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Solution processing of As-S chalcogenide glasses

Tomas Kohoutek *

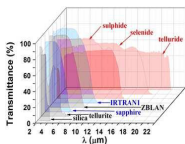
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University of Pardubice, Studentska 573, Pardubice 532 10, Czech Republic

* tomas.kohoutek@upce.cz

Chalcogenide glasses (ChGs) – properties, applications, processing

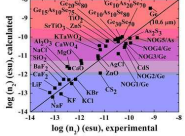
Important Properties of ChGs

Infrared Transparency



Compounds of S, Se, Te with non-transition metals Ge, Ga, As, Sb, etc.
Optically isotropic, transparent in infrared, high refractive index $n = 2 - 3.6$

High Optical Non-linearity



Extremely high optical non-linearity (more than $n \times 100$ vs. silica)
Easy shaping at low temperatures and allow for solution-processing

Applications of ChGs

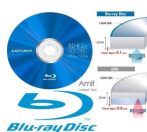
Infrared Light Transmitting Fibers



Infrared Lenses for Night Vision System



Blue-ray, DVD, CD Data Storage

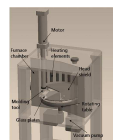


Flat Panel X-ray Detectors (3D-imaging)



Processing of Bulk ChGs

Molding

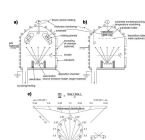


Mechanical Machining

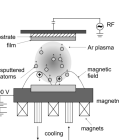


ChG Thin Film Deposition

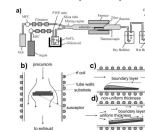
Thermal Evaporation



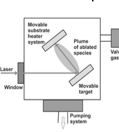
Magnetron Sputtering



Chemical Vapour Deposition

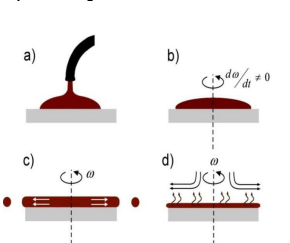


Pulse Laser Deposition

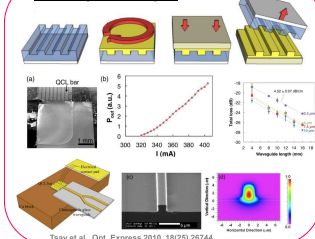


Solution processing of ChGs – not only thin film deposition

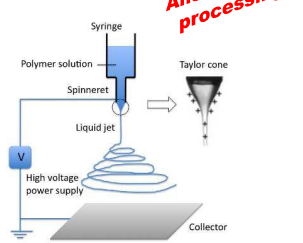
Spin-coating



Infrared Single-mode Waveguide

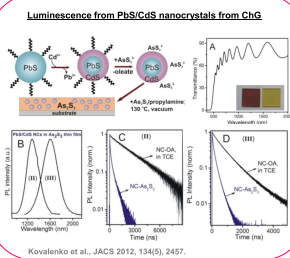
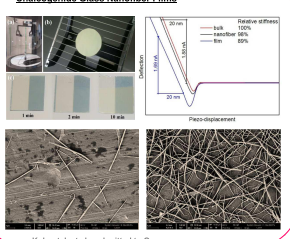


Electrospinning

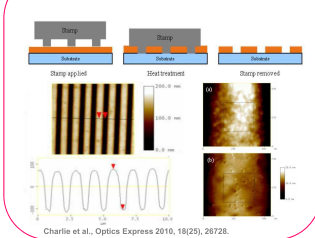


Annealing free processing !!!

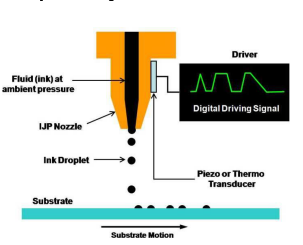
Chalcogenide Glass Nanofiber Films



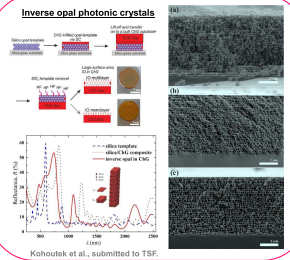
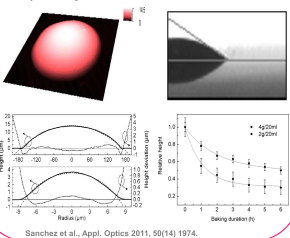
Diffraction grating in ChG (by imprinting)



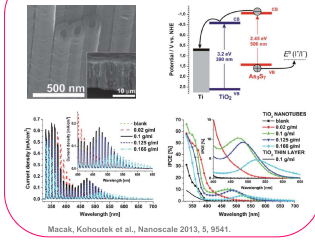
Inkjet Printing



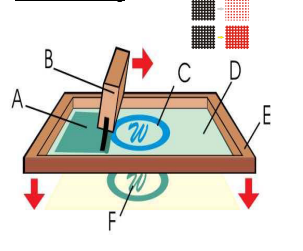
Inkjet Printing of Microlenses



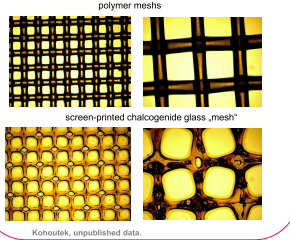
Sensitized TiO₂ nanotube arrays for photo-current generation



Screen Printing



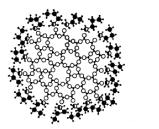
Infrared Detectable Security Elements



Solution processing of ChGs – important issues

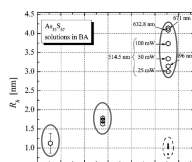
Formation of ChG glass solutions

1) In the process of dissolution of the ChG in propylamine solvent the nanoclusters are formed when the free-electron pairs present on nitrogen attack the As-S bonds in the glass leading to the formation of As-N bonds and the quaternary ammonium salt $R-NH_3^+$ (Chern *et al.*, JAP 1983).



Cluster size in ChG glass solutions

2) The dissolved ChG is present in amine solution in the form of nanoclusters, with the diameter of several nanometres (Kohoutek *et al.*, JAP 2008) surrounded by molecules of solvent bound to the cluster surfaces. There is a significant excess of free amine solvent.

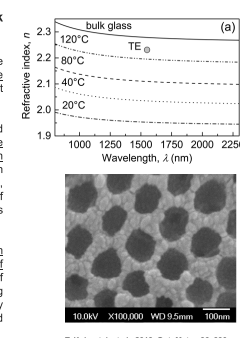
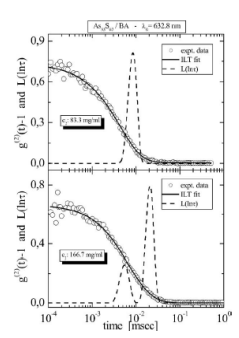


Re-formation of glass network from ChG solutions

3) The glass network is re-formed from the glass solution by aggregation of the nanoclusters. Evaporation of free solvent is promoted by the deposition process.

4) After solidification, the as-deposited glass (film) consists of aggregates with the diameters of some 15–20 times larger than the diameter of the nanoclusters in solution (Norian *et al.*, JAP 1984, Kohoutek *et al.*, JAP 2008). The amount of free solvent trapped in the network is reduced, but is still not negligible.

5) Long-term annealing under vacuum leads to essentially complete release of the solvent from the amorphous network of ChG glass (films). There is a cross-linking of the glass aggregates, followed by significant network densification and reduction in glass volume (film thickness).



Chern *et al.*, J. Appl. Phys., 1983, 54, 2701.

Kohoutek *et al.*, J. Appl. Phys., 2008, 103, 063511.

T. Kohoutek *et al.*, 2013, Opt. Mater. 36, 390.

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