Development and Characterization of Bulk and Epoxy Molding Compounds from Non-Metallic Fractions Recovered from Printed Circuit Boards †

Márcia Silva ¹, Raimundo Silva ², Paulo Nóvoa ³, Helena M. V. M. Soares ¹, Margarida M. S. M. Bastos ⁴ and António Marques ³,*

¹ REQUIMTE/LAQV, Department of Chemical Engineering (DEQ), Faculty of Engineering, University of Porto, Rua Roberto Frias, 4200-349 Porto, Portugal; up201502999@fe.up.pt (M.S.); hsoares@fe.up.pt (H.M.V.M.S.)
² Department of Material Engineering, School of Technology, State University of Amazonas, Av. Darcy Vargas, 1200, Manaus 69005-020, Brazil; masilva@uea.edu.br
³ Department of Mechanical Engineering (DEMEGI), Faculty of Engineering, University of Porto, Rua Roberto Frias, 4200-349 Porto, Portugal; up19840309@edu.fe.up.pt
⁴ LEPABE, Department of Chemical Engineering (DEQ), Faculty of Engineering, University of Porto, Rua Roberto Frias, 4200-349 Porto, Portugal; mbastos@fe.up.pt
* Correspondence: marques@fe.up.pt
† Presented at the Materiais 2022, Marinha Grande, Portugal, 10–13 April 2022.

Keywords: molding compounds; waste printed circuit boards; recycling process

The production of waste electrical and electronic equipment (WEEE) has been trending upwards in recent years due to their wide range of utilities. One part of WEEE is fundamental to almost all equipment: printed circuit boards (PCBs). PCBs have a metallic fraction with mostly iron, copper, nickel, and precious metals, e.g., gold, and a non-metallic fraction.

This non-metallic fraction from PCB is composed of fiberglass that can be used to replace a small part of ore materials used in the production of many compounds. These fibers are recovered with an organic process, called organic swelling, using organic solvents to separate the fiber layer without contaminants.

In this work, the recovered fibers were included in the manufacturing process of molding compounds. Molding compounds, specifically the ones based on bulk and epoxy resin, are glass-fiber-reinforced thermoset polymers that can be used in many different areas, for example, the building and construction, automotive, mass transport, electrical, sanitary, household and many other sectors. Ore materials are becoming scarce, and the use of recycled materials in the manufacturing processes of various composites is becoming more important. Recycling these thermoset polymers is difficult due to their characteristics. Therefore, it is more interesting and advantageous to include recycled materials, such as recovered fibers, in the production process. To each molding compound made using epoxy resin and bulk resin, three possible formulations are proposed: one with the partial use of long fibers, another with powder fiber mixed with fiberglass, and one with the full percentage of long fibers from WPCB.

To evaluate the influence of using WPCB fibers, mechanical tests were performed: flexural, tensile, and Charpy impact.

The aim of this study is to compare the formulations with recycled materials to the formulations without any adjustments to determine which formulation has the best mechanical qualities and can be an environmentally friendly alternative. According to the results, the most efficient way to use the recovered fibers would be in a smaller fraction and not in powder, so that it can maintain its normal mechanical characteristics and slightly improve them.
**Author Contributions:** Conceptualization, H.M.V.M.S., M.M.S.M.B. and A.M.; methodology, A.M. and P.N.; validation, P.N.; investigation, R.S., M.S. and P.N.; writing—original draft preparation, M.S.; writing—Review and Editing—A.M. and P.N.; visualization, M.S. and R.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** The work reported here was financially supported by: Project PTDC/EAMMIN/31041/2017—POCI-01–0145–FEDER–031041—funded by FEDER funds through COMPETE2020-Programa Operacional Competitividade e Internacionalização (POCI) and with financial support of FCT/MCTES through national funds (PIDDAC).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.