Westsächsische Hochschule Zwickau
University of Applied Sciences

AG MEMS

Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages

IR-Drying of photoresists: Experimental and theoretical consideration of drying kinetics of mono- and multi-layered coatings

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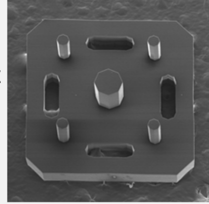
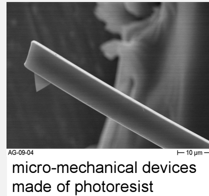
Motivation

- Epoxy-based photoresists (e.g. SU-8) are widely used in MEMS technology (e.g. LIGA)
- In addition, photoresists are also used for direct production of micro-mechanical devices with very high aspect ratio
- For successful processing, several parameters have to be observed within narrow tolerances
- Predict the drying time and control the residual solvent content while drying are very important tasks
- An IR-drying system has been developed and used for in-situ measuring of drying kinetics
- For simple analytical modelling of the drying process, an mono-parametric approach based on Fick´s Law has been used

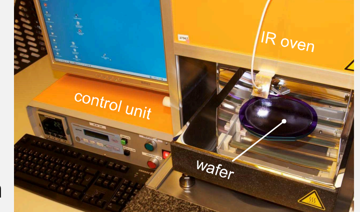


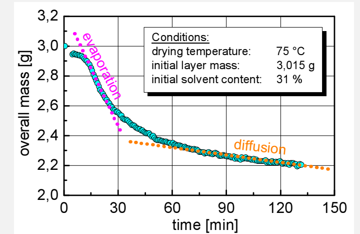


micro-mechanical devices made of photoresist

Equipment and Measurements

- An innovative IR-drying system has been developed and used in processing thick resist coatings
- Due to the infrared source used, the radiation is directly absorbed in the coating system
- A balance system determines the actual weight of the substrate and the resist layer while drying process
- This in-situ-determination of mass loss of the resist layer enables considerations of drying kinetics of mono- and multilayered resist systems



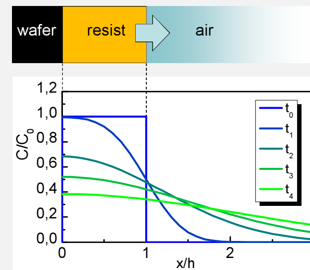


Theoretical modelling

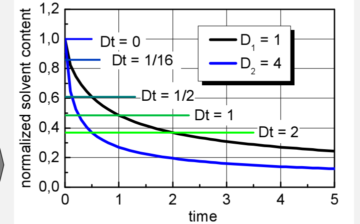
- Due to the ratio of molecule size between resist and solvent, physical drying is assumed as relevant drying process
- A simple, mono-parametric approach based on Fick´s Law (1) has been used for describing this process
- To match the measured data (only depends on time t), equation (2) must be integrated over layer thickness h, resulting in equation (3)

C solvent concentration
t time
D diffusion coefficient
x ordinate along layer thickness

$$\frac{\partial C}{\partial t} = D\left(\frac{\partial^2 C}{\partial x^2}\right) \quad (1)$$



$$C(x,t) = \frac{C_0}{2}\cdot\left[erf\left(\frac{x+h}{2\sqrt{Dt}}\right) - erf\left(\frac{x-h}{2\sqrt{Dt}}\right)\right] \quad (2)$$

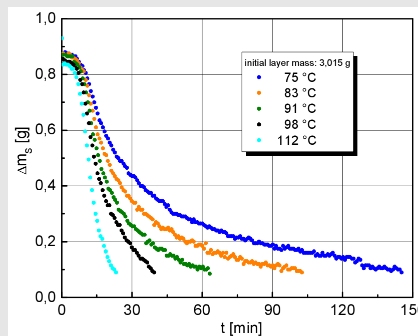


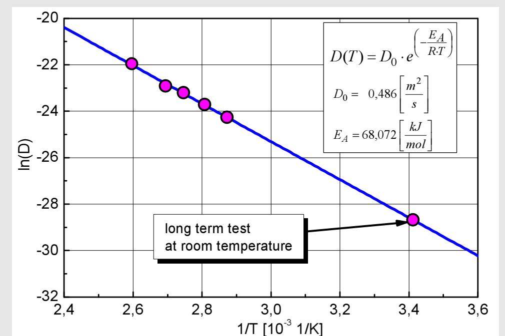
$$CI(t) = C_0 \cdot \left[h \cdot erf\left(\frac{h}{\sqrt{Dt}}\right) + \sqrt{\frac{Dt}{\pi}}\cdot\left(e^{\frac{-h^2}{Dt}} - 1\right)\right] \quad (3)$$

Results

Drying kinetics of mono layer systems

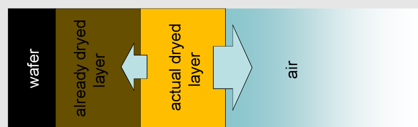
- The described IR-drying system was used to clarify drying kinetics of photoresist mono layers
- Data-fittings with equation (3) were performed on measurements at different temperatures
- An Arrhenius plot of the resulting diffusion coefficients D indicates a classical, thermally activated process
- Therefore, the assumption that diffusion is the major process in drying of photoresists should be valid





Drying kinetics of multi layer systems

- Measurements for drying of three consecutive layers each with approximately 740 µm thickness were performed
- The clear slowdown in drying time can be explained due to back diffusion of solvent in already dry regions of the underlying layers
- The presented, analytical approach should be expanded to these new boundary conditions for describing this slowdown



Good advices for adapting the presented, analytical approach to above model can be found in *R. M. Barrer, Diffusion in and through solids, The University Press, Cambridge, England, 1941*