Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 10 (2011) 930–935
Engineering Procedia

ICM11

Flexural Test On Recycled Polystyrene

P. N. S. Schmidt[a,*], M. O. H. Cioffi[a], H. J. C. Voorwald[a], Silveira, J. L. [b]

[a]Faculdade de Engenharia de Guaratinguetá – UNESP, Univ. Estadual Paulista, Department of Materials and Technology, Fatigue and Aeronautic Materials Research Group. Av. Ariberto Pereira da Cunha, 333, Guaratinguetá, 12516-410, SP – Brazil
[b] Faculdade de Engenharia de Guaratinguetá – UNESP, Univ. Estadual Paulista, Energy Department, Energetic System Otimization Group, Av. Ariberto Pereira da Cunha, 333, Guaratinguetá, 12516-410, SP – Brazil

Abstract

In socio-environmental scenario increased the nature resources concern beyond products and subproducts reuse. Recycling is the approach for a material or energy reintroducing in productive system. This method allows the reduction of garbage volume dumped in environment, saving energy and decreasing the requirement of natural resources use. In general, the ending of expanded polystyrene is deposited sanitary landfills or garbage dumps without control that take large volume and spreads easily by aeolian action, with consequently environmental pollution, however, the recycling avoids their misuse and the obtainment from petroleum is reduced. This work recycled expanded polystyrene via merger and/or dissolution by solvents for the production of integrated circuits boards. The obtained material was characterized in flexural mode according to ASTM D 790 and results were compared with phenolite, traditionally used. Specimens fractures were observed by electronic microscopy scanning in order to establish patterns. Expanded Polyestirene recycled as well as phenolite were also thermo analyzed by TGA and DSC. The method using dissolution produced very brittle materials. The method using merger showed no voids formation nor increased the brittleness of the material. The recycled polystyrene presented a strength value significantly lower than that for the phenolite.

Keywords: Expanded Polystyrene; Recycling; Integrated Circuit Boards.

1. Introduction

Fifty years ago the Expanded Polystyrene (EPS) was created composed by 98% air and 2% of raw material (polystyrene). The EPS known as Styrofoam is identified as a rigid cellular thermoplastic, resulted from the

* Corresponding author. Tel.: +55 12 3123-2865; fax: +55 12 3123-2852.
E-mail address: paula.schmidt@hotmail.com.

1877-7058 © 2011 Published by Elsevier Ltd. Selection and peer-review under responsibility of ICM11
doi:10.1016/j.proeng.2011.04.153

polymerization of styrene in water [1,2]. This material has been widely applied in many ways such as for packaging industry, consumer goods, building materials, beyond for die-cast processes of auto industry engine blocks [3,4].

The world production of polystyrene is approximately 3 million tons by year been packaging and consumer goods industries responsible for 54% of the total production, followed by the construction business with 46% [4,5].

The polystyrene is a solid transparent material, formed by the polymerization of many styrene molecules, (benzene and ethylene from petroleum). In the production of expanded polystyrene, the raw material is subjected to a process of physical transformation, without changing its chemical properties [6].

The structure of expanded polystyrene can be viewed in two levels. The macroscopic level, where the standard structure consisting of closed balls, usually with a diameter in the order of 2-4 mm indicated in Figure 1a. The cellular structure presented in each sphere is shown in Figure 1b [7].

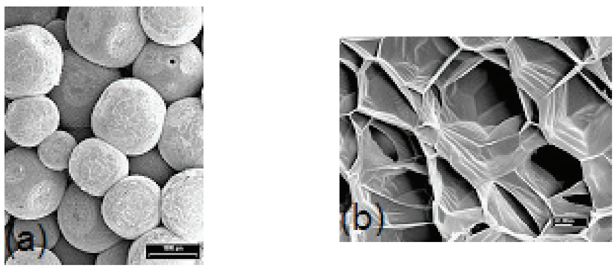

Figure 1: a- the macroscopic level; b- the microscopic level [7]

The EPS is a chemically inert material not biodegradable, ie, it does not decompose, does not disintegrate, does not disappear in the environment and does not contain CFCs, consequently the EPS does not chemically contaminate the soil, water or air. However it can be an environmental problem if not recycled because it is considered an eternal material and it takes up too much space (due to its low density). The technique of Styrofoam recycling can be done in several ways, depending on the final use of the product [8].

The tailings can be processed by compression mold into blocks again and injected to form containers for packaging;

They can be used as substrates for soil improvement, in drainages, in gardens, and for airing decayed materials;

They can be reused in the construction or to generate electricity or heating by direct combustion.

Printed circuit boards must have characteristics such as good insulation, stiffness, flexibility and heat resistance, due to the efforts they are submitted during their operation.

1.1 Printed Circuit Boards

The printed circuit boards are basic and essential components, widely used throughout the electronics industry, it is the most common and practical mean for final assembly and electronic circuits. The production generates the circulation of the electric current in a circuit by a thin layer of a conductor printed on the card, an insulating base, in which electronic components are fixed by welding, thus replacing the wiring. Resulting in an adequate distribution of components in a small space, allowing the reduction of equipment. Nowadays in industries, the most used materials as insulating bases are phenolite, paper epoxy, glass fiber and polyester fiber, but there are still boards made of polyester film, specific films based on various polymers or compounds of these materials. The determination of ideal material is based on physical characteristics established by the component applied efforts during the aperation [9].

2. Materials and Methods

The methodology was realized according to flowchart in Figure 2, and consisted into developing recycled expanded polystyrene-based materials via dissolution by solvents (acetone and d-limonene) and merger to produce integrated circuit boards. The obtained material was characterized in flexural mode according to ASTM D 790 and results were compared with phenolite, traditionally used, fractures were observed by electronic microscopy scanning in order to establish patterns. Expanded Polystyrene recycled as well as phenolite were also thermo analyzed by TGA and DSC.

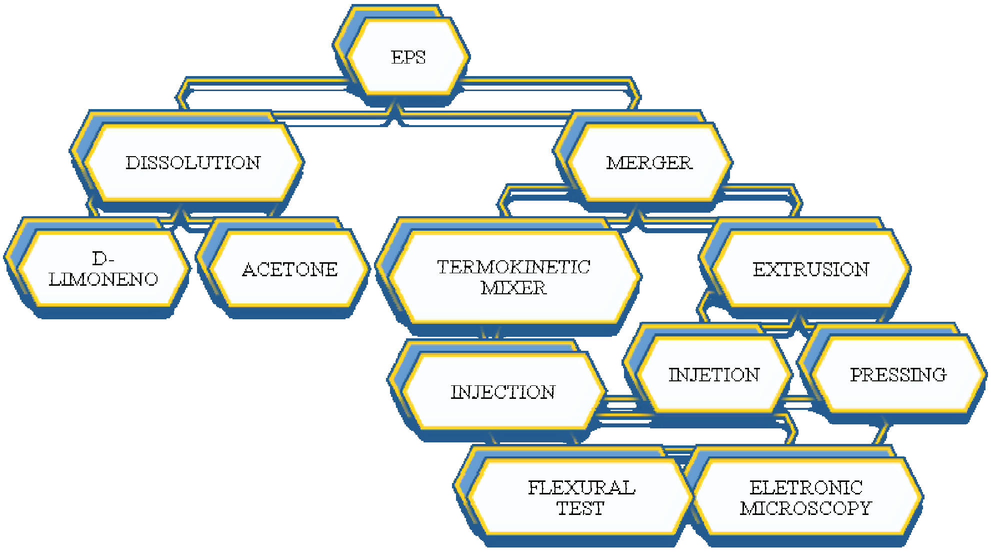

Figure 2 – Flowchart of the methodology

3. Results and Discussion

Tests were conducted by using some different solvents such as acetone and d-limonene. A air bubbled rustic plastic was obtained, according to figures 3 and 4. With a brittle characteristic classified it at not an adequate material to circuit board application.

Figure 3 - Initial results of the dissolution of EPS with acetone

Figure 4 - Initial results of the dissolution of EPS with d-limonene

Extrusion was performed, in foam state is turned into filaments (Figure 5) followed by a granulation process (Figure 6) pressure to obtain a recycled material plate as shown in Figure 7.

The extruded material presented itself uniform, without voids and fragile. After the pressing, the obtained board was more resistant, smoother and with no voids, a result that enables the desired application. Nevertheless comparative analysis with the material being currently used for this purpose is still required.

Figure 5 – Fillets

Figure 6 - Granular

Figure 7 - Pressed Plate PS

A termokinetic mixe rmodel MH-50H was also used for agglomerated the EPS, which was placed in the capsule, after merger was granulated.

The granules obtained in the termokinetic mixer and extruded were injected using bending specimens molds (figure 8).

Figure 8 – Specimens Bending: (a) Termokinetic mixer; (b) Extrusion

Bending tests was performed on the specimens produced in the three processing (thermokinetic mixer, extrusion and compression mold). The values of flexural strength obtained and the resistance values for all studied materials, are shown in Table 1.

Table 1: Values of flexural strength.

	Flexural Strength (MPa)
Phenolite	110 – 150
Termokinetic mixer	43,4
Extrusion	13,4
Pressed	6,5

According to data from Table 1 is observed that the recycled polystyrene present a strength value significantly lower than that for the phenolite, this can be explained by the fact phenolite be a hard and dense industrial plastic manufactured under the high pressure and heat application, known popularly as thermoset laminate, mainly composed of layers of special paper source (paper phenolic, kraft) and coagulated into a single mass with the use of phenolic resin with high mechanical strength for use in low and medium voltage.

The electron microscopy analysis was generated images from fractured specimens tested in bending and tension modes obtained by all processes.

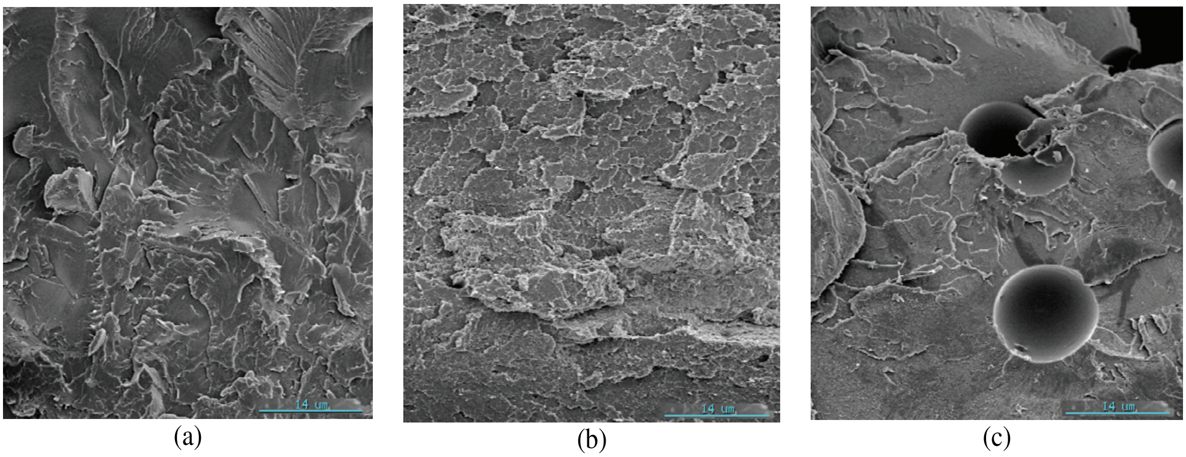

Figure 9 – (a) Sample processed by extrusion tested by bending; (b) Sample processed by termokinetic misture tested by bending; (c) Sample processed by compression mold tested by bending.

In the Figure 9a is possible to observe that there is no presence of voids and that fractured layers. In Figure 9b it is possible to see high roughness. In the Figure 9c is possible to observe a smooth appearance with fragile character by the presence of many pores.

The TGA analysis, Figure 10 shows mass loss percentage versus temperature curve, in a temperature range of 25°C to 500°C. It can be observed a weight loss up to 333.96°C. Between 333.96°C and 387.48°C there is a mass decrease regarding the air which is present in the PS particles, representing 64.360% of the EPS mass From 387.48 °C on, there is a thermal degradation.

The DSC curve, Figure 11, indicates that the glass transition temperature (Tg) of the expanded polystyrene occurs at about 106.6°C, the tg of the extruded polystyrene occurs at 101.1°C and the tg of the compressed polystyrene occurs at 101.8°C. It is observed that after the extrusion the Tg of the material decreases about 5°C, with a slightly difference to the next step. The heat flux between the three stages of the PS decreases, with large difference between the expanded, the extruded and the compressed stage.

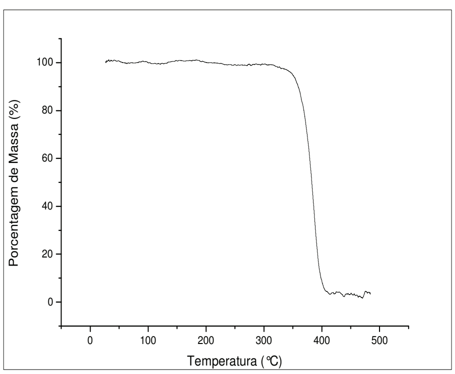

Figure 10 - Graph of TGA of PS expanded

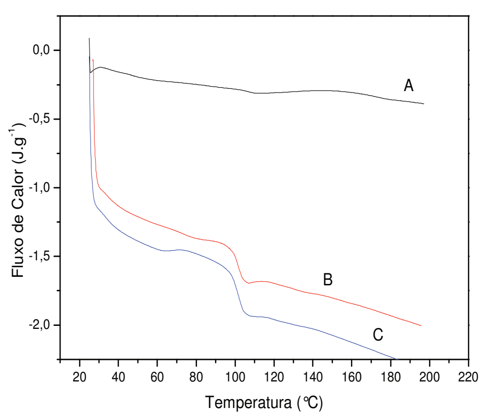

Figure 11 - Graph of the DSC, where A is the expanded PS, B is the extruded PS and C is the pressed PS

The Tg is an important characteristic since the thermal properties of the materials are dependent on this value, such as hardness (glassy material is harder than the rubber), volume and elasticity modulus.

4. Conclusion

With these results, it was concluded that the method followed by extrusion-compressing showed strength values lower than the material to be used for this application, which can be explained by the presence of many pores embrittlement. The method using extrusion and method using Termokinetic mixer followed by injection showed values higher than the resistance method using pressing but still smaller than the material used today for this application.

References

[1] TECHNICAL INFORMATION. *Properties – General* [CD-ROM]. Ludwigshafen, Alemanha: Catálogo Técnico da Basf, Julho 1992. nº 22246.

[2] CANEVAROLO, *Técnicas de Caracterização de Polímeros*, pg 167 e 168. Editora ArtLiber (2004);

[3] FRANCA, A.B.M.; VIANA, M.F.A.; RODRIGUES, M.F. *Estudo Comparativo Entre Laje Convencional e Lajes Com Blocos de EPS nas Modernas Construções de Concreto Armado.* João Pessoa, 1997. UFP - Universidade Federal da Paraíba.

[4] ABRAPEX - Associação Brasileira do Poliestireno Expandido. *Mercado de EPS e Reciclagem.* Available from Word Wide Web: <www.abrapex.com.br>.

[5] GROTE, Z., V. *Estudo do uso do EPS na Construção Civil: Uma Opção Para a Conservação de Energia.* Guaratinguetá, Obs: defesa - Maio de 1999. Aproximadamente 120 págs. Dissertação (Mestrado em Engenharia Mecânica) – Faculdade de Engenharia de Guaratinguetá, UNESP.

[6] Ambiente Brasil. Available from Word Wide Web: <http://ambientes.ambientebrasil.com.br/residuos/isopor/isopor_%28poliestireno_expandido_-_eps%29.html>.

[7] ROSSACCI, J., SHIVKUMAR S., *Bead fusion in polystirene foams* Department of Mechanical Engineering, Worcester Polytechnic Institute – 2002.

[8] GRUPO POLIMEX. *Reciclabilidade y ecologia* [on line]. México: Grupo Polimex, 1997. Available from Word Wide Web: <http://www.Polimex.com.mx/ reciclado.html >.

[9] CIRVALE. Available from Word Wide Web:. <www.cirvale.com.br>.