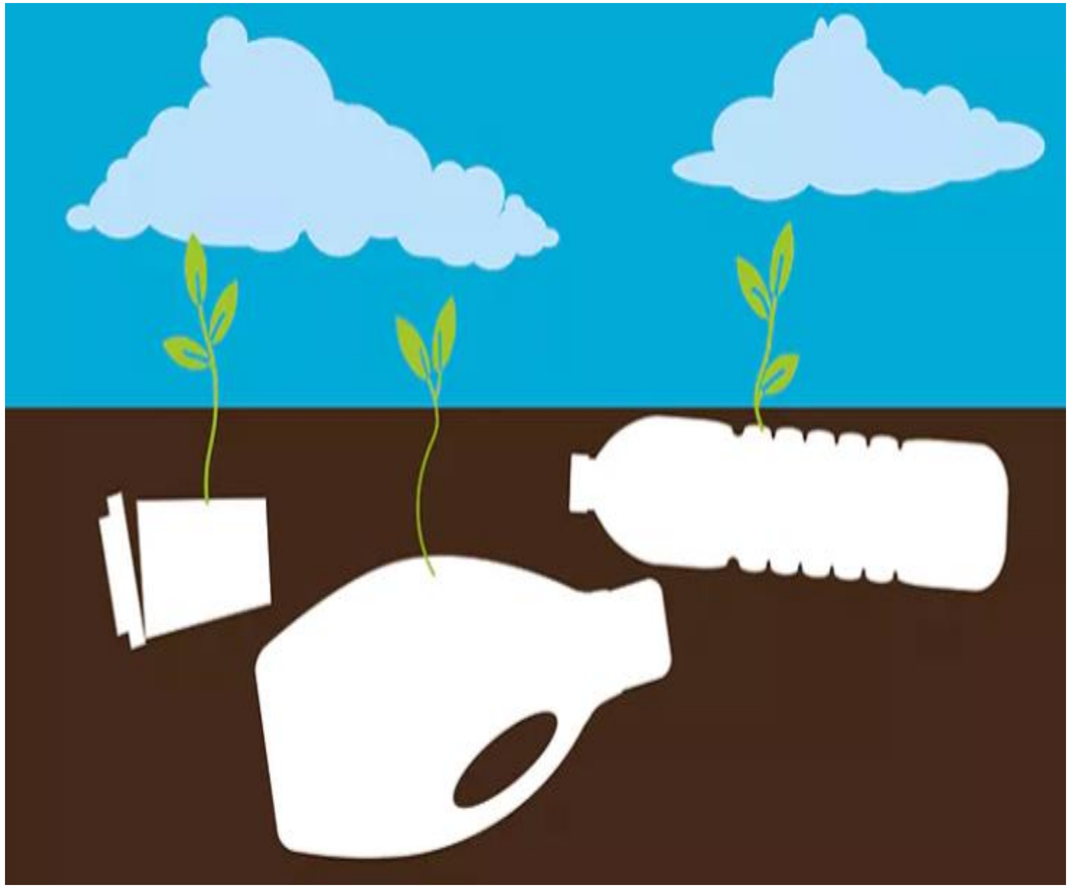
Compostability - the capacity of an organic material to be transformed into compost through the composting process.

Recycling

- Converts waste materials into new products.

- Common recyclable materials: glass, paper, cardboard, metal, plastic, tires, textiles, batteries, electronics.

Biodegradability

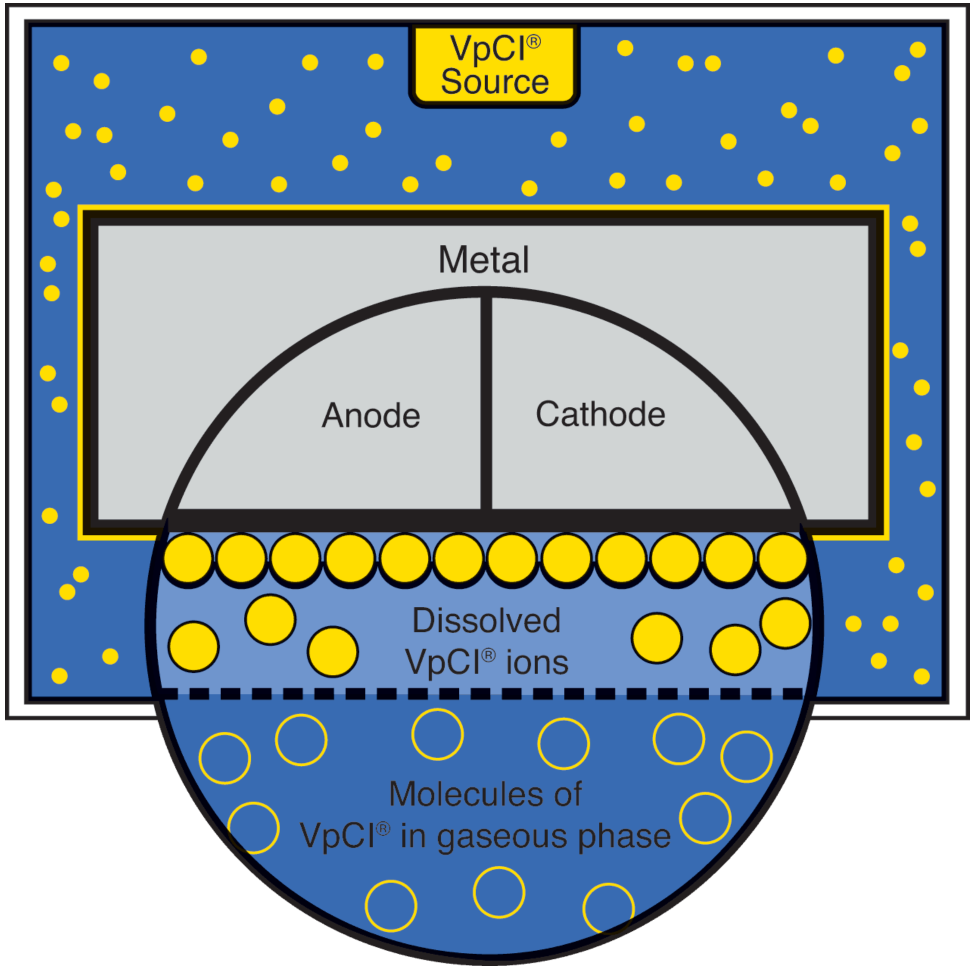


- **Biodegradable Packaging:**
  - **Made from biopolymers (organic compounds like cellulose and protein).**
  - **Derived from natural sources found in living organisms.**
- **Environmental Impact:**
  - **Breaks down into natural substances: water, carbon dioxide, and biomass.**
  - **Reduces long-term waste in the environment.**

Compostability

- Compostable packaging - type of packaging that naturally breaks down in the right environment.
- Decomposes within 3-6 months, similar to organic matter.
- Eco-friendly alternative to traditional plastic packaging.

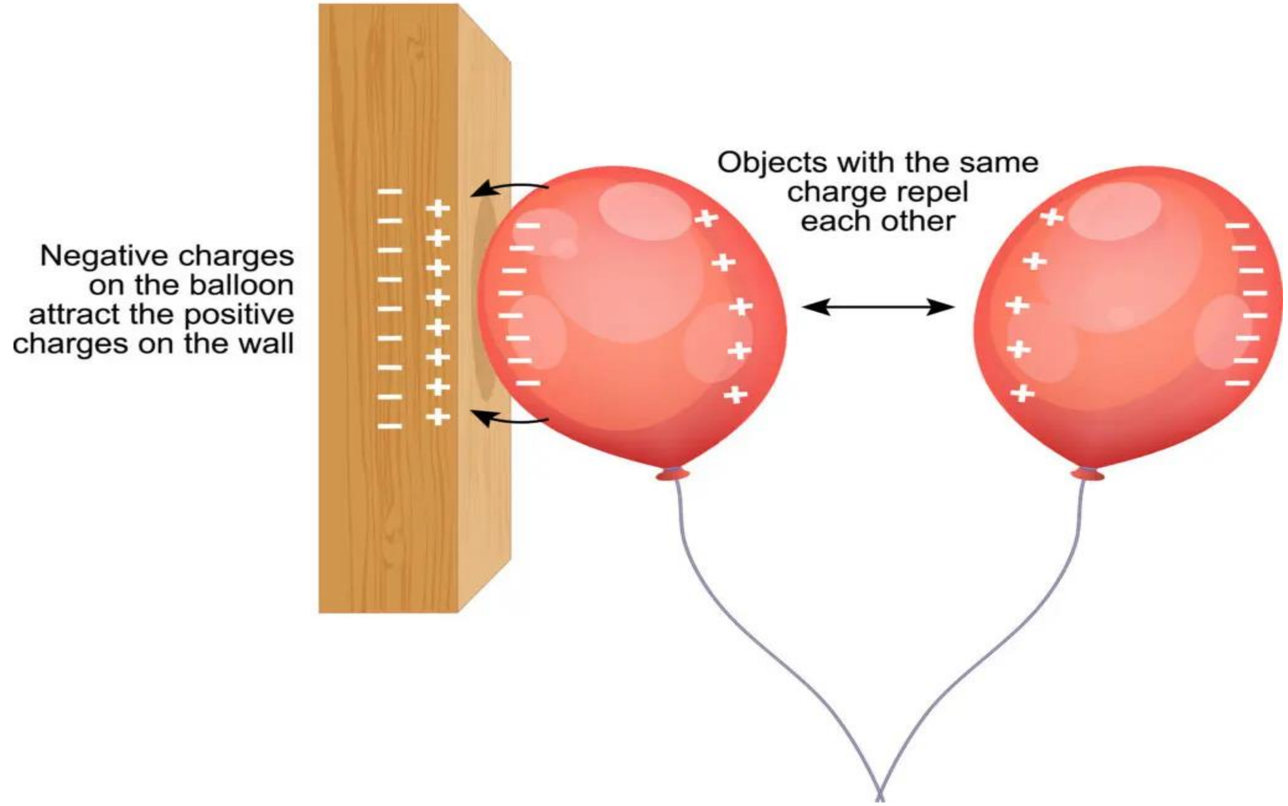
Vapor Corrosion Inhibitors



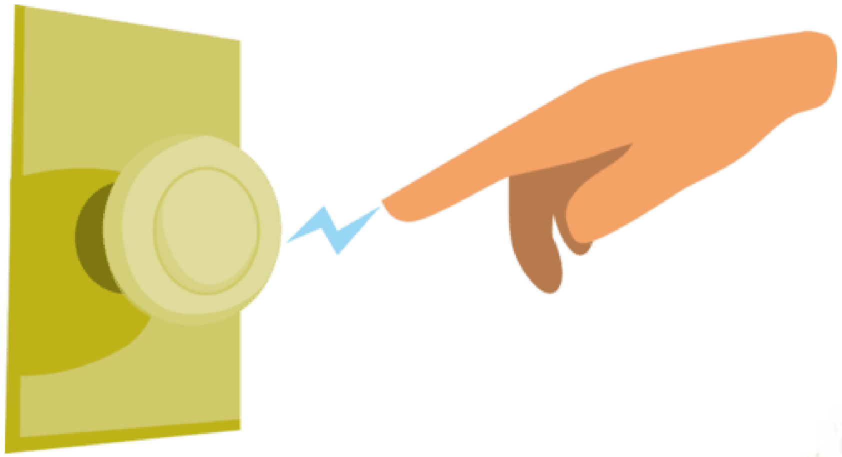
How VCI Works:

- ✓ Creates a protective environment in packages/enclosures.
- ✓ Forms an invisible shield on metal surfaces, preventing rust.
- ✓ Shield blocks oxygen, moisture, and corrosive elements.
- ✓ Dissipates when the metal is removed from packaging, ready for use—no cleaning needed.

Static Electricity

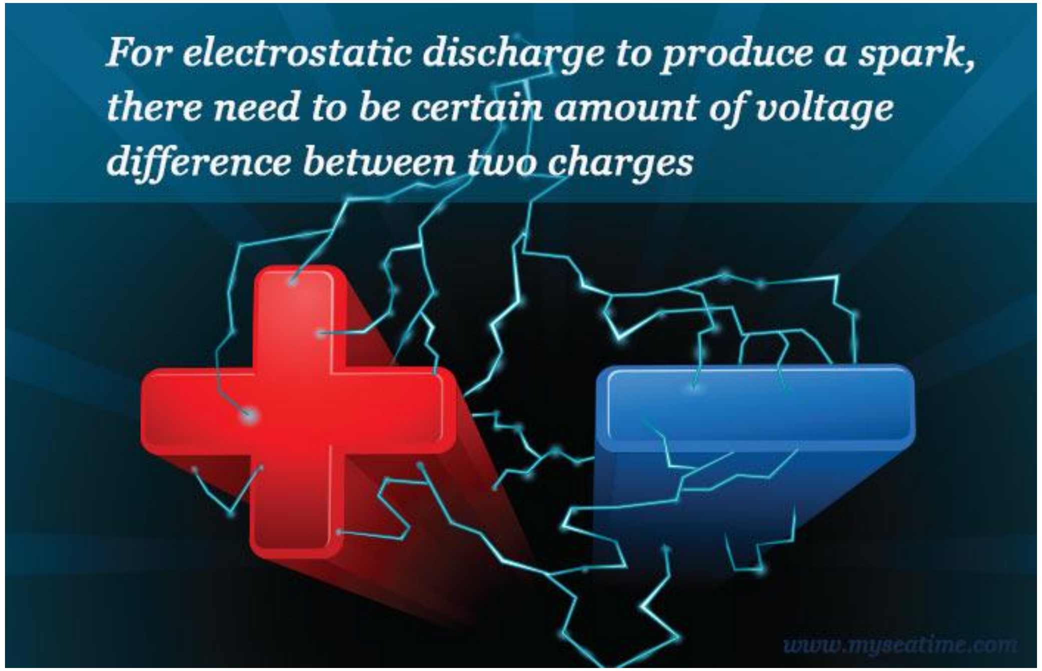


Electrostatic Charge: an imbalance of electrical charges on a material.



Electrostatic Discharge (ESD): the rapid, spontaneous transfer of electrostatic charge induced by a high electrostatic field.

- Most commonly created by the contact and separation of two materials.
- The mechanism is called "triboelectric charging" and involves the transfer of electrons.



Insulative Materials:

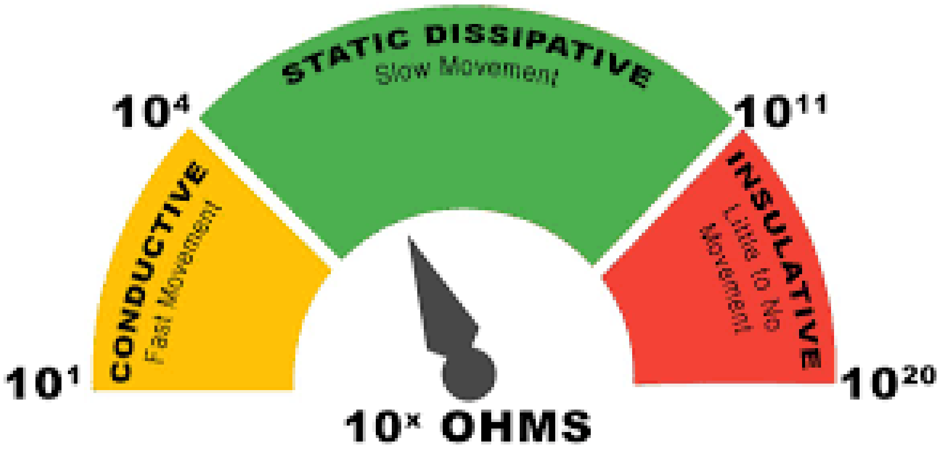
- Prevent or limit electron flow due to high electrical resistance (≥1.0 x 10^{11} ohms).
- Can generate a significant charge on the surface.

Dissipative Materials:

- Electrical resistance between insulative and conductive materials.
- Surface resistance: ≥1.0 x 10^4 but <1.0 x 10^{11} ohms.
- Ideal for contact with ESD-sensitive materials.

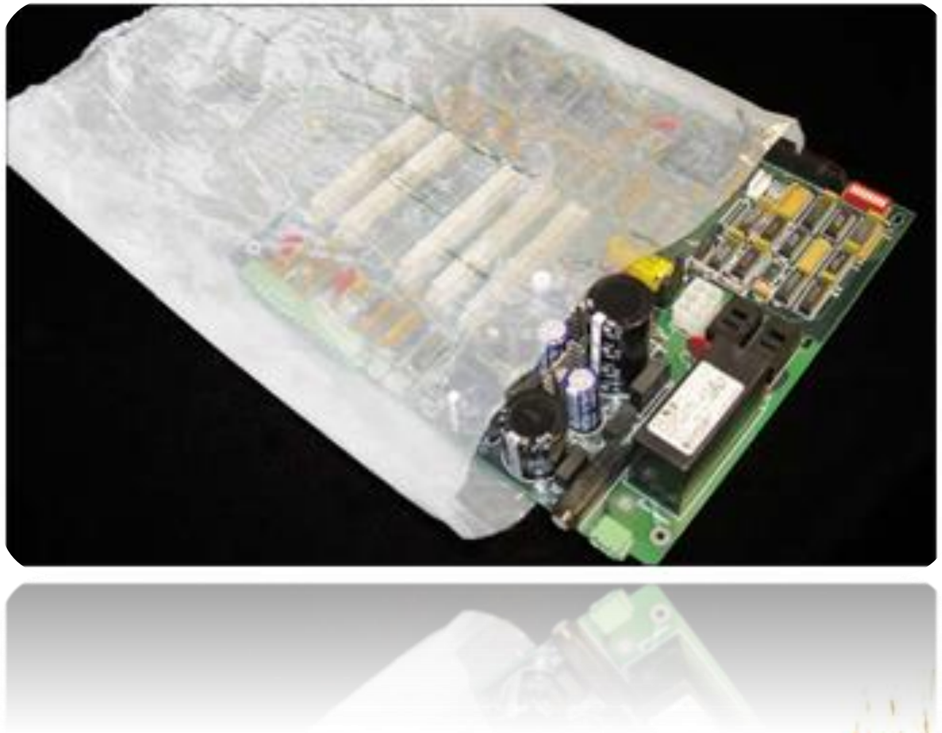
Conductive Materials:

- Allow electrons to flow easily across the surface or through the volume.
- Resistance: <1.0 x 10^4 ohms



VCI biodegradable and compostable packaging films with antistatic properties

- Packaging materials for storage and transportation of metal parts
- Impregnated with VCIs to provide corrosion protection in addition to the basic physical barrier
- Contains permanent anti-static agent to provide antistatic protection



VCI recyclable, biodegradable and compostable packaging paper

- Packaging materials for storage and transportation of metal parts
- Impregnated with VCIs to provide corrosion protection in addition to the basic physical barrier
- Made with 100% recycled content paper
- Contains 92% USDA-certified biobased content
- Compostable per ASTM D6868

Experimental Procedure

MATERIALS

- Biodegradable resin (commercially sourced)
- Proprietary VCI formulations
- Antistatic additive (commercially sourced)
- Natural kraft biodegradable paper (commercially sourced)
- Low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE) (commercially sourced)

PRODUCTION METHOD

- Films produced using monolayer blown film extrusion at 160-200°C.
- Two resin blends:
  - LDPE/LLDPE/VCI base without ESD additive.
  - Biodegradable resin/VCI base with ESD additive.
- VCI and antistatic additives added during extrusion.
- Paper coated with VCI aqueous solution

Experimental Procedure

EVALUATION OF PROPERTIES

- Changes in physical, thermal and mechanical properties
- Razor Blade Test, E-001 (Cortec method)
- NACE Standard VIA Test, TM0208-2018
- Thickness – ASTM D6988
- Impact puncture – ASTM D3420
- Tensile strength at Break – ASTM D882-02
- Elongation at Break – ASTM D882-02
- Yield Strength – ASTM D882-02
- Tear Strength – ASTM D1922

EVALUATION OF ESD PROPERTIES

- Static Decay Rate – MIL-81705 D
- Surface Resistivity – ASTM D-257

Results – Razor Blade

Table 1: Razor Blade Test- Carbon Steel for VCI ESD film

Sample	Panel #1	Panel #2	Panel #3	End Result
Biodegradable VCI ESD film	Pass	Pass	Pass	Pass
VCI paper	Pass	Pass	Pass	Pass
Control film	Fail	--	--	Fail
Control paper	Fail	--	--	Fail

Table 2: Razor Blade Test- Copper Panels

Sample	Panel #1	Panel #2	Panel #3	End Result
Biodegradable VCI ESD film	Pass	Pass	Pass	Pass
VCI paper	Pass	Pass	Pass	Pass
Control film	Fail	--	--	Fail
Control paper	Fail	--	--	Fail

Results – Razor Blade on Carbon Steel

Figure 1: Razor Blade Test- Carbon Steel for sample biodegradable VCI ESD film at the beginning (left) and end (right) of the test.

Figure 2: Razor Blade Test- Carbon Steel for sample VCI paper at the beginning (left) and end (right) of the test.

Results – Razor Blade on Copper

Figure 3: Razor Blade Test- Cooper for sample biodegradable VCI ESD film at the beginning (left) and end (right) of the test.

Figure 4: Razor Blade Test- Cooper for sample VCI paper at the beginning (left) and end (right) of the test.

Results – VIA NACE

Table 3: VIA NACE Test results

Sample	Plug #1	Plug #2	Plug #3	End Result
Biodegradable VCI ESD film	Grade 3	Grade 3	Grade 3	Pass
VCI polyethylene film	Grade 3	Grade 3	Grade 3	Pass
VCI paper	Grade 3	Grade 3	Grade 3	Pass
Control 1	Grade 0	--	--	Fail
Control 2	Grade 0	--	--	Fail

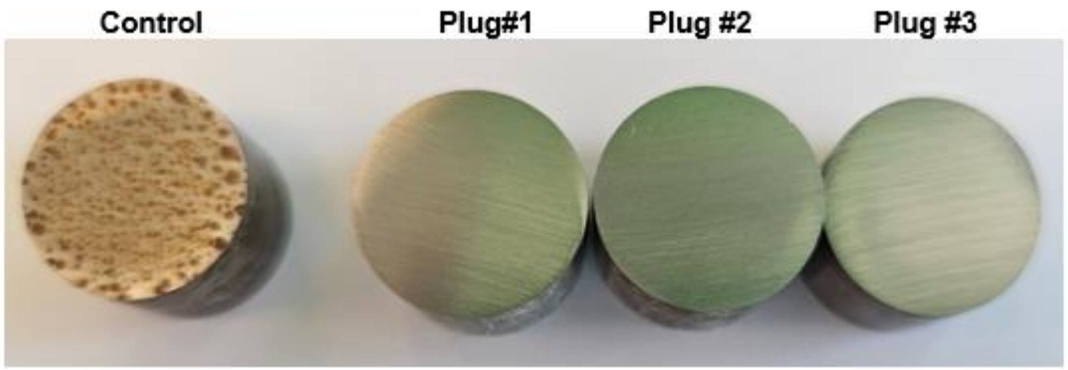


Figure 3: VIA NACE Test result for sample biodegradable VCI ESD film.

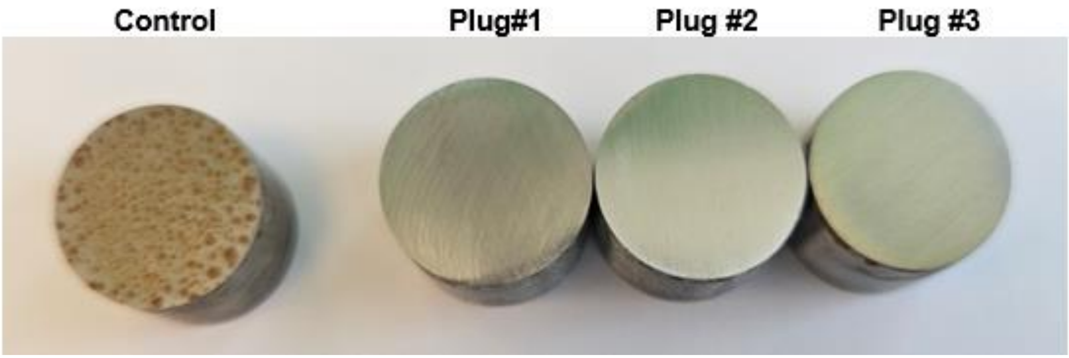


Figure 4: VIA NACE Test result for sample VCI polyethylene film.

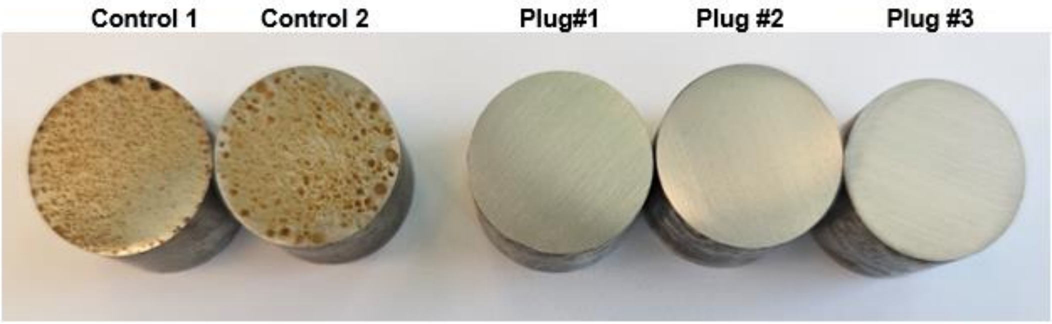


Figure 5: VIA NACE Test result for sample VCI paper

Results – Mechanical Properties of Film

Table 4: Results of mechanical properties for biodegradableVCI ESD film and VCI PE film.

Properties		Test method	Units	Biodegradable VCI ESD film	VCI polyethylene film
Thickness	MD	ASTM D6988	µm	64,80	58,60
	CD			70,80	61,20
Tensile Strength at Break	MD	ASTM D882	MPa	8,643	16,712
	CD			7,723	20,427
Percent Elongation at break	MD	ASTM D882	%	277,14	263,64
	CD			419,76	617,78
Yield Strength	MD	ASTM D882	MPa	7,20	14,58
	CD			5,67	7,40
Tear Strength	MD	ASTM D1922	mN	889,44	1255,68
	CD			4080,96	9051,36
Impact Elmendorf		ASTM D3420	mN	4394,88	11301,12
			J	0,38	0,97
BUR				2,55	2,55

Results – Mechanical Properties of Paper

Table 6: Results of mechanical properties for non-VCI and VCI paper.

Properties		Test method	Units	Non-VCI paper	VCI paper
Thickness	MD	ASTM D6988	µm	97,40	98,00
	CD			97,80	98,17
Tensile Strength at Break	MD	ASTM D882	MPa	57,246	17,518
	CD			37,619	13,543
Tear Strength	MD	ASTM D1922	mN	2328,24	2903,76
	CD			2511,36	2459,04

Results – Antistatic Properties

Table 5: Results of antistatic properties for ESD film

Surface Resistivity (Ohm/Sq)		Static Decay Rate (in seconds)			
Limit 1.0 x 10^5 to 1.0 x 10^{12}		Limit 2 second decay rate at 10% threshold			
		+ 5000 Volts		- 5000 Volts	
Outside Surface	Inside Surface	Outside Surface	Inside Surface	Outside Surface	Inside Surface
1,8 x 10^{10}	1,8 x 10^{10}	0,08	0,07	0,06	0,08

Conclusion

- This study compared the corrosion inhibition properties of compostable, biodegradable VCI ESD film and polyethylene VCI film.

- Both films demonstrated excellent corrosion protection according to the VIA NACE TM0208 standard, with the compostable film exhibiting slightly lower mechanical properties.

- VCI paper also proved effective in vapor phase corrosion protection, offering higher tear strength but lower tensile strength compared to non-VCI paper.