

## A GENETIC ALGORITHM FOR OPTIMIZATION OF METAL COATINGS

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### ABSTRACT

The study of thin film coatings plays a fundamental role in the development of optical filters and devices useful in many different fields of nanotechnologies (i.e. photovoltaics, thermovoltaics, low emissivity filters, etc.). GA simulates the survival of the fittest among individuals over consecutive generation for solving a problem. Each generation consists of a population of character strings that are analogous to the chromosome that we see in our DNA. Each individual represents a point in a search space and a possible solution. The individuals in the population are then made to go through a process of evolution. In particular the Genetic Algorithms are introduced as useful tool for searching the optimal thicknesses of the layers.

**Keywords:** Reflectance, Transmittance, Emittance, Genetic Algorithm

### INTRODUCTION

The minimum of reflectance from optimization of Simulated Annealing Algorithm at wavelength  $0.65 \mu\text{m}$  is 0.296 (Mirjalili *et al.*, 2015). By selecting the appropriate coating, It can be seen the reduction of 10.031 times in the  $0.65 \mu\text{m}$  wavelength, and the reduction of 6.51 times in the  $0.8 \mu\text{m}$  wavelength for the transmittance (Mirjalili *et al.*, 2014).

Under severe environmental conditions, radioactive properties degradation can be limited by using diffusion barriers (thin films of silicon oxide or dioxide), in order to prevent the diffusion of coating with substrate, and/or using protective over coatings (thin transparent oxide layers), to prevent abrasions and oxide growth (Van-Vliet, 2003).

Near-field radiative heat transfer has attracted significant attention in recent years due to its wide potential applications in microscale thermophotovoltaic (TPV) cells (Whale *et al.*, 2002) (Messina *et al.*, 2013), submicron thermal imaging (Dransfeld *et al.*, 1988) (Jones *et al.*, 2012).

### Modeling

#### MATERIALS AND METHODS

The transfer-matrix method provides a convenient way to calculate the radiative properties of multilayer structures of thin films. By assuming that the electromagnetic field in the  $j^{\text{th}}$  medium is a summation of forward and backward waves in the  $z$ -direction, the electric field in each layer can be expressed by (Fu *et al.*, 2003)(Oloomi *et al.*, 2009).

$$E_j = \begin{cases} \left[ A_1 e^{iq_1 z} + B_1 e^{-iq_1 z} \right] e^{(iq_x x - i\omega t)}, & j = 1 \\ \left[ A_j e^{iq_j(z-z_{j-1})} + B_j e^{-iq_j(z-z_{j-1})} \right] e^{(iq_x x - i\omega t)}, & j = 2, 3, \dots, N \end{cases} \quad (1)$$

Where  $A_j$  and  $B_j$  are the amplitudes of forward and backward waves in the  $j^{\text{th}}$  layer. Detailed descriptions of how to solve for  $A_j$  and  $B_j$  is given in (Fu *et al.*, 2003).

#### Genetic Algorithm

##### Optimization Problems

In a genetic algorithm, a population of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem is evolved toward better solutions. Each candidate solution has a set of

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properties (its chromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible (Whitley *et al.*, 1994). The evolution usually starts from a population of randomly generated individuals, and is an iterative process with the population in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated; the fitness is usually the value of the objective function in the optimization problem being solved. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

A typical genetic algorithm requires:

1. A genetic representation of the solution domain.
2. A fitness function to evaluate the solution domain.

**Initialization**

The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions. Often, the initial population is generated randomly, allowing the entire range of possible solutions (the *search space*). Occasionally, the solutions may be "seeded" in areas where optimal solutions are likely to be found.

**Genetic Operators**

For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each new child, and the process continues until a new population of solutions of appropriate size is generated. Although reproduction methods that are based on the use of two parents are more "biology inspired", some research (Eiben, 1994). Ting *et al.*, (2005) suggests that more than two "parents" generate higher quality chromosomes. These processes ultimately result in the next generation population of chromosomes that is different from the initial generation. Generally the average fitness will have increased by this procedure for the population, since only the best organisms from the first generation are selected for breeding, along with a small proportion of less fit solutions. These less fit solutions ensure genetic diversity within the genetic pool of the parents and therefore ensure the genetic diversity of the subsequent generation of children.

**RESULTS AND DISCUSSION**

**Results**

This paper considered the radiative properties of silicon coated with Silver, and Aluminum at room temperature for 9 layers with different coating procedures. Coherent formulation is used. The division of layer's materials and the thickness of each layer (according as micrometer) are the results of optimization of GA.

**Table 1: Distribution Gender layers for Minimum Emittance**

Wavelength( $\lambda$ )	The number of layers	Layer Genus 1	Layer Genus 2	Layer Genus 3	Layer Genus 4	Layer Genus 5	Layer Genus 6	Layer Genus 7	Layer Genus 8	Layer Genus 9	Minimum Emittance
0.6 $\mu$ m	9	AL	AL	Ag	Si	Ag	Ag	AL	Ag	Ag	0.102

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**Table 2: Layers thickness for Minimum Emittance**

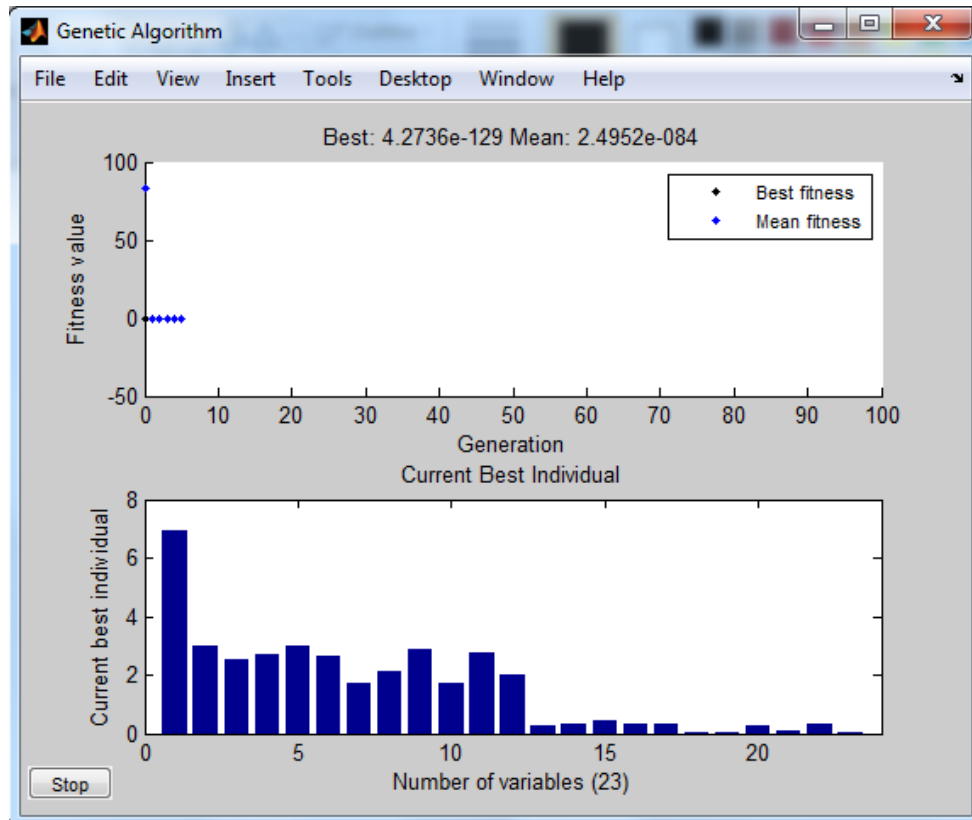
Wavelength( $\lambda$ )	Layer thickness 1	Layer thickness 2	Layer thickness 3	Layer thickness 4	Layer thickness 5	Layer thickness 6	Layer thickness 7	Layer thickness 8	Layer thickness 9	Total thickness of the coating ( $\mu\text{m}$ )
0.6 $\mu\text{m}$	0.554	0.654	0.087	500	0.236	0.129	0.031	0.268	0.026	501.985

The Maximum and Minimum Emittance, Reflectance and Transmittance at the wavelength 0.6  $\mu\text{m}$  are shown in the tables No (1) to (6). In this Article, the incidence angle of 45 ° is considered. The results are compared in Table (7) with colonial competitive algorithm (Teymoorzadi *et al.*, 2014).

Figure 1 shows Fitness diagram for Transmittance.

**Table 3: Distribution Gender layers for Minimum Reflectance Coefficient**

Wavelength( $\lambda$ )	The number of layers	Layer Genus 1	Layer Genus 2	Layer Genus 3	Layer Genus 4	Layer Genus 5	Layer Genus 6	Layer Genus 7	Layer Genus 8	Layer Genus 9	Minimum Reflectance
0.6 $\mu\text{m}$	9	Si	Ag	Ag	AL	Ag	AL	Ag	Ag	Ag	0.341



**Figure 1: Fitness diagram for Transmittance**

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**Table 4: Layers thickness for Minimum Reflectance Coefficient**

Wavelength( $\lambda$ )	Layer thickness 1	Layer thickness 2	Layer thickness 3	Layer thickness 4	Layer thickness 5	Layer thickness 6	Layer thickness 7	Layer thickness 8	Layer thickness 9	Total thickness of the coating ( $\mu\text{m}$ )
0.6 $\mu\text{m}$	500	0.579	0.607	0.636	0.581	0.294	0.273	0.21	0.329	503.509

**Table 5: Distribution Gender layers for Minimum Transmittance**

Wavelength( $\lambda$ )	The number of layers	Layer Genus 1	Layer Genus 2	Layer Genus 3	Layer Genus 4	Layer Genus 5	Layer Genus 6	Layer Genus 7	Layer Genus 8	Layer Genus 9	Minimum Transmittance
0.6 $\mu\text{m}$	9	AL	AL	AL	Si	Ag	Ag	AL	Ag	AL	$1.33 \cdot 10^{-121}$

**Table 6: Layers thickness for Minimum Transmittance**

Wavelength( $\lambda$ )	Layer thickness 1	Layer thickness 2	Layer thickness 3	Layer thickness 4	Layer thickness 5	Layer thickness 6	Layer thickness 7	Layer thickness 8	Layer thickness 9	Total thickness of the coating
0.6 $\mu\text{m}$	0.337	0.272	0.375	500	0.052	0.055	0.258	0.069	0.509	501.927

**Table 7: Comparison of the Genetic Algorithm with the colonial competitive algorithm (Teymoorzadi et al., 2014)**

Wavelength( $\lambda$ )	The number of layers	Layer Genus 1	Layer Genus 2	Layer Genus 3	Layer Genus 4	Layer Genus 5	Layer Genus 6	Layer Genus 7	Layer Genus 8	Layer Genus 9	Minimum Reflection Coefficient
0.6 $\mu\text{m}$	9	Si	Ag	Ag	AL	Ag	AL	Ag	Ag	Ag	0.341
0.65 $\mu\text{m}$ (Teymoorzadi et al., 2014)	9	Si <sub>3</sub> N <sub>4</sub>	SiO <sub>2</sub>	Si	SiO <sub>2</sub>	Si <sub>3</sub> N <sub>4</sub>	Si <sub>3</sub> N <sub>4</sub>	SiO <sub>2</sub>	Si	Si <sub>3</sub> N <sub>4</sub>	0.31

**Conclusion**

In conclusion, to eliminate the average reflectance of AR coatings to the greatest extent, a genetic algorithm is proposed to design and optimize the radiative properties.

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The minimum of emittance of metal thin film is 0.102. The minimum of reflectance is 0.341. It can use for many industrials.

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