Novel Polyurethane Materials for Use in Digital Imaging Equipment

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Abstract

A novel family of polyurethane foam has been created to replace more traditional siloxane and epichlorohydrin based polymers. These high-density foams tend to be conductive in the range of $1E^8$ to $1E^9$ ohms. The electrical resistance, as well as the mechanical behavior, can be tailored to provide desired properties.

I. Introduction

Polyurethane, used as either a molded foam or elastomer, are known for high durability, flexibility and low compression set. There would be several advantages to a conductive, high-density, "free-rise" foam for electro conductive roller applications:

- Lower cost alternative to molded foams and elastomer;
- Ease of fabrication and design turnaround time;
- Wide range of force-deflection or hardness properties; without loss in other physical properties;
- Excellent lot-to-lot consistency in electrical and physical properties.

The use of low density (~ 1.8 – 4.0 lbs. /cu.ft) "free-rise" foam for toner roller applications is well documented. These foams have either been post treated with a conductive carbon coating, or in the case of higher resitivity needs, foamed with insitu-conductive additives such as carbon, quaternary ammonium compounds and metallic salts. Since coatings tend to wear, the insitu method has been preferred for consistency of the electrical properties over time. Typically resistivity values in the $1E^{10}$ to $1E^{11}$ range can be expected in this density range with insitu-conductive foams. There are numerous technical challenges that must be over come in order to develop a higher density, insitu-conductive polyurethane foam with electrical resistivity values in the low 10^8 range maintaining good hardness values. For paper we concentrated on the use of a metallic salt to manage conductivity.

II. Discussion

A. Technical Challenges

It is understood that significant ionic motion or flow exists only in the amorphous regions of a polymer matrix while crystalline regions are nonconducting. [1]

By their nature, high density (7 – 10 lbs/cu.ft.), free rise polyurethane foams contain a high degree of hard segment. The ratio of hard to soft segment, or crystallinity, of the urethane matrix must to be balanced to the ionic conductance. In high-density, free rise foams the heat of reaction is typically low which requires unique catalysis. It has been taught in patent literature that the lowest electrical resistance achievable using ionic compounds, in this density range, is about $1E^8$.[2] Our goal was to achieve this level of conductance or resistivity with free rise foams while maintaining a broad range of mechanical properties in the nominal density range of 7 – 10 lbs/cu.ft. The foams also had to process well in a manufacturing setting.

B. Development Path / Results

Key considerations:

- Overall polymer compatibility, molecular weight and functionality.
- Isocyanate type, functionality and isomer ratio.
- Catalysis used to initiate the hard and soft segment formation.

As you will see, both the physical and electrical properties are interdependent. We were able to achieve this through a proprietary means of chemistry and processing.

Figure 1 shows the physical properties of three example foams produced by this method.

Figure 3 and 4 show resistivity and compression force.

Typically hardness values are reported in Shore units. Here Shore values as well as Compression Force Defection (CFD) values were measured. The CFD curves better characterize how a particular material will function under load, such as a roller used in digital imaging equipment. The ability to maintain a given resistivity value while tailoring the force deflection value adds a degree of design flexibility, i.e., the material can be tailored to the performance characteristics required for the particular application. Figure

2 shows the CFD curves for the three example foams listed in figure 1. What this shows is the force required to deflect the material to 80% of its thickness as well as the force being applied as it returns to zero defection. The area of the curve between the deflection and return is the energy absorbed by the material.

Example:	(1)	(2)	(3)
Density (lbs. / cu. ft.)	7.4	7.6	8.0
Tensile Strength (psi)	23.0	50.0	118.0
Elongation (%)	151	141	113
Tear Strength (lbs.)	1.7	2.4	2.7
Compression Force Defection (psi) @ 25%	1.06	3.00	5.20
Resistivity (Ohm / Sq.)	3.0 E^8	6.7 E^8	2.4 E^9

Figure 1. Physical Properties

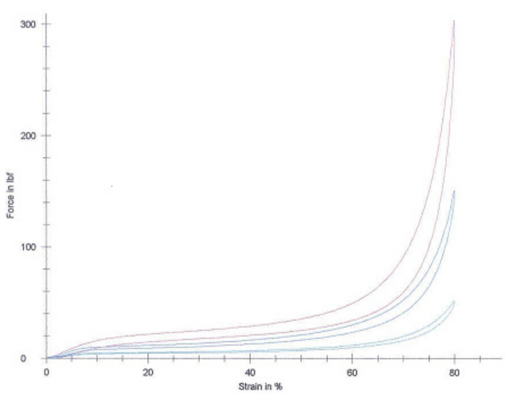
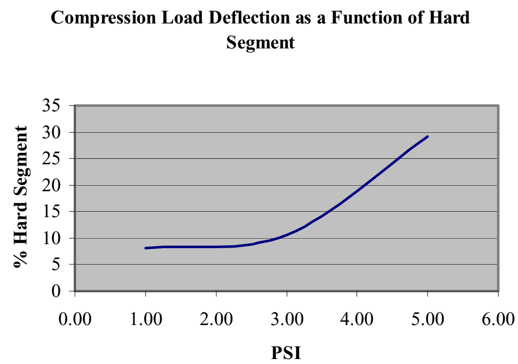
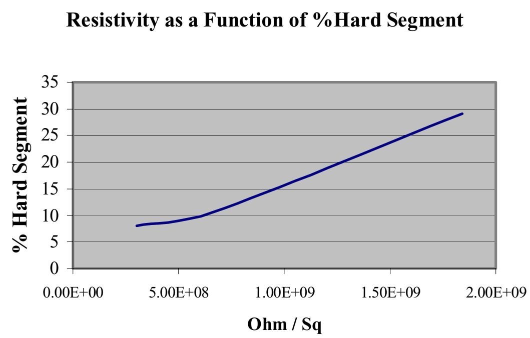


Figure 2





Figures 3 and 4

III. Conclusions

It is possible to produce high density, “free rise”, urethane foams using a metallic salt, that have ohm / sq. resistivity values in the low 1E^8 to 1E^9 range as well as exhibiting good hardness values. This technology provides a tunable, lower cost alternative to molded foam and elastomer.

References

1. C. Berthier, W. Gorecki, M. Minier, M. B. Armand, J. M. Chabagno, and P. Rigaud, *Solid State Ionics,* 11, 91 (1983)
2. Poh Poh Gan, Michael Bessette, United States Patent Number 5,855,818, *Electrically Conductive Fiber Filled Elastomeric Foam* (57), 46

Biography

Joe Lovette studied chemistry and mathematics at the University of Delaware prior to joining Foamex’s Corporate R&D Group in 1967. Joe currently serves as a technical adviser to the Foamex Technical Products Group.