10th World Congress on Structural and Multidisciplinary Optimization
May 19 - 24, 2013, Orlando, Florida, USA

Optimal Shape for Optical Absorption in Organic Thin Film Solar Cells

Songtao Xia[1], Guangyong Li[2], Xiaoping Qian[1]

[1]Department of Mechanical, Materials and Aerospace Engineering, Illinois Institute of Technology, Chicago, IL 60616. Email: qian@iit.edu
[2]Department of Electrical and Computer Engineering, University of Pittsburgh, Pittsburgh, PA 15261. Email: gul6@pitt.edu

1. Abstract
Organic thin film solar cells are attractive because they can be fabricated as large area devices at low cost and relatively low processing temperatures, compared with inorganic solar cells. However, one of the main drawbacks which prevents it from commercialization is the insufficient light absorption in the thin films. The property of organic solar cells (OSCs) materials demands structures to absorb incident light efficiently in the active layer of low thickness. In the pursuit of increasing the power conversion efficiency of OSCs, novel design of light trapping geometries which enhance the light absorption has been drawing much attention.
In this paper, the optical performance of organic thin film solar cells are analyzed using the finite element method solving the Maxwell's equation. This enables us to take into account the wave interference and diffraction effects in small structures, leading to more accurate results. Shape optimization is then performed with the goal of maximizing the light absorption in the active layer, while keeping its thickness low. The used optimization algorithm is based on the gradient of the objective and constraint functions, where sensitivities are obtained efficiently from the adjoint approach. To avoid irregular shapes in the structure, such as large oscillation and sharp corners, two different shape representation techniques, finite element node based curve with Helmholtz filter and B-spline with variant number of control points, are discussed and both are demonstrated being effective in smoothing the design shapes. Moreover, as a commonly used geometry representation in computer aided design (CAD) systems, B-spline allows us to choose fewer design variables independent of the finite element mesh, making it much appealing in such shape optimization problems.
Though the design space of the optimization problem consists of a large class of variable shapes, periodic grating structures are observed in all the optimized shapes. This confirms the known grating effect of light propagation in textured structures. Compared with a planar structure with already optimized thickness, the light absorption in our optimized structure has been further increased by about 28%, in the active layer of commonly acceptable thickness of 150 nm under the incident light of AM 1.5G global spectrum. Particularly, the optimized shapes are manufacturable which makes it very promising for the commercialization of OSCs.

2. Keywords: light absorption, shape optimization, adjoint sensitivity, Helmholtz filter, B-spline.