INORGANIC THIN FILM MATERIALS FOR MICROLITHOGRAPHY

by

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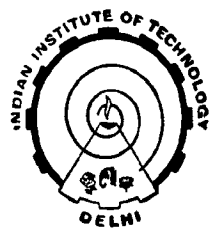
Thesis submitted
in fulfilment of the requirements
of the degree of

DOCTOR OF PHILOSOPHY



to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

April, 1986

CERTIFICATE

I am satisfied that the Thesis presented by Pramod Kumar Gupta is worthy of consideration for the award of the Degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under my guidance and supervision and that the results contained in it have not been submitted in part or full to any other University or institute for award of any degree/diploma.

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ACKNOWLEDGEMENTS

I take this opportunity to express my gratitude to Professor K.L. Chopra for his guidance and constructive criticism at every stage, which have contributed greatly towards the completion of this work.

It is indeed my pleasure to thank Dr. Bhanwar Singh (Advanced Micro Devices, Sunnyvale, USA) for introducing me to the Thin Film Laboratory, IIT New Delhi. The assistance of Mr. A.N. Tiwari for Talystep and Spectrophotometer measurements is gratefully acknowledged. I thank Dr. S. Rajagopalan and Miss Jagriti Singh for their help during the e-beam and ion-beam irradiation studies, respectively. I also wish to thank Professor S.K. Deb of SERI, USA, for discussions on colouration mechanism in WO_3 and MoO_3 films. Thanks are also due to Miss Joyti Bhan, Dr. B.R. Mehta, Satyendra Kumar, Ajay Kumar and Sunil Kumar, and all my colleagues of the Thin Film Laboratory for their help and cooperation.

I would like to thank Mr. Balraj Khatri for his technical assistance in maintaining the vacuum systems.

I am grateful to Mr. Sharma of IIT Delhi, and Dr. S.K. Sharma and Mr. S.U.M. Rao of NPL, New Delhi, for their help in scanning electron microscopy studies.

The financial support extended by Tata Energy Research Institute and Department of Electronics is gratefully acknowledged.

Finally, I am grateful to Mr. V.N. Sharma for his neat and skilful typing and to my friends Mr. Rajesh Rampal and Mr. Anil Kumar for their help in the preparation of this Thesis.

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ABSTRACT

In the present work, thin films of the following materials have been explored as inorganic resists: (i) WO_3 as photo, electron and ion resist; (ii) obliquely deposited amorphous P_4Se_{10} as photoresist and Ag/P_4Se_{10} as photo and ion resist; (iii) amorphous Si as ion resist; (iv) amorphous MoO_3 as ion resist; and (v) obliquely deposited amorphous $Bi_{10}Ge_{20}Se_{70}$ as photoresist, and $Bi_{10}Ge_{20}S_{70}$ and $Ag/Bi_{10}Ge_{20}Se_{70}$ as photo and ion resist.

Thin films of amorphous and polycrystalline WO_3 used in these studies were prepared by thermal and e-beam evaporation techniques. These films were found to change their colour on irradiation to UV light, e-beam and glow discharge hydrogen plasma and the coloured films showed insolubility in alkaline solution. The effect of colouration on the change in solubility has been studied by measuring the solubilities of electrolytically coloured and bleached films. This change in solubility on irradiation has been exploited for lithographic application. The effects of substrate temperature (during deposition and H_2 plasma exposure) and the exposure time on etching rate and selectivity ratio have been studied. The lithographic parameters, sensitivity (S) and contrast (γ), have been estimated. The contrast (γ) values for a-WO_3 films exposed to photons, electrons and H_2 plasma are $\sim$ 2.3, 4, and 2.3, respectively, and for poly-WO_3 exposed to H_2 plasma is $\sim$ 3.3. The sensitivity (S) values for photons and electrons are $\sim 10^{20}$ photons/cm^2 and $\sim 10^{-3}$ C/cm^2, respectively. Various patterns on these films

have been replicated by exposing the films to photons, electrons and H_2 plasma through a mask and by subsequent development in alkaline solution. In addition to these studies, the optical and electrical properties of the as-deposited and coloured films have been correlated with their etching characteristics.

Thin films of a-Si deposited by Kaufman ion-beam source and magnetron sputtering have been explored as ion and ion-beam resist materials. It has been observed that the etching rate of the exposed region in CF_4 plasma decreases compared to the unexposed region, thus giving rise to the negative tone behaviour. The effects of exposure time, substrate temperature (during plasma exposure), and H_2 (incorporated during deposition) concentration in the films on etching rate and selectivity ratio have been studied in detail. The sensitivity and contrast were found to be $\sim 10^{18}$ ions/cm^2 and 1.1, respectively. A grating pattern of 20 μm pitch by lift off technique and various other patterns have been replicated using this material as ion resist. The possibility of mask fabrication for deep UV lithography has been explored using a-Si as masking material. In addition to these studies, the effect of plasma exposure on etching characteristic of n-type single crystal Si has been studied and different patterns have been replicated.

Thin films of amorphous phosphorous decaselenide (P_4Se_{10}) deposited at an angle of 80° have been explored as photoresists. Depending upon the substrate temperature during plasma etching in CF_4 gas, both positive and negative tone behaviour of the photoresist have been observed. The effects

of substrate temperature, exposure time, and angle of deposition on etching rate and selectivity ratio have been studied. To estimate the lithographic parameters, the photon exposure characteristics of this material as positive and negative photoresists have been investigated. Contrast values of 2.5 and 2.9 for positive and negative, respectively, have been obtained with a sensitivity of 10^{20} photons/cm^2 for both the photoresists. In addition to these studies on pure P_4Se_{10}, the thin films of Ag/P_4Se_{10} have been explored as photo and ion resist. The etching characteristics of this bilayer as photo and ion resist have been studied as a function of exposure time. The etching rates of this material have been found to decrease after photons and ions exposure, thus giving rise to negative tone of the resist. The contrast values of 2.9 and [illegible] for photon and ion irradiation, respectively, have been [illegible].

Thin films of amorphous MoO_3 prepared by thermal evaporation have been explored as ion resists. It has been observed that when the films of MoO_3 are irradiated with hydrogen ions, these change their colour from light blue to dark blue and the solubility in alkaline solution decreases drastically. This change in solubility on colouration has been exploited f lithographic applications. The effects of substrate temperature (during plasma exposure) and exposure time on etching rate and selectivity ratio have been studied. The contrast value of 4.2 has been obtained. The optical properties of as-deposited and plasma coloured films and their correlation with etching characteristics have been studied.

Obliquely deposited thin films of amorphous $Bi_{10}Ge_{20}Se_{70}$ (80°) as photoresists and $Ag/Bi_{10}Ge_{20}Se_{70}$ (80°) and $Bi_{10}Ge_{20}S_{70}$ (80°) as photo and ion resists have been explored for lithographic applications. Thin films without Ag overlayer showed a positive tone behaviour whereas a negative tone is observed with Ag overlayer. The effects of exposure time and angle of deposition on etching rate and selectivity ratio have been studied. The contrast values were found to vary from 1.25 to 5.0 depending upon the type of resist and the exposure tool used.

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