Determining the response of CNT-based sensors to a thermosetting resin

together with

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Program
Materials Science

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Context

- CNT/polymer nanocomposites are highly sensitive strain sensors applied in wide range of spheres.
- Single-walled carbon nanotube (SWCNT) used as reinforcement, having high electrical conductivity due to unique structure compiled by carbon atoms with high energy sp^2 bonds. Thermosetting epoxy resin based on Bisphenol A has good coating property suitable for matrix application. Novaprint 3D is a developing company aimed to create innovational composite materials via 3D Fused Deposition Modeling printing method.

Objectives

The task was detecting resistance changes during polymerization of epoxy resin in SWCNT/Epoxy thin films nanocomposite having different thicknesses in order to understand what is happening inside the sample during polymerization. Three types of films were measured:

- Low thickness (~90% transmittance)
- Moderate thickness (70/80% transmittance)
- High thickness (60% transmittance)

Process

- We prepared 3 types of SWCNT thin films 2x2 cm^2 size and transferred them into glass substrate.
- The thicknesses of SWCNT thin films were measured by UV-vis-NIR.
- Afterwards, contacts were added to SWCNT thin films according to Fig. 1–4 using silver paste.
- Then CR80 epoxy resin and CH80-2 hardener were added to SWCNT thin films.
- Samples resistance were measured for 24 hours by 2 and 4 point methods at room temperature.

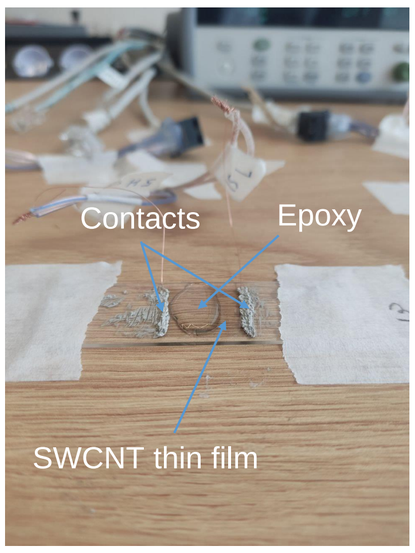


Fig. 1 SWCNT thin film 2 point measurement

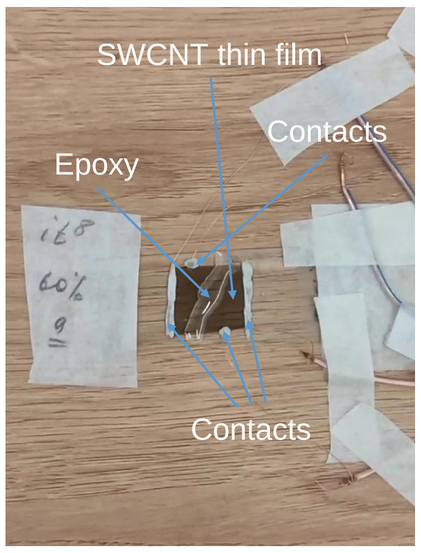


Fig. 2 SWCNT thin film 4 point measurement

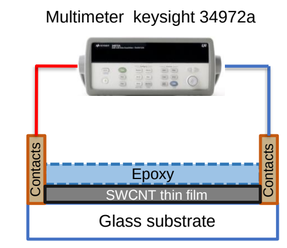


Fig. 3 Scheme of 2 point method set up

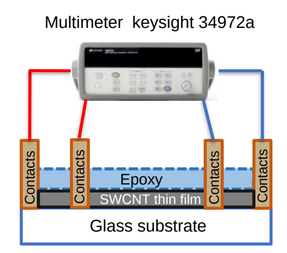
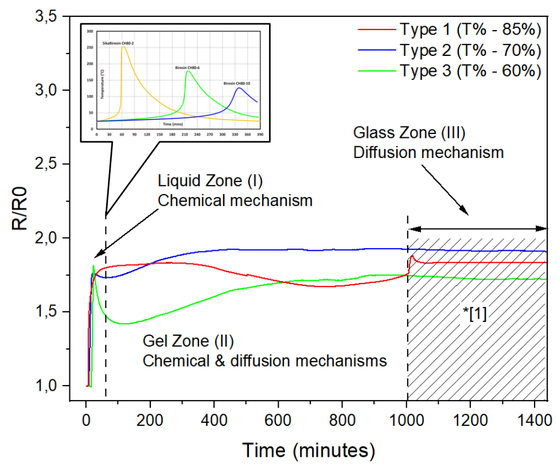


Fig. 4 Scheme of 4 point method set up

Results

- Electrical resistance vs time plots of curing process (Fig. 5 and 6) were built using experimental data. There are several curing zones were established. Initial liquid Zone (I) is controlled by chemical kinetics, followed by cross-linking at gel point (60 minutes). Steep increase of resistance observed at ~ 20-30 minutes of curing due to epoxy penetration into SWCNT thin films pores. Gel Zone (II) has a competition of diffusion limitation and chemical mechanism going until cessation (1440 minutes) of polymerization in Glass zone (III).
- Type 2 SWCNT thin film has the highest sensitivity, having significant resistance change (R/R_0) ~ 1,9 for 2 point testing and ~ 2,7 for 4 point testing . Type 1 and 3 SWCNT thin film have much less resistance change comparing to type 2 sample.



*[1] - manufacturer stated complete cure https://industry.sika.com/content/dam/dms/global-industry/0/Biresin-CR80-New-incl.-new-hardeners.pdf

Fig. 5 Change in electrical resistance during the curing resin process by 2 point method

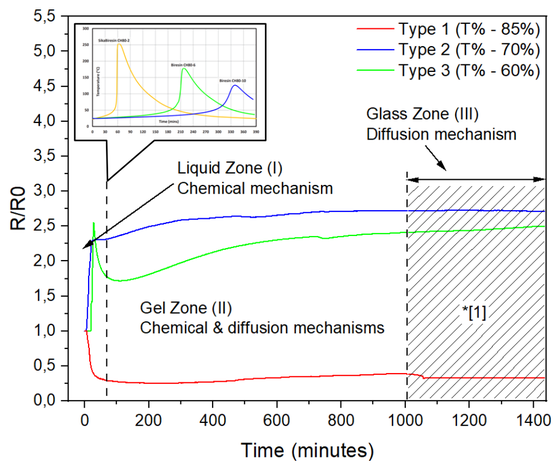


Fig. 6 Change in electrical resistance during the curing resin process by 4 point method

Conclusions

- SWCNT thin film could be used as resistor response sensor.
- During the internship, I studied how piezoresistive sensors based on CNT and epoxy resin are working and could be manufactured. I personally created samples for resistance change measurement during the epoxy resin curing. I learned the 2 and 4 point continuous multimeter testing technics and UV-vis-NIR method.

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