Dense moisture stable titania and silica ion assisted deposited films deposited using a compact cold cathode ion source.

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Introduction: Considerable data has been published on the benefits of ion assisted deposition (IAD) (1,2,3). The cold cathode ion source is a relatively mature device but has generally been regarded as having limited utility in applications requiring large area, uniform ion beams or improving the oxidation of reactive processes and increasing the refractive index of deposited films. A majority of the thin film community did not regard the early versions of the cold cathode ion source as equivalents to the Kaufman gridded ion sources, end-Hall ion sources, Advanced Plasma Source (APS) or Reactive Low Voltage Ion Plating in producing high-index, moisture stable films.

One of the major advantages of the cold cathode ion source is that it can generate an oxygen ion beam. Considerable developments have been made to increase the ion current density (ICD) of the cold cathode ion sources. Recent work has established that these second-generation devices can be used to make moisture stable stacks of dense optical films of silicon dioxide (as a low index material) and either titanium dioxide, tantalum pentoxide or niobium pentoxide. These results compare favorably with the best of the data obtained with alternative energetic processes.

The size of ion sources used in optical thin film applications presents a "packaging challenge" in small to mid-size coating systems. Efforts at reducing the size of second generation cold cathode ion source has been extraordinarily successful. In addition to reducing the size we have found that the compact source produces a higher ion current density and works well in larger chambers. Furthermore, the compact ion source produced dense, moisture stable films over a broader parameter space than the larger, second generation cold cathode ion sources. A comparison of the ICD distribution and the optical film characteristics produced by the second generation and compact cold cathode ion sources follows.

Experimental method: ICD measurements using Faraday probes were done in a 29" cryo-pumped (measured 1500 L/sec oxygen pumping speed at 1-5 x 10^{-4} Torr pressure) optical coating system with a Meissner trap. Six probes were spaced 5 cm apart with the first probe directly over and 40 cm above the ion source. Data was taken over the entire operational range [0-600 drive volts, 0-4+ drive amps, 1-5 x 10^{-4} Torr O_2 pressure].

Single layer (SL) films and stacks were done in the same system on samples located along the radius of a 28" diameter, domed calotte. The starting conditions for all coating runs was a pressure =5 x 10^{-6} Torr and a temperature of 40°C (except for SL films and stacks containing tantalum pentoxide where the starting temperature was 120°C). The center of the calotte was 24" above an e-gun centered on the base-plate and the cold cathode ion source was offset 10" from the center of the chamber, tilted slightly so as to be aimed half way between the center and the edge of the calotte. Optical characterization and moisture stability determination were made from spectral measurements made on all samples using techniques reported previously (4).

Results: Considerable data was taken over a wide range of ion source parameters. First we determined the voltage/current characteristics of each ion source and then the ICD achieved for various drive currents and oxygen pressures used to produced dense moisture stable films. Figure 1a. shows the V/I characteristics and figure 1b. shows the ICD measurements over a 25 cm offset for various O_2 pressures for the larger ion source equipped with a 40 mm diameter open aperture. Figure 2a. shows the V/I characteristics and figure 2b. shows the ICD measurements over a 25 cm offset for various drive currents and O_2 pressures for the compact ion source. Although the compact ion source was characterized for drive currents up to 4 ampere and chamber pressures up to 5 x 10^{-4} Torr, the data here-in is for the 1 to 4 ampere drive currents and 1 to 2 x 10^{-4} Torr pressure range which produced the best high index films.

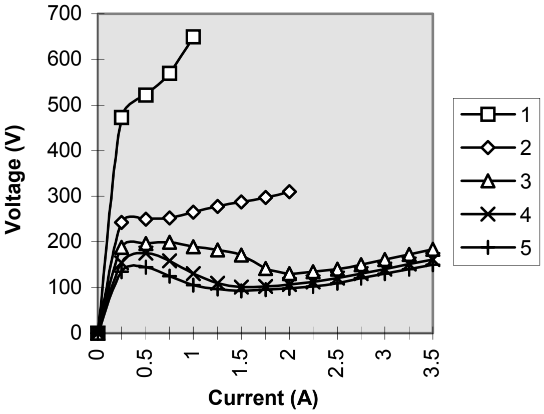

Figure 1a. V/I for larger ion source. Chamber pressures (x10^{-4} Torr) is a variable.

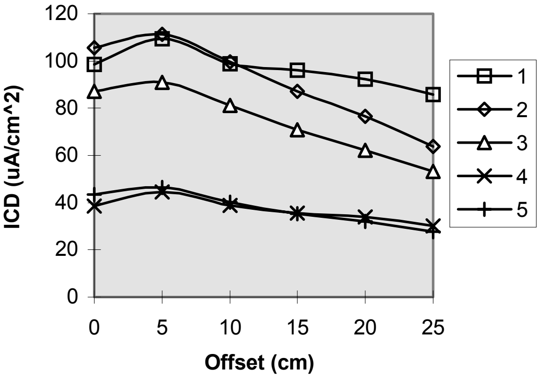

Figure 1b. Current density (C-D) vs. offset for larger ion source. Chamber pressure (x10^{-4} Torr) is a variable.

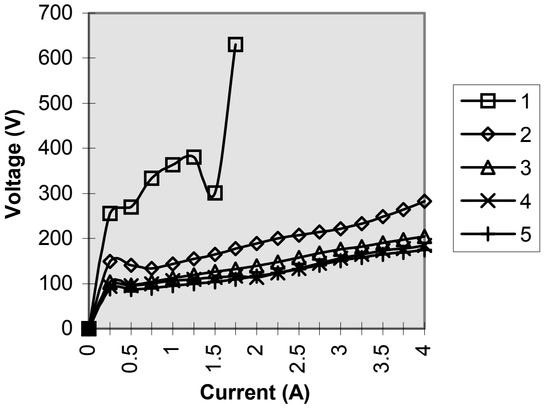

Figure 2a. V/I for compact ion source. Chamber pressures (x10^{-4} Torr) is a variable.

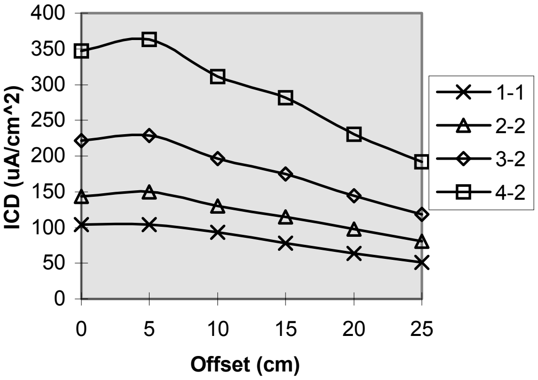

Figure 2b. Current density (C-D) vs. offset for compact ion source. x-y is a variable where x= drive current and y= chamber pressure (x10^{-4} Torr).

The variable deposition parameters for single layer IAD deposited thin films of TiO_2 and the measured properties of the films are shown in Table I for a non-IAD (non) deposited film, IAD films using the large (L) second generation cold cathode ion source and IAD films using the compact (C) cold cathode ion source. All films were deposited at 3.5 Å/sec., 40°C starting temperature and using Ti_2O_3 source material (except L-2, see note in Table I). The compact cold cathode ion source has only been tested with a full open aperture. The larger ion source can be run with a variety of apertures (open flat screen and domed screens) up to 95 mm diameters. Data for the large ion source is shown for a 40 mm open aperture (L-1) and a 95 mm domed screen (L-2). The refractive index profile for all of these films is plotted in figure 3 using the relationship $n = A + (B / (\lambda - C)^2)$ where A, B and C are determined by a best curve fit to the data calculated from the data taken from the spectral scans.

All of the IAD films with data shown in Table I. and refractive index plotted in Figure 3 are moisture stable, showing no significant variation in refractive index when exposed to the full range of humidity, 0% to 100%. The range of refractive indexes for the films prepared using the compact ion source increase as the ICD increases except for C-1 which had the highest ICD but intermediate index. All of the films have a very slight amount of inhomogeniety, typically increasing in index. The spectral profile of the C-2 film indicates that whatever inhomogeniety is present is not unidirectional, possibly due to the strong LCD or some control parameter varying slightly during the film deposition.

Table I.

Type	**non**	**L-1**	**L-2**	**C-1**	**C-2**	**C-3**	**C-4**
O_2 (sccm)	25	15	unk	40	26	27	20
D_V (V)	-	632	545	137	134	143	205
D_I (A)	-	1	0.9	4	3	2	1
P ($x10^{-4}$ Torr)	1.3	1	3.3	2.2	1.3	1.6	1.0
A	2.072	2.2813	2.3037	2.349	2.321	2.322	2.315
B	26266	11640	19297	20220	60697	46015	26095
C	99.1	241.1	177.1	184.9	38.9	73.7	141.6
n (λ=560 nm)	2.200	2.396	2.44	2.493	2.544	2.517	2.464
k (λ=560 nm)	0.0001	0.0003	0.0016	0.0001	0.006	0.0002	0

Sample L-2 was prepared at a Beta site in a 44” chamber.

Stacks of several material composition were deposited using the larger second generation cold cathode ion source with silicon dioxide as the low index material and TiO_2, Ta_2O_5 and Nb_2O_5 as the high index materials. These results have been reported previously (5). For comparison of the two ion sources, the spectral scans of two stacks (design [HL]6) of TiO_2/SiO_2 using the parameters shown for the L-1 and C-2 SL are compared in Figure 4. Both stacks are moisture stable and have refractive index ratios (H/L) of 1.641 and 1.655 respectively

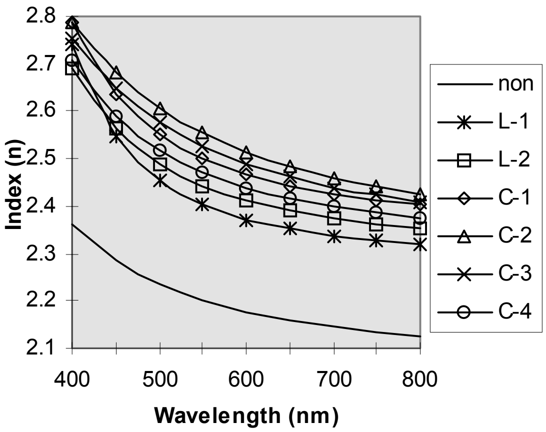

Figure 3. Refractive index vs. wavelength for films prepared as summarized in Table I.

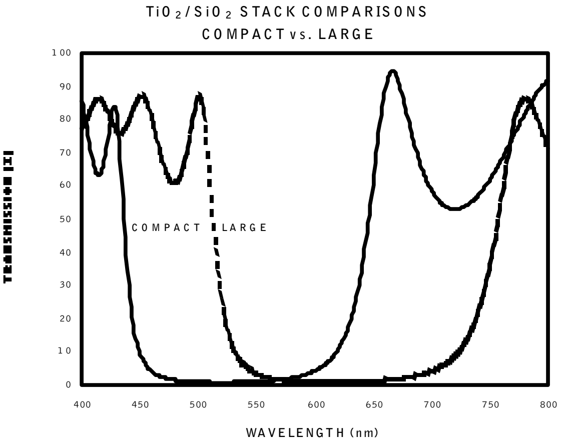

Figure 4. Spectral plot of $TiO_2/Si0_2$ stacks.

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