

Java Applet Technology for Design Interference Optical Coating

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Abstract:

Java is a high-level , third generation programming language were introduced Javaoptics Open Source Physics (OSP) as a new simulation for design one of the most important interference optical coating called antireflection coating. It is recent developments in deign thin-film coatings. (OSP) shows multiple beam interferences from a parallel dielectric thin film and the evolution of reflection factors. It is simple to use and efficiently also can serve educational purposes. The obtained results have been compared with needle method.

Key words: Antireflection Coating, Optical Filters, Interference Filters, Java Applet Technology

Introduction:

Optical coatings are coatings thin film multi layers of materials with differences in refractive indices [1] that allow design antireflection coating (AR) with specific spectral characteristics. AR coatings have been widely used in many applications including glass lenses, eyeglasses, lasers, mirrors, solar cells, IR diodes, multipurpose broad and narrow band-pass filters, architectural and automotive glass and displays such as cathode ray tubes, as well as plasma, liquid crystal and flat panel displays [2].

The concept thin film layer was revolutionized when, 70 year ago. Baumeister [3] demonstrated the possibility to optimize thin film filters and coatings using computer program. Before then, most thin film layers consisted of quarter wave layers, and their design relied on graphical methods [3-9]. Since then, a large variety of complex design procedures have been developed that rely on sophisticated numerical methods and the use of computers to find spectral

analysis [8, 9] or optical constants. We have adopted Java technology very powerful technique that allows one to design antireflection coating.

In this paper, we adopted a Java Applet in frame Javaoptics as Open Source Physics (OSP) for the computation and the visualization of the reflection of interference thin film as simulation to design AR coating [10, 11]. We recourse to needle optimization methods for comparison with Javaoptics software technique.

Theory

1. Java optics

Java (with a capital J) is a high-level, third generation programming language (from SUN Microsystems), like C, Fortran, Smalltalk, Perl and many others (11, 12). We can use Java to write computer applications that do any of thousands of other things computer software can do. Among the different types of programs that can be written in Java, are primarily interested in applets. Java applets [13] were

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introduced in the first version of the Java language in 1995.

Java applets introduce Javaoptics applets are programs written in Java It is an excellent teaching language for Physical Optics have recently adopted the Open Source Physics (OSP) [13] for developing new applications. OSP is a project based in Davidson College seeking to create and distribute curricular materials for physics education

2- Interference optical coating

Liddell defines a thin film in mathematical terms: A thin film is one whose thickness is of the order of the wavelength of light and whose extent is infinite compared to its thickness. The film is characterized by its refractive index, its absorption coefficient and its thickness. It should be stressed that it is not simply the "thin" thickness that provides thin films with special and distinctive properties, but more importantly, the microstructure resulting from the unique way of their coming into being by progressive addition of the basic building blocks one by one[14].

Java Optics applet shows multiple beam interferences from a parallel dielectric thin film. The evolution of reflection and refraction factors when the index of refraction and the absorption of the film and the substrate can be studied. These can be constant or have a wavelength dependency. This applet allows the study of the factors that take part in an experiment with a thin-film layer. The experiment consists of two possible configurations. In the first one light with a given wavelength λ comes onto a sample consisting of a glass substrate with a thin-film coating on top of it. On a second configuration, the sample consists of a thin-film layer surrounded by air. The applet allows studying the influence of the thickness, the

refractive index and the extinction coefficient of the film on the reflectance and transmittance properties of the sample. Furthermore, it permits visualizing this influence with respect to the wavelength through a graphical representation (spectrum). Finally, the applet has the possibility of carrying out a virtual experiment where, from a measured spectrum, the values of thickness and refractive index of the thin-film layer can be deduced. The most important elements that can be calculated by the program are the Transmittance ($T(\lambda)$) and Reflectance ($R(\lambda)$) spectra of the sample. To calculate these values from the refractive index n and extinction coefficient k and the thickness of the thin film d it is necessary to consider the model in figure 1. We assume that thin film is shown in figure 1 as plane-parallel plate with thickness d and is characterized by a refractive index n . If absorption occurs, the refractive index is given by $(n + ik)$, where k is the imaginary component of the complex refractive index that accounts for any absorption of the thin-film material. A light beam incident at an angle with a wavelength λ on such a plane parallel plate of transparent material as shown in Figure 1. The light beam is then divided into two parts, a reflected beam and a transmitted beam which enters the material. When the transmitted beam in the material reaches the second surface, it is again split into a refracted beam and a reflected beam. The reflected beam goes back to the first surface, and this process of splitting of the reflected beam continues as shown in Figure 1. The angles and magnitudes of these beams are determined by the polarization and wavelength of light, the angle of incidence of the beam with the plate, and the index of refraction of the plate material.

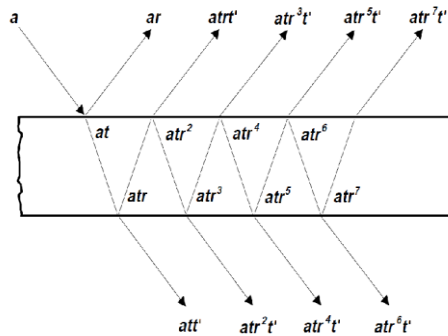


Fig.(1) A light beam incident on a plane parallel-sided thin film.

The reflected beams ar , $atrt'$, atr^3t' , etc., differ from each other in both amplitude and phase. The overall reflectance of the light beam by the plate is determined by the multiple-beam interference of these various reflected component waves. If the incident light beam is perpendicular to the plate surface, the polarization ceases to be a factor, and the overall reflectance is determined solely by the refractive index and thickness of the material and the wavelength of the light.

As we considering an incident light wave perpendicular to the film surface (Figure.2), we can first derive expressions for calculations of reflection and transmission coefficients of a single thin-film layer.

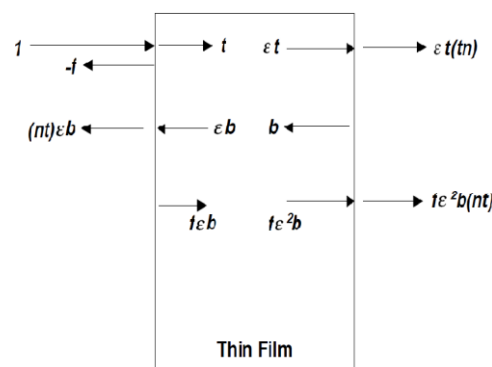


Fig.(2) A single thin-film with light incident (1) on the left.

As shown in Figure 2, a light beam with wavelength λ is incident on the left side of the thin-film layer. The

total amplitude of incident light is represented by 1, and it is sufficient to consider only the electric field vector. The incident beam may be thought to be divided at the left surface of the thin-film into a transmitted component and reflected component, with amplitudes $-f$ and t (i.e. the Fresnel coefficients of reflection and transmission, and in this case, $n = \tilde{n}$, $n = 1$), respectively, where

$$f = \frac{\tilde{n} - 1}{\tilde{n} + 1} \quad \text{and} \quad t = \frac{2}{\tilde{n} + 1} \tag{1}$$

\tilde{n} is the complex refractive index of the thin-film, and $\tilde{n} = n + ik$, where n is the ordinary index of refraction and k is the attenuation coefficient. The transmitted beam component with amplitude t now undergoes a phase shift as it travels a distance d (the thickness of the film) up to the right hand surface of the film, so the phase shifted amplitude of the transmitted beam becomes ϵt , where

$$\epsilon = e^{i \frac{2\pi \tilde{n} d}{\lambda}} \tag{.2}$$

At the right-hand boundary of the film, the beam is again divided up into transmitted and reflected components. The transmitted component that goes off the film at the right-hand surface has an amplitude of $\epsilon t(tn)$. As the reflected component is one of an infinite series of reflected components at this interface, they can be combined together to represent the interference combination of all of the reflected components by b in Figure.2; ϵb is the phase shifted result of this leftward-travelling wave at the inside left-hand surface of the film. At the left hand surface, the wave with amplitude ϵb is split into a refracted (transmitted) component with amplitude $nt \epsilon b$ and a reflected component travelling back to

the right with amplitude $f \epsilon b$. At the right-hand surface, the phase-shifted rightward travelling wave, here with amplitude $f\epsilon^2b$, is also split into two components: a reflected component already accounted for by b and a transmitted component with amplitude $f\epsilon^2bnt$. Expressions for the reflection and transmission coefficients of the thin-film can now be taken directly from Figure 2.:

$$r_f = -f + n\epsilon b \text{ and } t_f = (\epsilon t + \epsilon^2 b)nt \quad (3)$$

Eliminating the unknown b from equation (3), the complex reflection and transmission coefficients can be given in terms of the refractive index and thickness of the film and the wavelength of the incident light (using equations (1) and (2)):

$$r_f = \frac{-f + \epsilon^2 f}{1 - f^2 \epsilon^2} \quad (4)$$

$$t_f = \frac{\epsilon(1 - f^2)}{1 - f^2 \epsilon^2} \quad (5)$$

From the perspective of connectionist models, a single thin-film layer can be used as a simple processing unit in a conventional connectionist model, and the calculation of its reflection or transmission coefficients, as shown by equations (4) and (5), can be seen as its activation function with the reflection or transmission coefficients as its outputs.

It is believe that the availability of Javaoptics software is significant advance for the optical coating community. The aim is to present what Java optics offers so the reader can decide where there is interest in using it to justify the choices we made during its creation, to show how to use it to explain under what conditions it can be

used or modified, and to describe its implementation so that one can determine if it can be adopted to fit his or her specification needs.

Java Optics applet shows multiple beam interferences from a parallel dielectric thin film. The evolution of reflection and refraction factors. The final Reflectance and Transmittance of the sample depend as well on the Reflectance and Transmittance of the second face of the substrate. Since the latter do not depend on the characteristics of the film, this second face does not affect the distribution of R and T maxima and minima.

Result and Discussion:

In this section a design were present for (AR) coating for single layer using Javaoptics applets as Open Source Physics in two cases normal and oblique light incidence. The selected material, thickness for layer coating, phase difference and incidence angles are displayed. It is necessary to determine the reflectivity spectrum of the film also physical thickness and the refractive index of the material over the desired wavelength. This appears clearly in figures (3.a-e).

Figures (3.a-e) shows design ARC's with refractive index $n_{-1} = 1.38$, $n_s = 1.5$ for layer coating and substrate subsequent. Where these figures display by using java technique the transmission (T) and reflection (R) in the same time also allows changing the angle of incidence (θ) and the values of the refractive index (n).

The block diagram for design AR coating at normal incidence shows in figure.(3.a). Furthermore this figure appear the phase difference between transmission rays

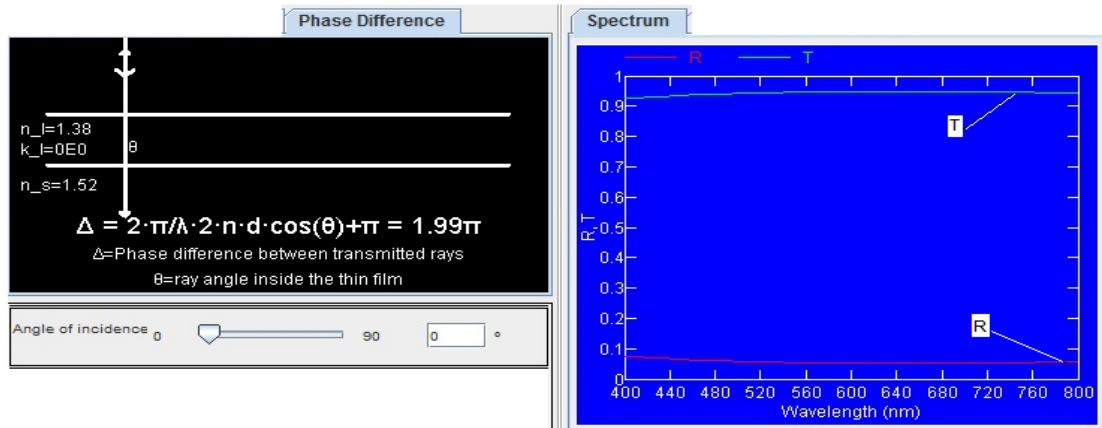


Fig. (3.a) Reflection R and Transmission T vs. wavelength at normal incidence (to the right)with sketch of phase difference (on the left)

AR coating is not an easy task to be done for oblique incidence, but it is easy done with Javaoptics(OSP) technique this shows in figures (3.b-e).These figures display the behavior of reflection and transmission spectra for the range of incident angles as well

as the diagram of the path followed by a beam inside the thin film. For the selected wavelength it shows the value of the refractive index and of the extinction coefficient of the film (n_f and k_f on the diagram), as well as the refractive index of the substrate.

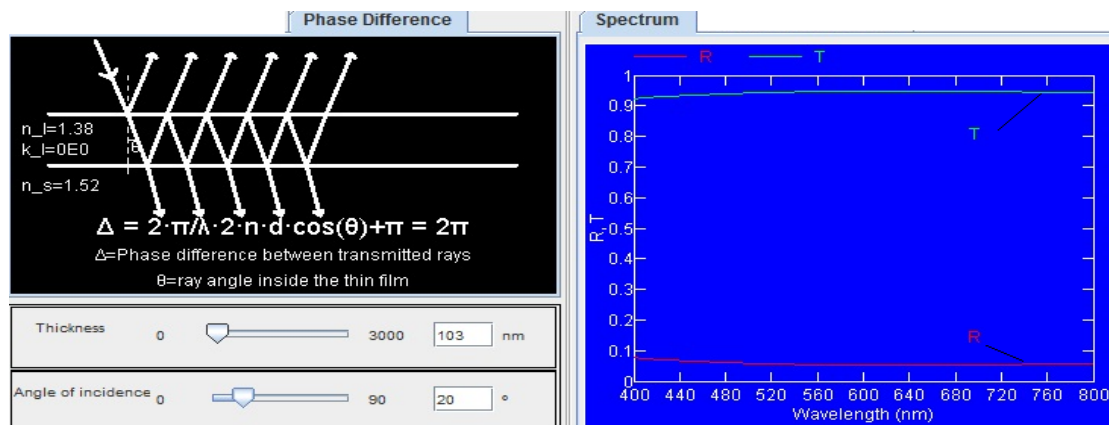


Fig . (3.b) Reflection R and Transmission T vs. wavelength at angle incidence = 20° (to the right), with sketch of phase difference (on the left).

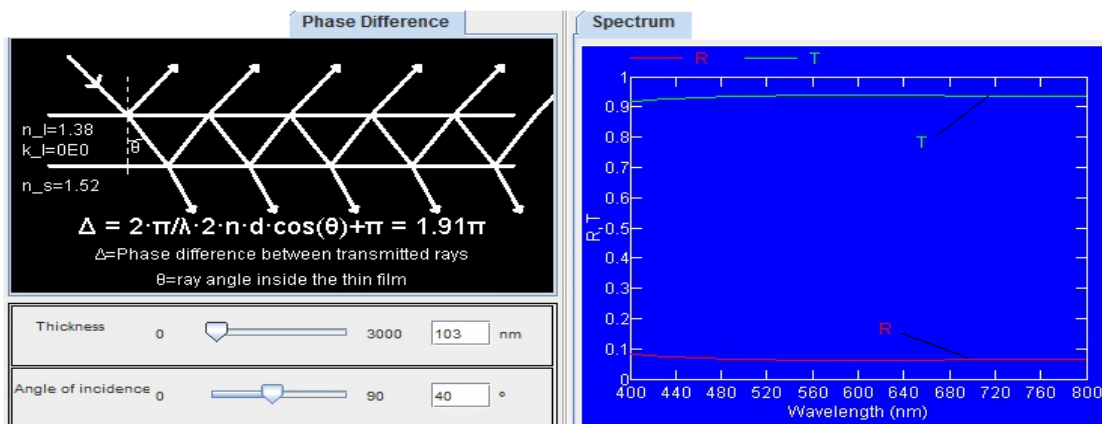


Fig . (3.c) Reflection R and Transmission T vs. wavelength at angle incidence = 40° (to the right), with sketch of phase difference (on the left).

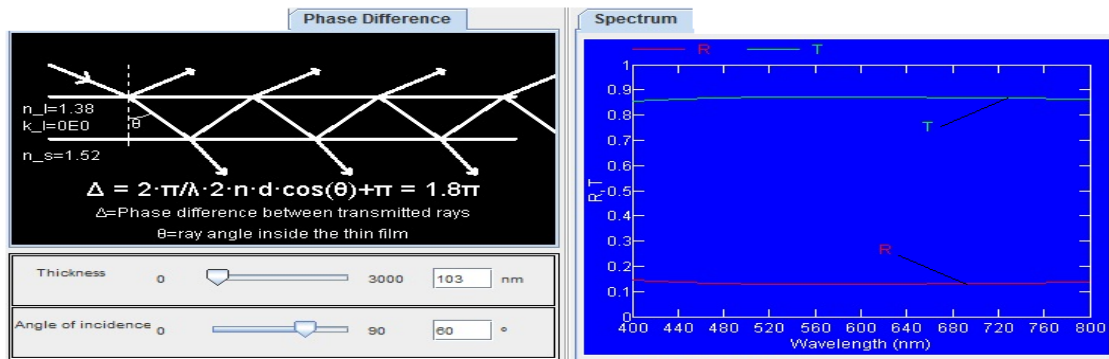


Fig. (3.d) Reflection R and Transmission T vs. wavelength at angle incidence = 60° (to the right), with sketch of phase difference (on the left).

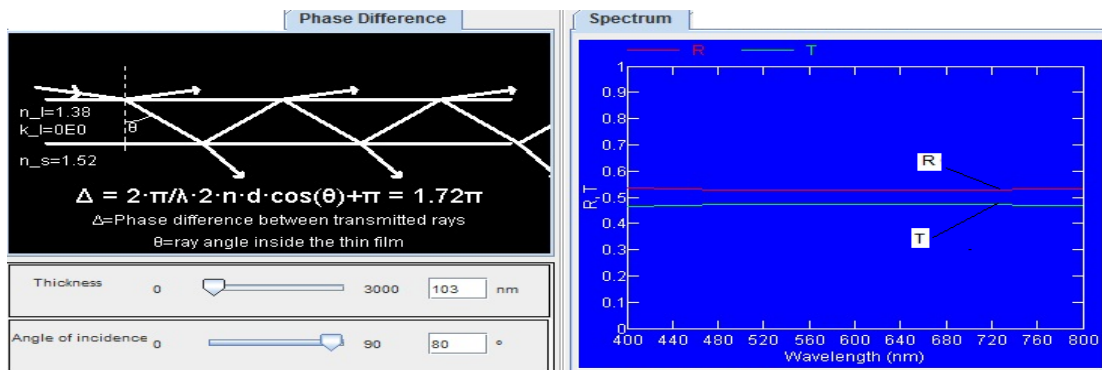


Fig. (3.e) Reflection R and Transmission T vs. wavelength at angle incidence = 80° (to the right), with sketch of phase difference (on the left).

It can be seen from the figures (3.b-e) the behavior of reflection and transmission for design AR coating at oblique light incident this allows easier and faster. Now in this paper it demonstrate the comparison between

Java optics techniques with one of the depended synthesis method called needle optimization method in frame Open Filter program [6]. this shows in figure (3.f)

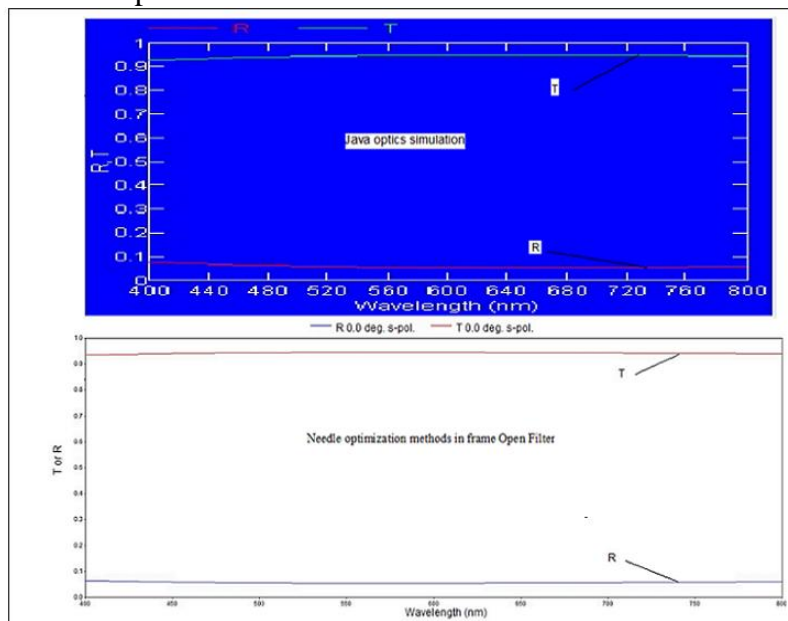


Fig. (3.f) Reflection R and Transmission T vs. wavelength at normal incidence in two different approaches Java optics and needle methods

The Java optics allows changing the thickness of the film (d), the wavelength (λ) the angle of incidence (θ). In addition, the values of the refractive index and of the extinction

coefficient can be changed this let one facility design other example of ARC s with different characteristic this shows in figure (3.g)

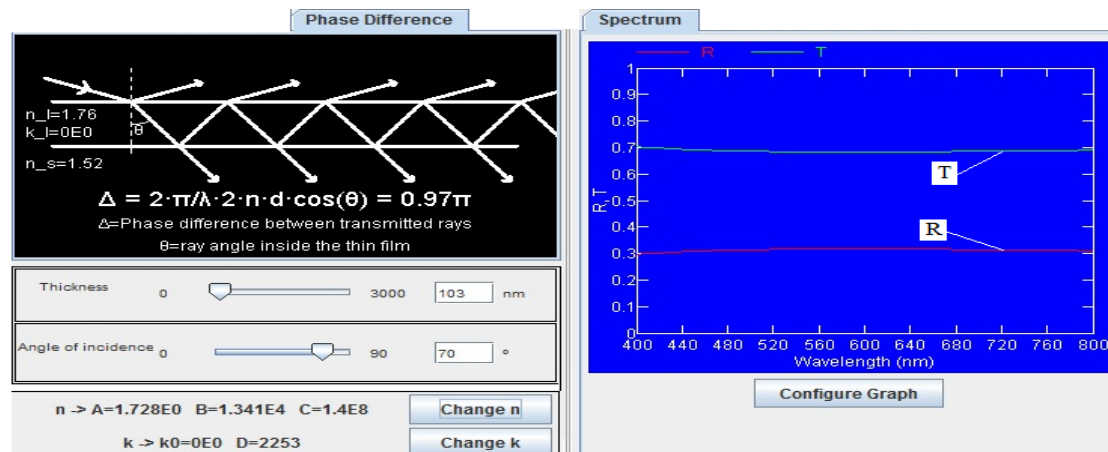


Fig .(3.g) Reflection R and Transmission T vs. wavelength at angle incidence $= 70^{\circ}$ (to the right) , $n_1 = 1.76, n_s = 1.52$ (on the left).

Conclusion :

In this paper work carried out to overcome the difficult that arise in designer AR coating at oblique incident by depend Java optics apples technology as simulation open source. Results are demonstrate that the design AR coating by using Java optics technique is flexible, efficient and fast ,also mention that Java optics appears offers for many channels in design ARC's like changing the thickness of the layer (d), the angle of incidence (θ),and the values of the refractive index (n) also extinction coefficient (k) can be changed. These offers can serve as examples of concepts being learnt as well as illustrating phenomena. They can have the capability of user interactive visualization of results and with a built in graphical user interface.

Results mention a good agreement of Java optics and needle method. This manuscript succinctly present that Java optic can be depend in an ensemble of teaching and searching resources for physical optics at university level confidently.

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تكنولوجيا جافا لتصميم طلاء التداخل البصري

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الخلاصة :

جافا لغة البرمجة العالية المستوى والحيل الثالث من لغات البرمجة عرضت حديثاً برنامج محاكاة (جافا بصريات) , والذي تم استخدامه في هذا البحث والى اول مرة لتصميم واحد من اهم المرشحات البصرية المستندة على ظاهرة التداخل البصري يدعى الطلاء المضاد للانعكاس. تعد هذه التقنية تطوير واطافة جديدة في طرائق تصميم طلاء الأغشية الرقيقة , وتقدم عرض الى ظاهرة التداخل المتعدد للغشاء الرقيق وحساب الانعكاسية وتمكن من تصميم الطلاء المضاد للانعكاس ذو الطبقة المفردة. في هذا البحث تم اجراء مقارنة النتائج التي تم التوصل اليها في التصميم بتقانة جافا مع نتائج التصميم لطريقة اخرى مهمة في تصميم طلاء المضاد للانعكاس وتدعى طريقة نيدل .