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Hybrid Genetic Programming Designed Laser-Induced Graphene Based Absorber

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***Abstract*—Hybrid genetic programming (HGP) is applied to the design and optimization of a laser-induced graphene (LIG) based metasurface (MS) electromagnetic absorber. The HGP designed absorber has bandwidths of 115.4%and 56.5% for absorptivity above 70% and 80%, respectively. It is 5.1 mm thick, with a unit cell (UC) periodicity of 8.7 mm. The LIG is generated on a polyimide substrate. The MS absorber has copper ground plane backing.**

I. INTRODUCTION

Metasurface (MS) electromagnetic absorbers are desirable for many applications. MS absorbers can be implemented in stealth applications, where the objective is to minimize radar signatures with minimal material thickness [1]. Absorbers can be used for the shielding of sensitive spacecraft electronic devices from increased radiation in space [2]. Conventional electromagnetic absorbers are comprised of lossy materials [1]. MS absorbers have utilized metal-insulator-metal (MIM) structure, which in many cases leads to narrow absorption bandwidth since resonance is used [3], [4]. In this work we present an absorber that utilizes laser-induced graphene on an insulator that is metal backed.

II. LASER-INDUCE GRAPHENE

Flexible MS absorbers improve conformability to various platforms where concealment is desired. Laser-induced graphene (LIG) has growing interest for applications that require device flexibility [5-7]. LIG does not require additive chemical or high-temperature treatments [8]. The LIG is generated by scribing on a carbonated polymer by an infrared CO2 laser [8]. The production of LIG is an inexpensive and quick process that offers precision and high throughput [9].

III. HYBRID GENETIC PROGRAMMING

The hybrid genetic programming (HGP) algorithm utilizes genetic programming (GP) for a design's typology and parameter optimization. This is combined with a lower-level optimizer, such as genetic algorithm or conjugate gradient method, to improve optimization efficiency of parameter values.

GP is an evolutionary inspired algorithm [10]. A population of potential designs have genetic inspired operations applied to them based on each designs' performance. The application of the genetic operations generates the next generation of potential designs.

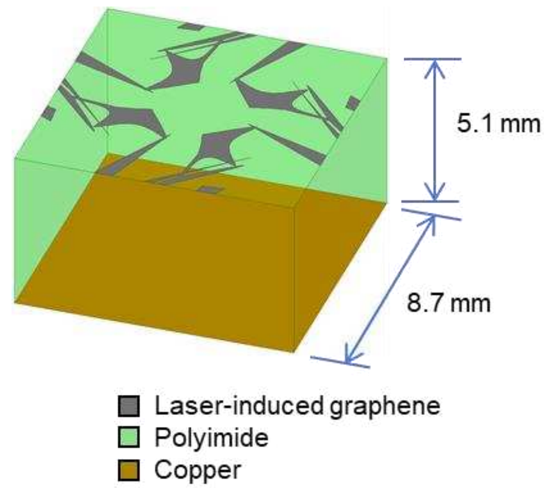

Figure 1. HGP design LIG MS absorber.

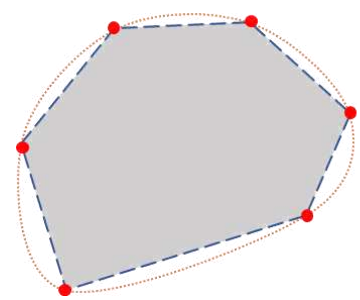

Figure 2. HGP MS building block polygon. Vertices (red), cubic spline (orange), and straight-line segment (blue) are illustrated.

The members of the population are represented by tree structed graphs, where the nodes represent operations or parameter values. The performance of the potential designs is judged using a fitness or cost function. The genetic operations applied are crossover, mutation, and elitism. Crossover mixes aspects of two designs to generate a new design for the next generation. Mutation randomly mutates part of a design. Elitism copies a design from one generation to the next. The designs generate by HGP are evaluated using full-wave electromagnetic simulations.

The fitness function used in the optimization of the LIG MS absorber is defined as:

$$fitness = \sum_{i=1}^{N} 1 - \Gamma_i^2 \quad (1)$$

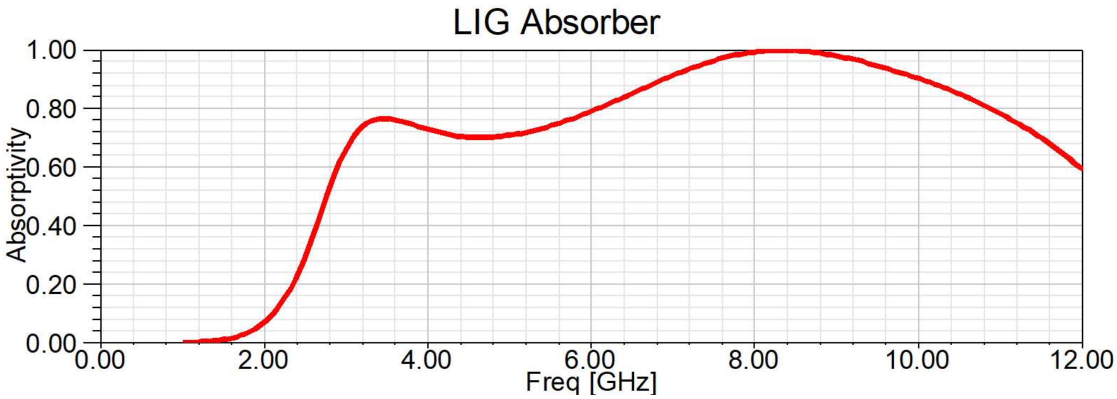

Figure 3. Absorptivity of HGP designed LIG MS absorber.

where, N is the number of frequencies being solved for using the full-wave finite element method (FEM) simulations, Γ_i is the reflection coefficient at the simulated frequency i.

The LIG patterning is synthesized and optimized as multiple polygons. An example of one of these building-block polygons is shown if Fig. 2. The number of polygons in the design is variable and is part of the optimization. For each polygon the number of vertices, the location of the vertices, the center location of the polygon, and the connection type between the vertices are optimized. The vertices for each polygon can either be connected by a straight-line segment or by a cubic spline.

IV. HGP Absorber Design

The HGP optimized LIG MS absorber design is illustrated in Fig. 1. The UC periodicity is 8.7 mm in length. The thickness is 5.1 mm. The substrate is polyimide, where the dielectric constant (ϵ_r) is 3.5 and the loss tangent ($\tan\delta$) is 0.0026. The top patterning is composed of LIG and the UC is copper backed.

V. Results

For 70% absorptivity, the minimum frequency is 3.08 GHz and the maximum frequency is 11.48 GHz. The bandwidth is 115.4%. For 80% absorptivity, the minimum and maximum frequencies are 6.08 GHz and 10.87 GHz, respectively. The band width is 56.5%. The LIG based MS absorber's absorptivity performance is summarized in Table I and can be seen in Fig. 2.

VI. Conclusion

HGP was implemented to develop and optimize a flexible MS absorber based on the LIG fabrication process. The absorber UC is composed of polyimide, graphene, and copper backing. The UC's periodicity is 8.7 mm in length and the thickness is 5.1 mm. The bandwidth is 115.4% and 56.5% for absorptivity above 70% and 80%, respectively.

Future work includes optimization of absorber designs with the inclusion of the effects of the incident angle, as well as polarization. Fabrication and measurement of the HGP designed MS absorber will also be conducted.

Table I. Performance of Absorber.

Absorptivity	f_{min}	f_{max}	***BW***
70%	3.08	11.48	115.4%
80%	6.08	10.87	56.5%

Frequency is in GHz.

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