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Development of 3-D Ag-doped chalcogenide glass hard masks using dry reactive ion etching (RIE)

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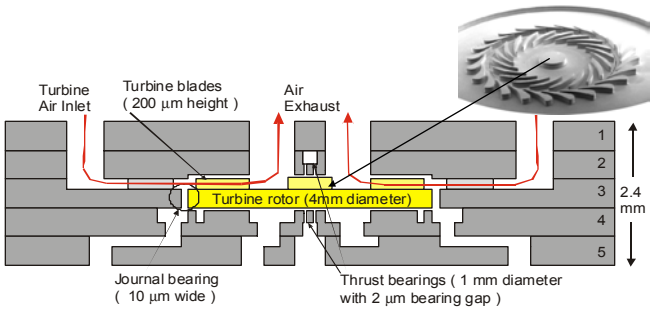
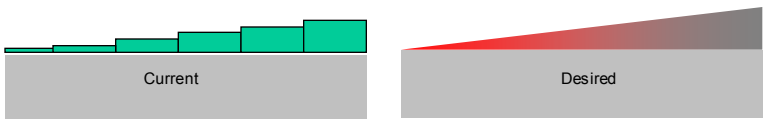
Goal:

Develop inorganic hard masks for the fabrication of MEMS, microelectronic and photonic devices.





Background:

- Chalcogenide glasses (alloys of S, Se, Te with elements of IV and V groups) have unique multi-functional photosensitive properties such as possibility to enhance selectivity of photoresists using Ag photodiffusion into chalcogenide glassy film

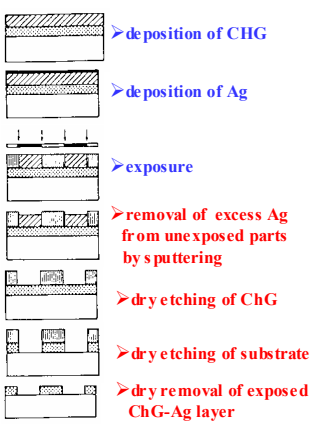
- RIE is a mature dry etch technology capable of controlling anisotropy

- Photoresist Variables: Composition, ChG film thickness, Silver film thickness, Exposure light wavelength, Exposure intensity, Exposure time

- RIE Variables: Gas composition, Gas pressure, Flow rate, Substrate temperature, Electric field, Etch time

Experimental details:

Dry process



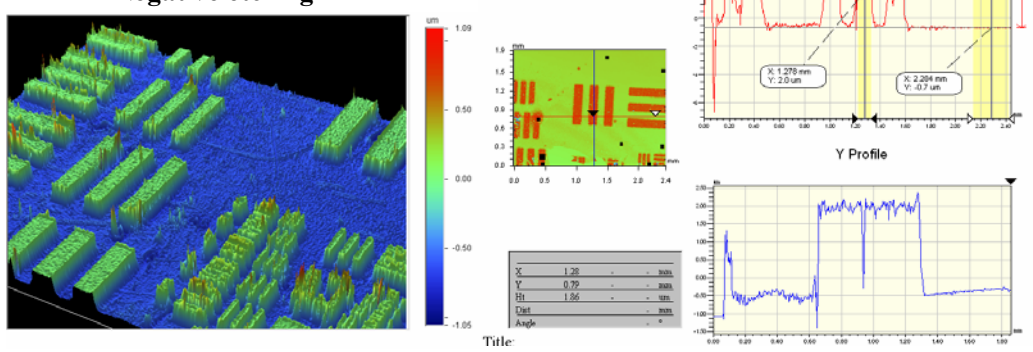
- **Thin films were prepared by thermal evaporation method on Si substrates**
- **Samples were exposed to band gap light using Cr mask**
- **For negative etching silver was removed from unexposed parts**
- **CF_4 and O_2 chosen as etchant**
- **CF_4 is believed to have lower contrast compared to SF_6**
- **O_2 known to help dissociate the Fluorine ion in a CF_4 plasma**

- **Unaxis (PlasmaTherm) 720 RIE system**

RIE system

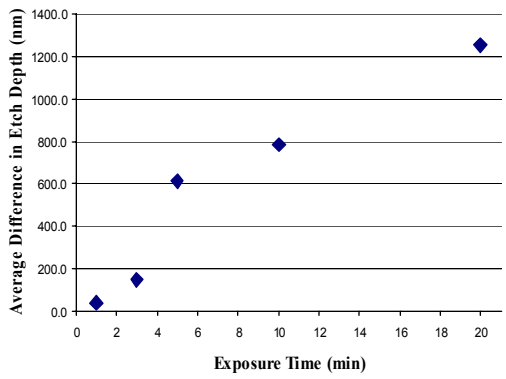
Etch Results:

Negative etching



Sample exposed 5 minutes to the UV light

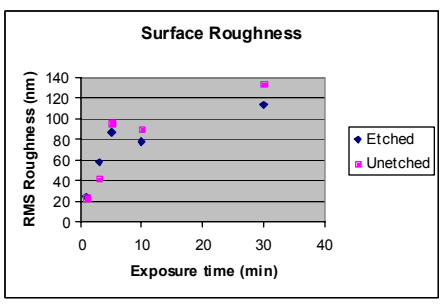
Selectivity Results



Problems:

I. Edge effect. Possible reasons: Ag re-deposition, structural features

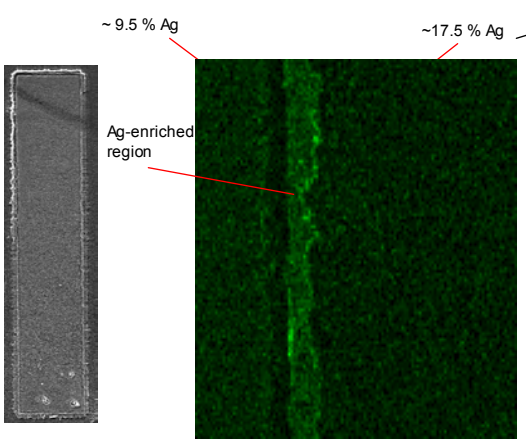
II. Formation of "grass" Possible reasons: oxidation of As- enriched layer



Ag free region has lower roughness than Ag-diffused region.

Ag-free film: Isotropic chemical etching

Ag-diffused region: Chemically less reactive, anisotropic sputtering is relatively more dominant



Ag color concentrational profile on the border of non-irradiated and irradiated parts (edge effect) of the sample exposed 5 minutes

Conclusions:

- Chalcogenide glasses show promise for gray hard mask for 3-D lithography

- Selective etching is demonstrated by varying metal content

- Linear relationship is observed between light exposure and differential etching

- Edge effects can be explained by the formation of silver-enriched regions

- "Grass" effect appears to be connected with oxidation of As-enriched surface layer