OPTIMISATION OF THE LITHOGRAPHY AND PYROLYSIS PROCESS OF SU-8 RESIST FOR FABRICATION OF CONDUCTIVE MICROSTRUCTURES

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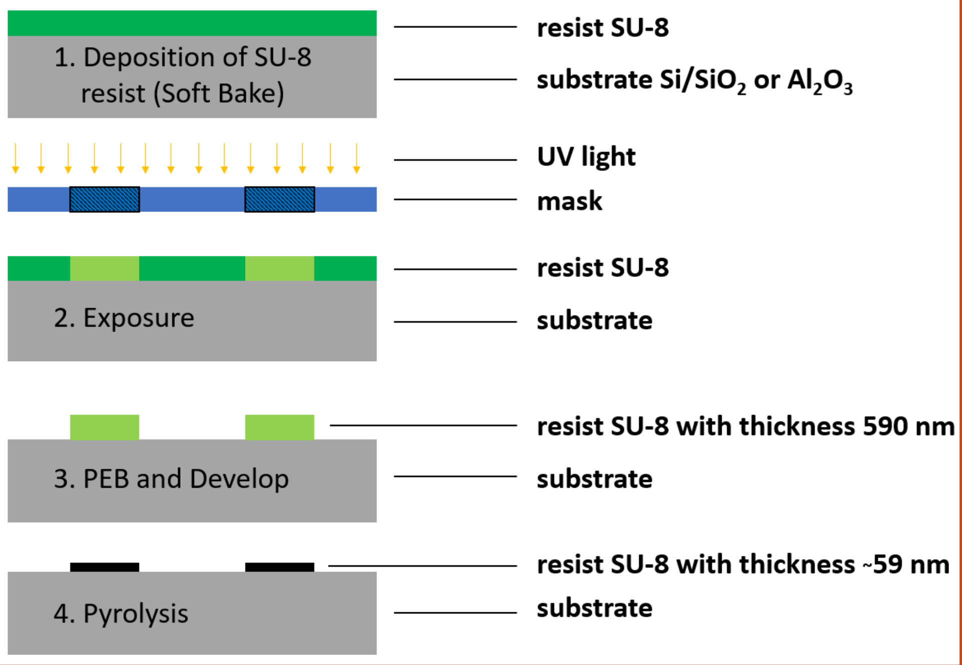
Abstract

This work presents the fabrication and characterization of carbon microstructures from SU-8 photoresist by rapid thermal pyrolysis. The aim was to optimize lithography and pyrolysis parameters to obtain conductive microstructures for sensor use. Structures were prepared on Si/SiO_2 and Al_2O_3 substrates and pyrolyzed up to 1200 °C in nitrogen. The effect of temperature and dwell time on electrical properties was studied, showing that higher temperatures and longer dwell times lower electrical resistance. The results confirm rapid thermal pyrolysis as an efficient, low-cost method for producing carbon microelectrodes for sensor applications

Introduction

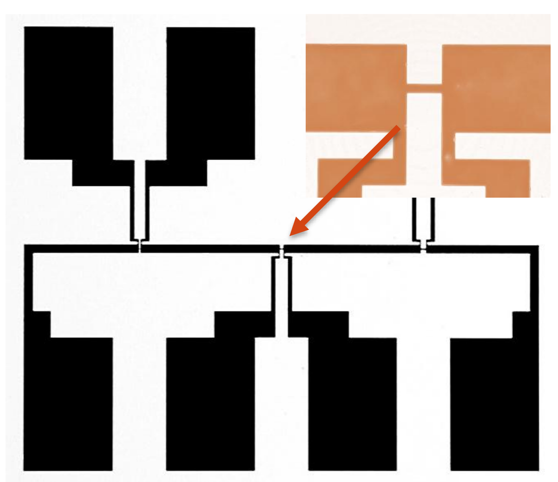
From a technological perspective, there is an ongoing effort to replace expensive and complex fabrication processes with simpler and more cost-effective alternatives. One such approach involves the use of the negative epoxy-based photoresist SU-8, which serves not only as a structural material but, after pyrolysis, also as a precursor for conductive carbon microstructures.

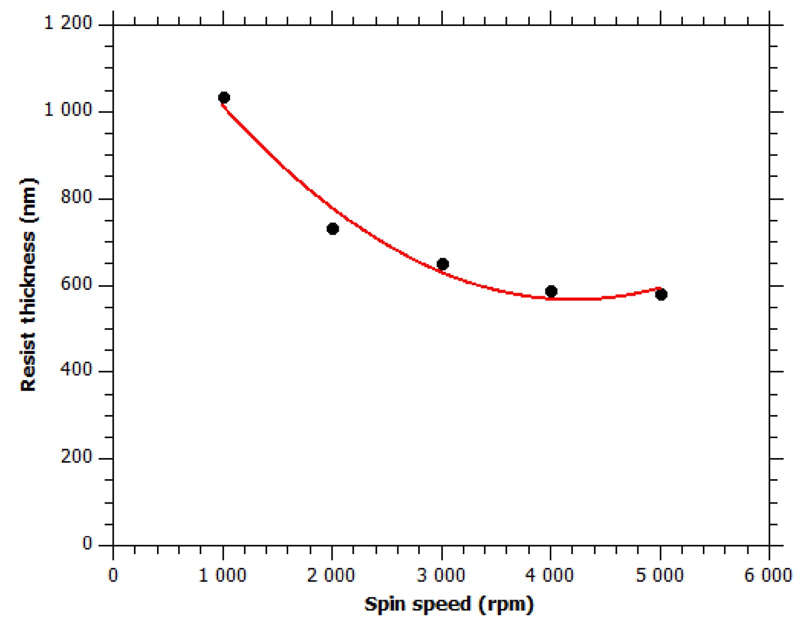
Fabrication of conductive microstructure

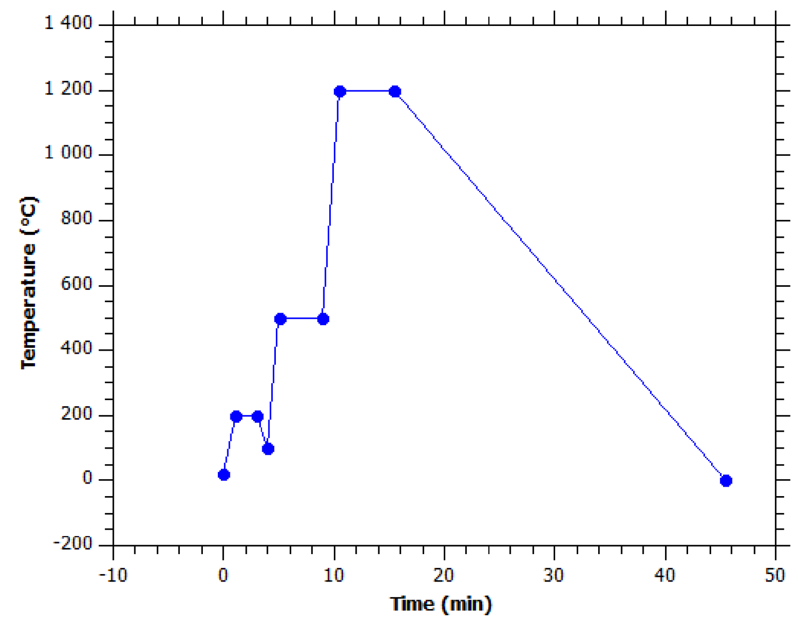


Experimental methods

- Bridge-shaped microstructures for electrical transport measurements were fabricated on Si substrates with a 300 nm SiO_2 layer and on monocrystalline Al_2O_3 substrates.
- A negative epoxy-based photoresist, SU-8 2000, was applied onto these substrates using spin-coating. Based on optimisation, a spin speed of 4000 rpm was selected as ideal, resulting in a layer thickness of approximately 590 nm. After soft-baking, UV exposure was performed using a 365 nm i-line LED source through a contact photolithographic mask, followed by development in the SU-8 Developer to reveal the structures.
- The conversion of the SU-8 into a carbon material was carried out using rapid thermal processing in a protective nitrogen atmosphere. The temperature was increased at the rate of 10 °C/s up to the target temperature of up to 1200 °C, where the samples were held for 1 to 7 minutes. This was followed by controlled cooling at the rate of 300 °C/min in the first minute and then spontaneous cooling with a nearly exponential decrease from 120 °C/min to 30 °C/min down to room temperature.



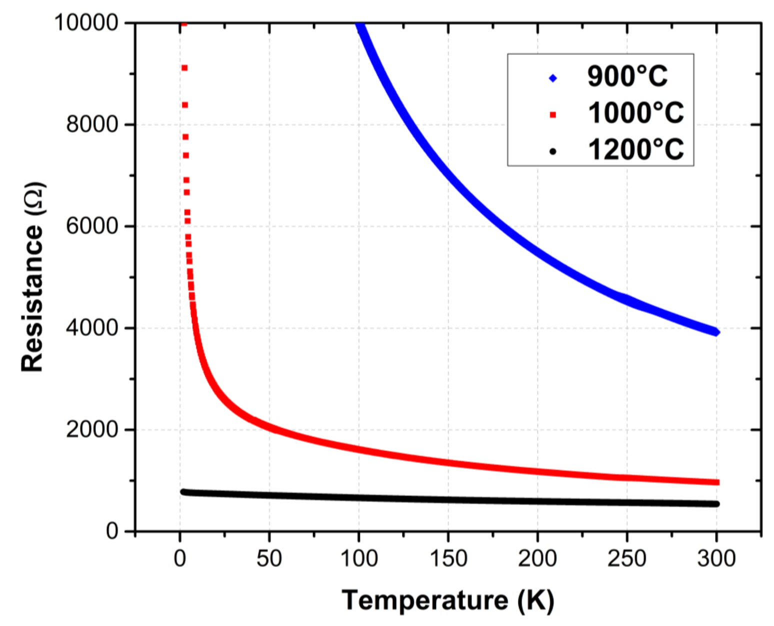


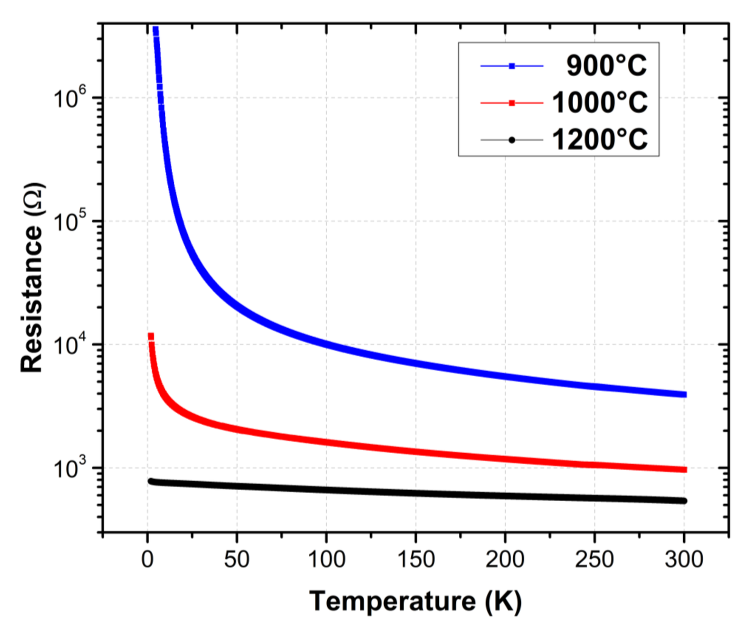


Results & Discussion

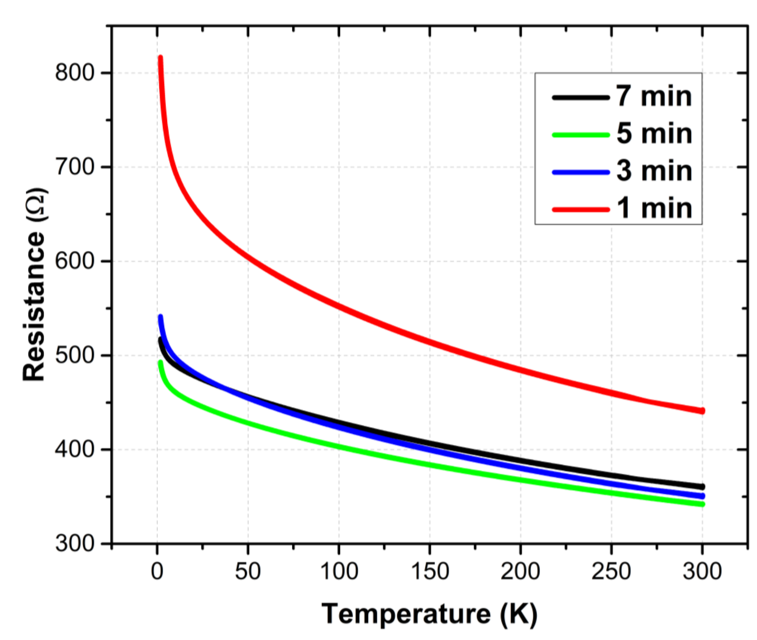
The results demonstrate a significant dependence of the electrical properties of pyrolysed SU-8 microstructures on the pyrolysis temperature and the dwell time at the target temperature.

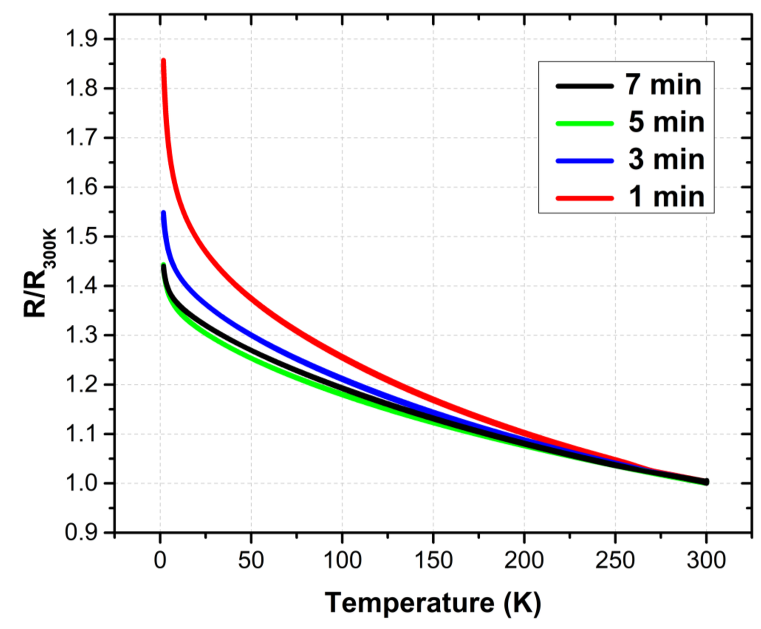
- The graphs shows the dependence of the electrical resistance on temperature obtained using the PPMS for samples pyrolysed at 900 °C, 1000 °C, and 1200 °C with a constant dwell time of 5 minutes. The left panel shows the data in linear scale and the right panel in logarithmic scale.
- The aim of these measurements was to identify the optimal temperature that would ensure the lowest possible electrical resistance of the resulting structures. Based on the results, pyrolysis at 1200 °C was identified as the most suitable within the capabilities of our RTP system, and this condition was subsequently used in further experiments.





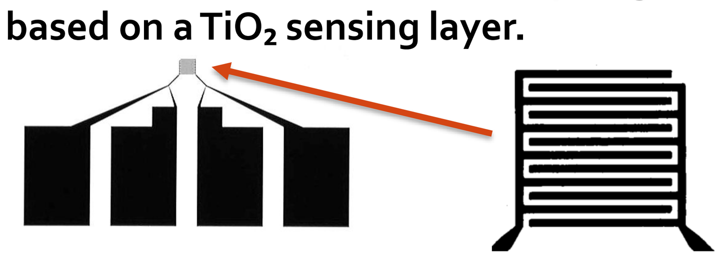
- Another set of graphs presents the dependence of electrical resistance on temperature for structures pyrolysed at a constant temperature of 1200 °C but with different dwell times (1, 3, 5, and 7 minutes). The left panel shows absolute values of the resistance, while the right panel shows the same data normalized to the resistance at 300 K for each respective dwell time.
- Based on the results, an optimal pyrolysis time of 5 minutes was identified, as longer annealing did not result in any significant improvement in the electrical properties.



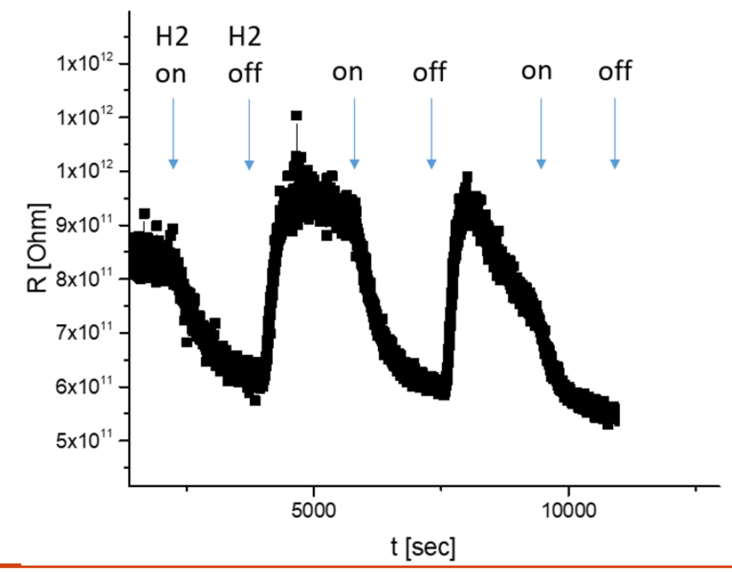


Application

- A second type of microstructure with comb-shaped contacts was used to fabricate a hydrogen (H_2) gas sensor based on a TiO_2 sensing layer.



- These results demonstrate the potential of replacing conventional platinum electrodes and complex deposition techniques with SU-8 carbon electrodes fabricated by a much simpler pyrolysis-based process.



Conclusion

- Conductive microstructures were successfully fabricated on both Si/SiO_2 and Al_2O_3 substrates
- Electrical resistance of SU-8-derived carbon microstructures decreases with increasing pyrolysis temperature
- Optimal pyrolysis temperature was identified as 1200 °C, giving the lowest electrical resistance within the RTP system limits
- Optimal dwell time was found to be 5 minutes, while longer annealing did not further improve conductivity
- Rapid thermal pyrolysis under these conditions provides an efficient route to conductive carbon microstructures for sensor applications

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