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Application of Nanocomposite and Stereolithography to Fabrication Medical Models

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Abstract – Infrared Laser Stereolithography is a novel technology in RP based on the principle of localized cure of epoxy/silica nanocomposite material through the action of infrared laser. To optimize and control the manufacturing process, experiments and simulations were carried out to examine the fundamental relationships of reaction curing of the material and the laser operational parameters. From this, the aim of this work is to evaluate the influence of the type of NS in the curing behavior of epoxy/silica nanocomposite. Through the results, it is possible conclude that the NS particle plays an important key in controlling the localized curing and the diffusion of heat through adjoining areas and the blockade of the contact between reagents does not happen, hence curing occurs locally.

As it is well known, the term rapid prototyping (RP) refers to a number of different but related technologies that can be used for building very complex physical models and prototype parts directly from 3D CAD model. The most interesting and challenging applications of rapid RP technologies are in the field of medicine which have found application for planning treatment for complex surgery procedures, training, surgical simulation, diagnosis, design and manufacturing of implants as well as medical tools [1]. Advances in medical imaging technology (CT, MRI), and in computer-based image processing and modeling have made it possible to geometrically model and visualize anatomical structures and interpret the information obtained for each patient, which can be used by computer-assisted surgery tools that help the surgeon to follow the proposed surgical plan. The 3D reconstructions from CT and MRI scans have been used to precisely plan both the exact position as well as safe pathway to removal or ablation tumor. In addition, the physician can use the 3D image for patient education to show and explain the patient's problem and can be used for pre-operative planning, or surgical simulation to optimize the surgical procedure [2].

Among these technologies is Infrared Laser Stereolithography, a novel technology in RP based on the principle of localized cure of nanocomposite material through the action of infrared laser (CO_2 laser). In order to optimize and control the manufacturing process, experiments and simulations were carried out to examine the fundamental relationships of reaction curing and of the CO_2 laser operational parameters. The relationships can be used to control the localized cure and material morphology that will determine properties of the final product. Numerical model is propose to describe different effects involved in localized curing, presenting a good agreement the experimental obtained by DSC and the layer of nanocomposite material cured by the Infrared Laser Stereolithography process. From this, the aim of this work is to evaluate the influence of the type of nanosilica (NS) in the curing behavior of epoxy/silica nanocomposite. The nanocomposite using DGEBA prepolymer, DETA curing agent and two types of NS, hydrophilic and hydrophobic, as filler, were prepared.

Through the results, it is possible conclude that the NS particle plays an important key in controlling the localized curing and using the right amount of NS, the diffusion of heat through adjoining areas and the blockade of the contact between reagents does not happen, hence curing occurs locally.

Different thermal analysis experiments allow concluding that the hydrophilic NS serves to significantly increase the curing reactions that occur at temperatures below 90 ºC and the DGEBA/DETA/NS system studied reveals that for high temperatures the cure time is low and the reaction rate is high due to the amount of energy that is offered to start the curing system process.

The observation of results obtained from the numerical simulation allows an analysis of the system operational parameters (laser beam diameter, scanning speed, laser power and the variation of the temperature increase at the edge and the center of the surface of the sample) for its influence on the results allow an optimization of the process. The tests show that the experimental results match the simulations carried out properly and that the nanocomposite material does not present heat sink when irradiated by laser, which for the conventional stereolithography resin suffers contraction when exposed to UV laser spectral region. Also, result shows an improvement with respect to heat sink effect, but an adjustment must be made in operating conditions and sample characteristics for which the cure is located within the dimensions of the laser beam diameter.

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[2] S. Singare, Q. Lian, W. P. Wang, J. Wang, Y. Liu, D. Li and B. Lu. *Rapid Prototyping Journal* 15 (2009) 19-23.