Novel Preparation of Antireflection Nanofilms from Al-Ni-Cr Alloy

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Abstract

Al-Ni-Cr alloy ingots contains 0.25, 0.5, 0.99, 1.98 at.% of Ni-Cr were prepared by melting together of high purity wire aluminium , powder of nickel and very small pieces of chromium in an electric furnace at 800 ^oC under a pure argon atmosphere. Specimens Al and Al-Ni-Cr alloys were annealed at 560 ^oC for 1300 hr, and rapid quenched in water. Nanofilms prepared with thicknesses 8, 15, 25 nm of Al and Al-Ni-Cr alloys were deposited by thermal evaporation technique under vacuum of 10^{-5} mbar onto glass substrate temperature 298 K and rate of deposition 0.2 nm/sec. The crystallite size of such nanofilms were measured using AFM images and found to be ranged of 4.754 -10.204 nm and roughness ranged of 0.538-2.65nm. The measured transmittance values increases with decreasing thickness with the range of 90-94% at 8 nm. The optical band gaps calculated decreases with increasing concentration of Ni-Cr .

Key words: Al-Ni-Cr, nanofilms, transmittance, optical band gap.

Introduction

The formation of thin films containing nanoparticles can lead to novel applications in the areas of photonics, catalysis, electronics, magnetism, and biomedical engineering [1]. Despite the recent advances in creating various types of functional nanoparticles [2-4], it still remains a challenge to create conformal thin films of nanoparticles with precise control over the physicochemical properties.

Antireflection (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. In addition, highly reflecting dielectric mirrors have been developed to be used in gas lasers and in Fabry-Perot interferometers [5,14]. Many techniques based on top-down lithography, such as photolithography [15], electron-beam lithography [16], laser interference lithography [17], and nanoimprint lithography [18] have been used to generate antireflective SWS on Si surfaces.

Experimental

The most important step in the study of nanofilms is their synthesis. For the investigation, we used an Al-1.8at.%Ni-0.18at.%Cr alloy prepared by melting together of high purity wire aluminium , powder of nickel and very small pieces of chromium in an electric furnace type (Via P.da Cannobia, 10, 20122 MILANO, Italy), at 800 ^oC under an argon atmosphere. The alloy obtained diluted three times by pure aluminum to obtain the following alloys: Al-0.9at.%Ni-0.09at.%Cr, Al-0.45at.%Ni-0.05at.%Cr, Al-0.23at.%Ni-0.02at.%Cr.

The composition of aluminum alloys adopted in the search in terms of atomic percentage and weight percentage shown in Table(1).

Table (1): Composition of prepared samples(at.% and wt.%).

Alloy symbol	Al		Ni		Cr	
	at.%	wt.%	at.%	wt.%	at.%	wt.%
S_1	100	100	0	0	0	0
S_2	99.75	99.446	0.23	0.495	0.02	0.037
S_3	99.5	98.031	0.45	0.958	0.05	0.096
S_4	99.01	97.896	0.9	1.935	0.09	0.168
S_5	98.02	95.836	1.8	3.827	0.18	0.337

Heat treatment is an important operation in the final fabrication process of any engineering component. The objective of heat treatment however, is to make the metal better suited, structurally and physically for some specific application, so the product expose to annealing at 560 ^oC for 1300 hr, followed by rapid quenched water. After structural and some mechanical testes, the prepared specimens have been milled to get a powder. The powder of prepared specimens was used as a source of the thermal evaporation to prepare the films.

UV-Visible spectrophotometer (UV SPECTROPHOTOMETER SHIMADZU MODEL UV-1800) used to measure the transmittance (T) as a function of variation wavelength in spectral range of 200- 1100 nm for Al and Al-Ni-Cr nanofilms with various content of Ni-Cr onto glass substrate at room temperature has been measured. The optical energy gap (E_g^{opt}) is calculated from the relationship between $(\alpha h\nu)^n$ and $h\nu$ according to relation [22] :

$$\alpha h\nu = \beta\,(h\nu - E_g^{opt})^n \qquad (1)$$

where n is an integer depending on the nature of electronic transitions. For the direct allowed transitions, n has a value of 1/2 while for the indirect allowed transitions, n = 2, and β is estimable constant.

All films were prepared by thermal evaporation technique in thicknesses of 8, 15, 25 nm, and vacuum system are 10^{-5} mbar supplied by Blazers model [BL 510], and deposited onto glass substrate at R.T.

Atomic force microscope AFM (Model AA3000) to study the morphology of surface for films. UV–Visible spectra were recorded on a UV–Visible spectrometer (Shimadzu UV3600, Shimadzu, Japan).

Result and discussion

The optical behavior of single and multiple homogeneous coatings is well understood [23, 24]. Therefore, it must be check the homogeneity of the film surface. The check by morphologic study is good proof for homogeneity.

2D and 3D AFM surface images films for Al and its alloys with various contain of Ni-Cr were shown in Figs.(2-6).

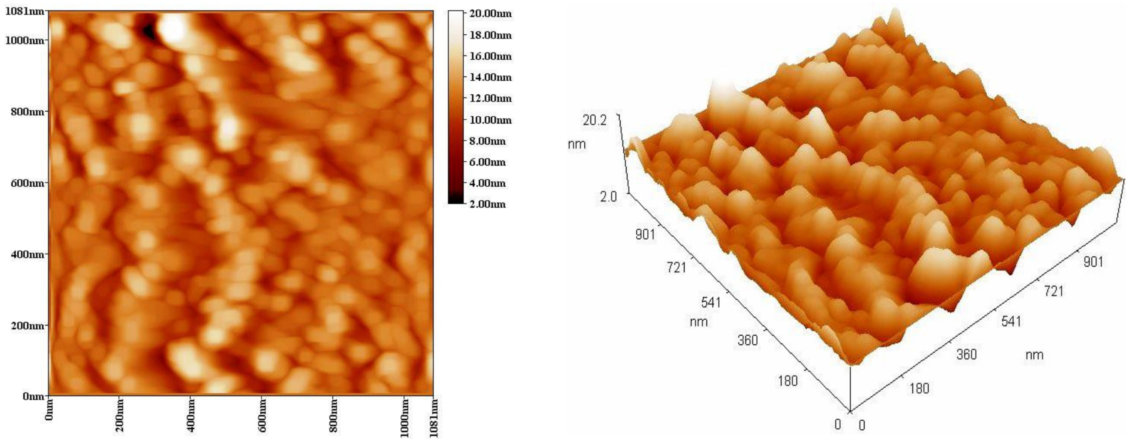

Fig.(2): AFM images for nanostructured film evaporated from S_1 sample, (a) 2D, and (b) 3D.

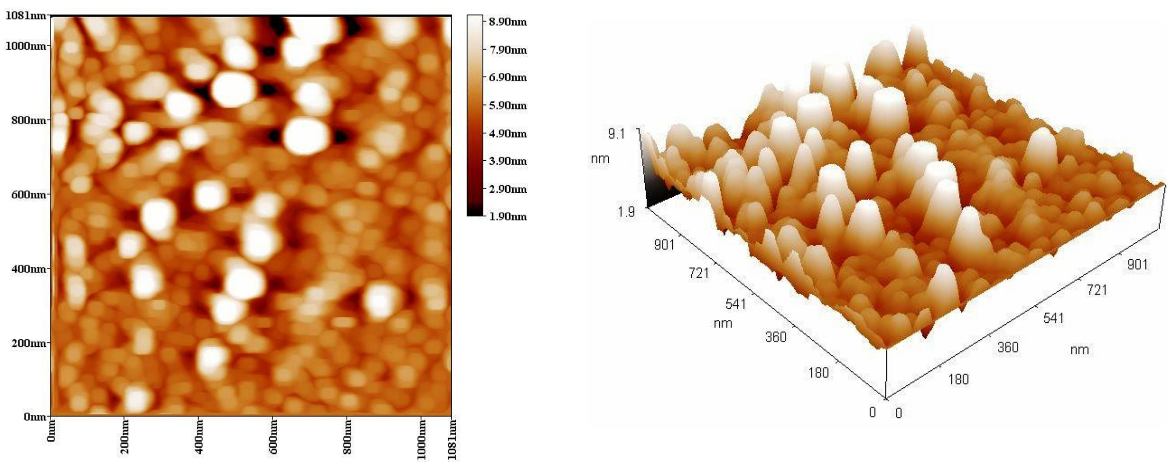

Fig.(3): AFM images for nanostructured film evaporated from S_2 sample, (a) 2D, and (b) 3D.

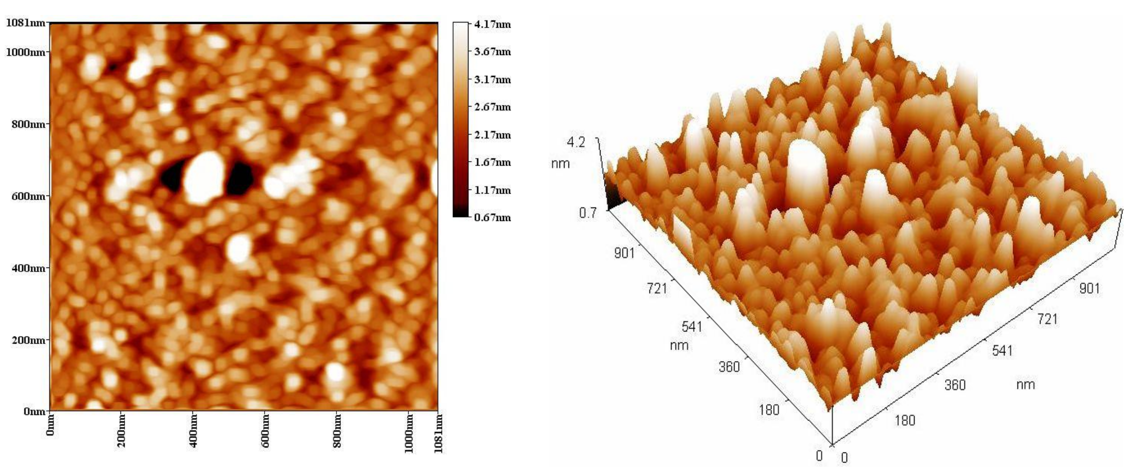

Fig.(4): AFM images for nanostructured film evaporated from S_3 sample, (a) 2D, and (b) 3D.

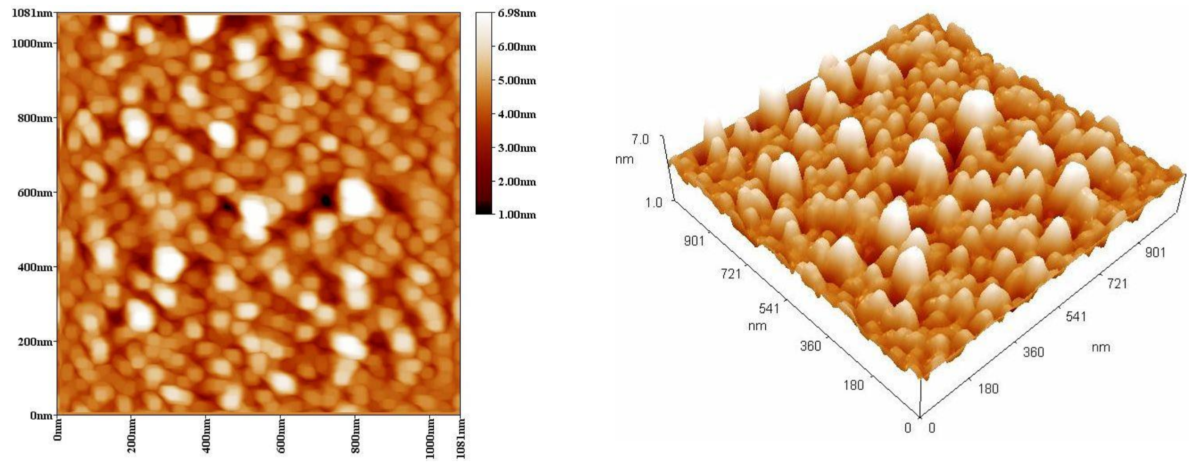

Fig.(5): AFM images for nanostructured film evaporated from S_4 sample, (a) 2D, and (b) 3D.

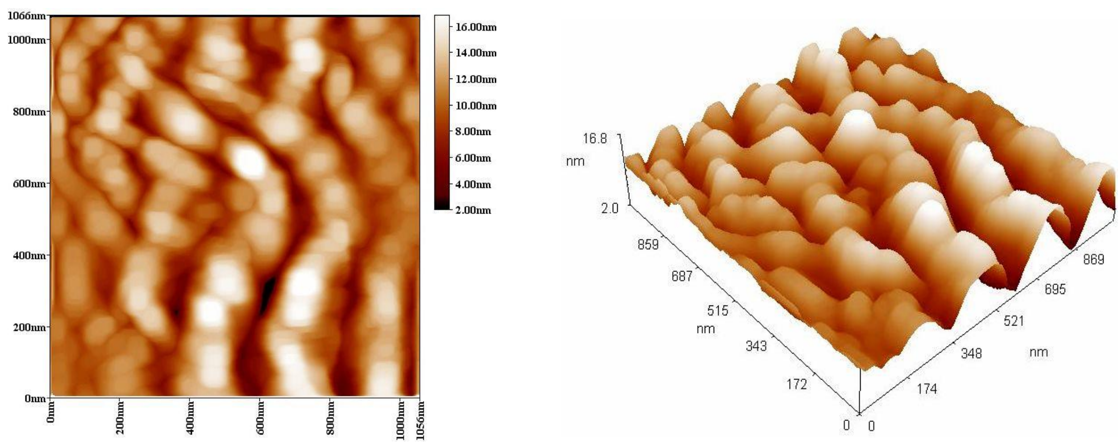

Fig.(6): AFM images for nanostructured film evaporated from S_5 sample, (a) 2D, and (b) 3D

Out of the figures it can notes a familiar granular structure with grain size around some of nanometers, a root mean square (RMS) roughness ranged of 0.538-2.65 nm, and a maximum peak to peak height Sz (ten point height) ranged of 1.79-8.52 nm. However, some of the small grains agglomerated to form greater grains. The AFM data for the Al and Al-Ni-Cr nanofilms are given in Table (2).

Table (2): AFM data for films prepared from Al and its alloys with Ni-Cr.

Alloy sample	**Roughness average Sa(nm)**	**Root mean square Sq(nm)**	**Ten point height Sz(nm)**	**Crystallite size (nm)**
S_1	1.390	1.830	6.250	6.358
S_2	0.891	1.240	3.800	5.893
S_3	0.392	0.538	1.790	4.474
S_4	0.620	0.832	2.940	4.754
S_5	2.100	2.650	8.520	10.204

1- For all the deposited nanofilms at thickness of 8 nm as in Fig.(7), the optical study at wavelength longer than 340 nm shows a highly transmittance. All the films demonstrate more than 90% of transmittance, and the maximum value is reached to 94% depends upon radiation energy as well as the composition of the film. The highly transmittance is due to crystalline nature of the prepared films. Below 340 nm there is a sharp fall in the transmittance of the films where value reached approximately 10%, which is due to the strong absorbance in this region. UV-VIS transmittance measurements have shown that the nanofilms are highly transparent in the visible wavelength region, ranged of 90% which makes them suitable for sensor applications. This explains the possibility of the use of nanofilms as a protective window of solar cells which allow the passage of solar radiation among the visible light region and protects it from the radiation located within the UV region which is considered undesirable.

2- For all the deposited nanofilms at thickness of 15 nm as in Fig.(8), the optical study indicate that the transmittance values at wavelength longer than 340 nm were less than it is in the case of thickness at 8 nm. The value of transmittance was found in the range between 46% for sample S_5 to 78% for sample S_1. Below 340 nm there is a sharp fall in the transmittance of the films, where value reached approximately 10%.

3- For all the deposited nanofilms at thickness of 25 nm as in Fig.(9), the optical study indicate that the transmittance values at wavelength longer than 340 nm dropped to low values, where they found in the range between 13% for sample S_5 to 32% for sample S_1, and approximately 10% of transmittance in the UV region.

The results clearly indicate that the deposited nanofilms are found to be very sensitive to the thickness.

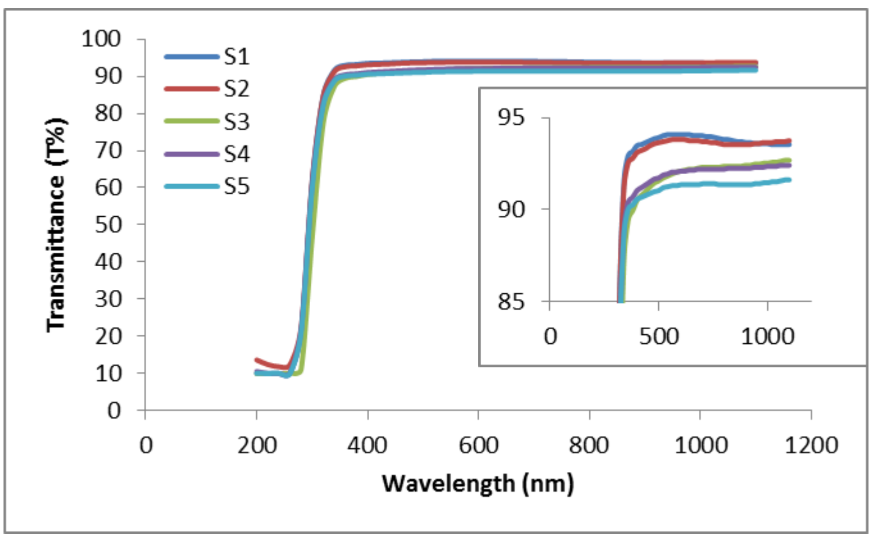

Fig.(7): Transmittance spectra of Al and Al-Ni-Cr nanofilms measured at thickness of 8 nm.

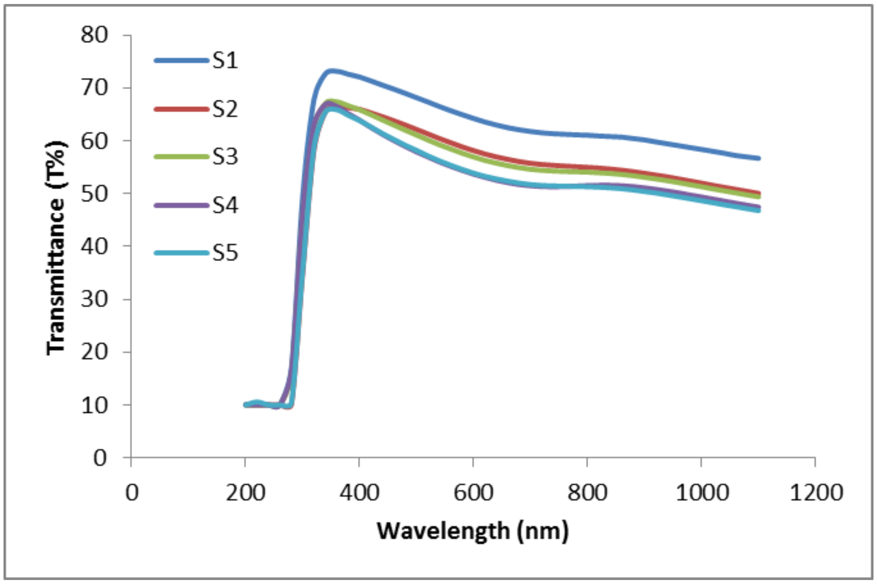

Fig.(8): Transmittance spectra of Al and Al-Ni-Cr nanofilms measured at thickness of 15 nm.

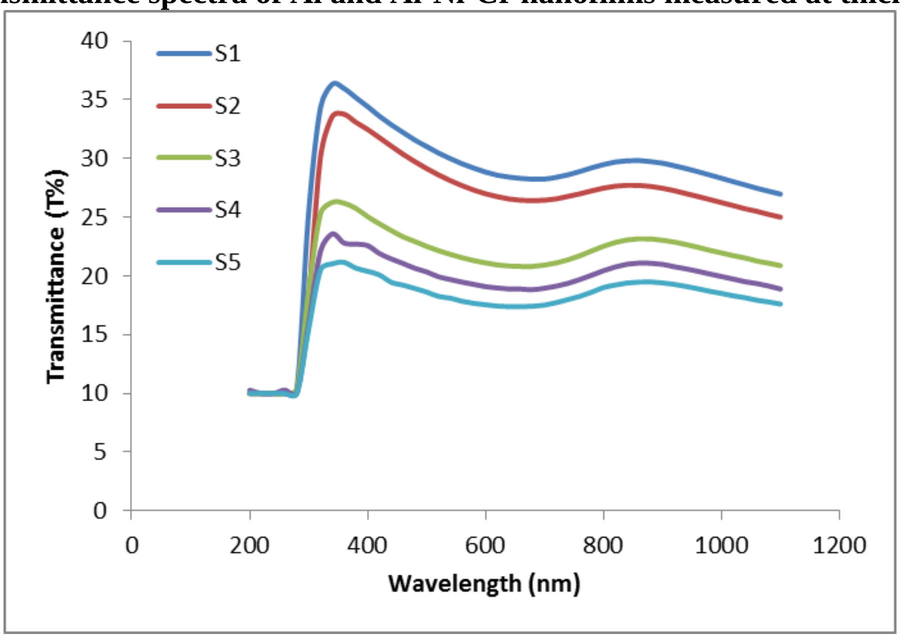

Fig.(9): Transmittance spectra of Al and Al-Ni-Cr nanofilms measured at thickness of 25 nm.

The measured values of optical energy gap E_g^{opt} for Al and Al-Ni-Cr nanofilms are listed in Table (3).

Table(3): Optical energy gap values with thickness and Ni-Cr content

Thin film symbol	Thickness (nm)		
	8	15	25
S1	2.3	1.55	1.5
S2	2.27	1.5	1.45
S3	2.25	1.45	1.4
S4	2.2	1.35	1.3
S5	2.1	1.3	1.2

It can be noted from Table(4) that the values of the optical energy gap of Al and Al-Ni-Cr nanofilms are decreases with increasing both of Ni-Cr contents and thickness. The decrease of energy gap is attributed to the increase of disorder in the material, that means allowing excitation secondary levels inside the energy gap and increase the width of these levels with the increasing Ni-Cr content which leads to decrease the width gap. The increase of the density of localized states inside the energy gap causes the decrease of optical energy gap.

Conclusion

From the experimental results we conclude that the crystallite size of such nanofilms found to be in ranged of 4.754 nm -10.204 nm and roughness ranged of 0.538-2.65nm. The measured transmittance values increases with decreasing thickness taken the range of 90-94% at 8 nm,which makes them suitable for sensor applications. The optical band gaps calculated decreases with increasing concentration of Ni-Cr.

References

[1] Fendler, J. H., Nanoparticles and Nanostructured Films: Preparation, Characterization and Applications; Wiley-VCH Verlag GmbH: Weinheim, Germany, 1998.
[2] Alivisatos, A. P. Science **1996**, 271, 933-937.
[3] Hyeon, T. Chem. Commun. **2003**, 927-934.
[4] Pellegrino, T.; Kudera, S.; Liedl, T.; Javier, A. M.; Manna, L.; Parak, W. J. Small **2005**, 1, 48-63.

[5] Introduction to Modern Optics, Grant R. Fowles, Holt Richard and Winston, Inc., New York, 1968.

[6] Thin Film Device Applications, Kasturi Lal Chopra, Inderjeet Kaur, Plenium Press, New York, 1983.

[7] H. A. Macleod, Thin-Film Optical Filters, Adam Hilger, Bristol, 1986.

[8] Handbook of Infrared Optical Materials, Paul Klocek, Marcel Dekker, Inc., New York, 1991.

[9] Introduction to Optics, Frank L. Pedrotti, S.J. Leno S. Pedrotti, Prentice-Hall, Inc., New Jersey, 1993.

[10] Thin Films for Optical Systems, Francois R. Flory, Marcel Dekker, Inc., Newyork, 1995.

[11] D. Pekker, L. Pekker, Thin Solid Films, **425**, (2003), 203

[12] P. Nubile, *Thin Solid Films*, **342**, (1999), 257.

[13] V.M. Aroutiounian, K.R. Maroutyan, A.L. Zatikyan, K.J. Touryan, *Thin Solid Films,* **403{404**, (2002), 517.

[14] H.G. Shanbhogue, C.L. Nagendra, M.N. Annapurna, S.A. Kumar, *App. Opt.* **36**, (1997), 6339.

[15] Heine, C.; Morf, R. H. Submicrometer gratings for solar energy applications. *Appl. Opt.* **1995**, *34*, 2476–2482.

[16] Kanamori, Y.; Roy, E.; Chen, Y. Antireflection subwavelength gratings fabricated by spin-coating replication. *Microelectron. Eng.* **2005**, *78–79*, 287–293.

[17] Aydin, C.; Zaslavsky, A.; Sonek, G. J.; Goldstein, J. Reduction of reflection losses in ZnGeP2 using motheye antireflection surface relief structures. *Appl. Phys. Lett.* **2002**, *80*, 2242–2244.

[18] Zhang, G. M.; Zhang, J.; Xie, G. Y.; Liu, Z. F.; Shao, H. B. Cicada wings: A stamp from nature for nanoimprint lithography. *Small* **2006**, *2*, 1440–1443.

[19] F. T. Arecchi and E. O. Schulz, Laser Handbook V-II, ch9. North-Holland publ. co. Amsterdam 1972.

[20] H. A. Macleod, Thin-Film optical Filters(therd edition, published by institute of physics publishing, wholly owned by the institute of physics, London, 2001) chap.3.

[21] P. Nostell; Ph.D. Thesis at Uppsala University, 2000.

[22] Mahalingam T, Dhanasekaran V, Ravi G, Lee S, Chu JP, Lim H J Optoelectron Adv Mater 12:1327, 2010.

[23] M. Born, E. Wolf; Principles of Optics, Pergamon Press, 1964.

[24] O.S. Heavens; Optical Properties of Thin Solid Films, Dover Publications Inc., New York, 1991.