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Lithography-based ceramic manufacture (LCM) of auxetic structures: present capabilities and challenges

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Abstract

Auxetic metamaterials are known for having a negative Poisson's ratio (NPR) and for displaying the unexpected properties of lateral expansion when stretched and densification when compressed. Even though a wide set of micro-manufacturing resources have been used for the development of auxetic metamaterials and related devices, additional precision and an extension to other families of materials is needed for their industrial expansion. In addition, their manufacture using ceramic materials is still challenging. In this study we present a very promising approach for the development of auxetic metamaterials and devices based on the use of lithography-based ceramic manufacturing. The process stands out for its precision and complex three-dimensional geometries attainable, without the need of supporting structures, and for enabling the manufacture of ceramic auxetics with their geometry controlled from the design stage with micrometric precision. To our knowledge it represents the first example of application of this technology to the manufacture of auxetic geometries using ceramic materials. We have used a special three-dimensional auxetic design whose remarkable NPR has been previously highlighted.

Keywords: auxetics, negative poisson ratio, metamaterials, additive manufacturing technologies, lithography-based ceramic manufacture

(Some figures may appear in colour only in the online journal)

1. Introduction

Conventional materials experiment a typical reduction in width when stretched. A quantitative measure of this dimensional change can be defined by a relevant property called 'Poisson's ratio' and defined as: $\nu = -d\varepsilon_{trans}/d\varepsilon_{axial}$, being ε_{trans} and ε_{axial} the transverse and axial strains when the material is stretched or compressed in the axial direction. In a more general case, ν_{ij} is the Poisson's ratio that corresponds to a contraction in direction 'j' when an extension is applied in direction 'i'. For most materials (and structures) the value of Poisson's ratio is positive and reflects a tendency to conserve volume. Auxetic materials (or metamaterials) are those with a negative Poisson's ratio (NPR), i.e. for displaying the unexpected property of lateral expansion when stretched, as well as a counterintuitive shrinking when compressed [1–6]. Natural auxetics (including some minerals, furs, skins…) and man-made ones (Gore-Tex®, polymeric foams) have been described and very special attention has been paid, since their discovery, to the search and development of auxetic structures designed and controlled even down to molecular scale levels [5–7].

