Electronic Supporting Information (ESI)

I. Breakdown voltage measurement method and test platform

AC breakdown experimental platform (as shown in **Figure S1**) was used to measure the AC breakdown voltage of the composite. The sample was placed between two copper cylindrical electrodes. 50 Hz AC voltage with a rising rate of 2kV/s was applied to the electrode by the AC test transformer and voltage regulator. After the breakdown of the sample, the breakdown voltage was recorded by the voltage monitoring system. The interval time between the breakdown tests was set as 5 min to avoid the interference of space charges, and all the breakdown tests were repeated for at least 9 times. All experiments were conducted at room temperature.

Weibull model [1]was used to describe AC breakdown field strength and failure probability. First, we arranged the test data, that is, breakdown field strength obtained in the previous tests, from small to large, and calculated the sample failure probability according to the following formula:

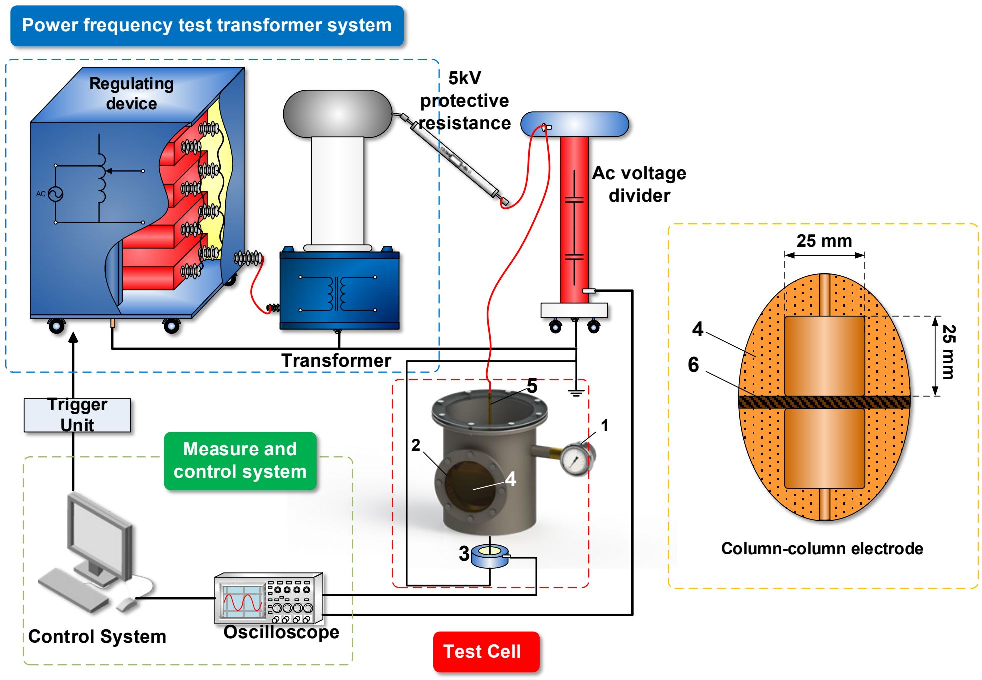
$$P(i) = \frac{i}{n+1} \times 100\% \tag{S.1}$$

Where $P(i)$ is the actual probability value of the sample; i is the rank; n is the sample total.

Generally, Weibull's cumulative probability distribution can be expressed by the following formula:

$$P(x) = 1 - \exp[-(x/\alpha)^{\beta}] \tag{S.2}$$

Where $P(x)$ is the cumulative probability value of failure data; x is the AC frequency breakdown field strength; β is the shape parameter[2][3]; α is the scale parameter of Weibull distribution and represents AC frequency breakdown with a cumulative probability of 63.12%. The values of α is considered the average breakdown field strength of the sample.



1. barometer; 2.inception window; 3. current sensor; 4. insulation oil; 5. high voltage terminal; 6. composite epoxy resin

Fig. S1 AC breakdown experimental platform

II. Frequency domain dielectric spectroscopy measurement method

The dielectric spectroscopy of the UVMM triple-response microcapsule/EP composites and the undoped epoxy resin materials were measured using the NovoControl Concept 80 broadband dielectric spectrometer (NovoControl Tech, Montabaul, Germany). The test frequency ranges from 10^{-1}Hz to 10^{7}Hz, and the temperature was set to 30°C. Calibration conversion module was used to prevent measurement error caused by leakage current.

III. Tensile property test method

We used the tensile strength tester(CRS-UTM200MA) to test the tensile strength of the UVMM triple-response microcapsule/EP composites and the undoped epoxy resin materials. The materials were dumbbell-shaped, and the original length of sample was 20 mm and the fracture surface was a circle with a radius of 10 mm. The measurement was conducted at room temperature.

$$\sigma=\frac{P}{bd} \tag{S.3}$$

σ: Stress; *P: load; b:* the length of fracture surface; *d:* the width of fracture surface

$$\varepsilon=\frac{G-G_0}{G_0}\times 100\% \tag{S.4}$$

ε: Strain*; G:* the length of sample at fracture; G_0*:* the original length of sample;

IV. Synthesis of UV, moisture double-response microcapsules

120 mL of ultrapure water, anionic surfactant GA (7 g), cationic surfactant DTAB (0.2g) and amphiphillic TiO_2 (1g) were added into a 500 mL beaker, and mechanically stirred at 500 r/min for 3 h. The TDI prepolymer (9.0 g) was dissolved in 20 mL CB and mechanically stirred at 65 °C for 10 min until the prepolymer was completely dissolved. We added 27.0 g healing agent into the mixture and mechanical stirred it for 20 min and then slowly poured the mixture into GA solution. After heating water bath pot at 50℃, we added 6.3 g BD to the emulsion drop by drop and heated it at 70 °C for reaction of 1 h. After cooling to room temperature, we added deionized water and washed it for 3 times. After being pumped and filtered, it was placed in the air for drying for 24 h. The average capsule yield was 75 wt%, and the structures of microcapsule and functional core-shell nanoparticles are shown in **Fig. S2**.

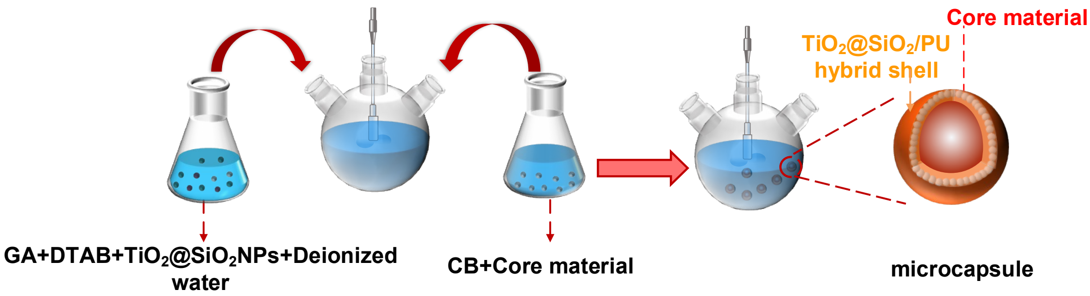


Fig. S2 Synthesis of UV, moisture double-response microcapsules

V. Electrical tree experiment platform

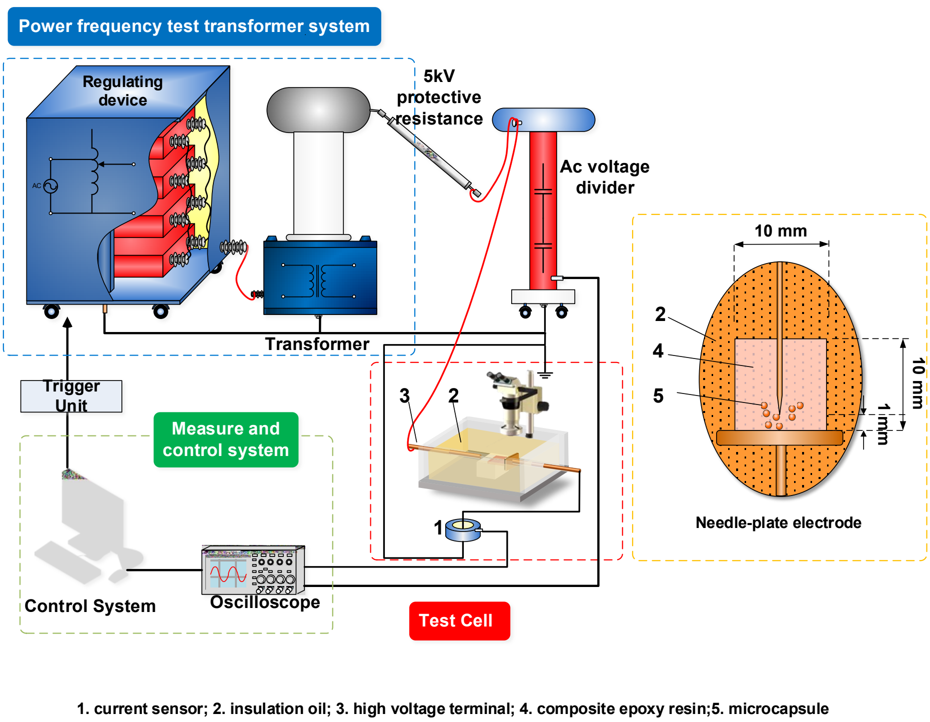


Fig. S3 Electrical tree experiment platform

VI. Process of release of healing agents

Please see **Movie 1** for details.

VII. Calculation Method of Repair effect

In order to prove the repair effect of composite materials, the following formula is used.

When cracks occur in the composite material, the average volume of cracks is:

$$V_C = DLW \tag{S.5}$$

Where D 、 L and W is the depth of the crack, the length of the crack and the width of the crack.

Assume that the radius of microcapsule is R . The number of broken capsules is:

$$N = \frac{\eta DL}{\pi R^2} \tag{S.6}$$

Where η is the concentration of the microcapsule in the concentrated area of epoxy resin.

Therefore, the total volume of the broken capsules is:

$$V_{microcapsule} = \frac{4}{3}\pi R^3 = \frac{4\eta RDL}{3} \tag{S.7}$$

Because the shell of the capsule has a certain thickness S , the volume of the released core material is roughly:

$$V_{healing} = \frac{(R-S)^3}{R^3} V_{microcapsule} = \frac{(R-S)^3}{R^3}\frac{4\eta DL}{3} \tag{S.8}$$

T is the average shell thickness of microcapsule, then the ratio of the volume of the released core material to the volume of the required remediation agent is:

$$\lambda = \frac{V_{healing}}{V_C} = \frac{4\eta (R-S)^3}{3WR^2} \tag{S.9}$$

The mass fraction of microcapsules in the concentrated area of epoxy resin is $\omega = \frac{m_{microcapsule}}{m_{EP}} = 12.5\%$, the density of microcapsules $\rho_{microcapsule}$ is 1.0615 g/cm^3, which is approximately equal to the density of PU acrylate oligomer, and the density of epoxy resin ρ_{EP} is 1.2 g/cm^3.

Therefore, the concentration or volume ratio of microcapsules in the concentrated area of epoxy resin is:

$$\eta=\frac{\frac{m_{microcapsule}}{\rho_{microcapsule}}}{\frac{m_{EP}}{\rho_{EP}}}=12.5\%\times\frac{1.2}{1.0615}=14.13\% \tag{S.10}$$

When $\lambda \geq 1$, and considering that the curing of polyurethane acrylate oligomers tends to be accompanied by volume expansion, it can be considered that the cracks are completely repaired. For targeted microcapsule/epoxy resin composites, the values η、R、S and W are 14.13%, 87.6um, 4 um, and 10 um.

It is calculated that λ=1.42 ≥ 1 so the scratches can theoretically be repaired.

VIII. OM image of composite materials

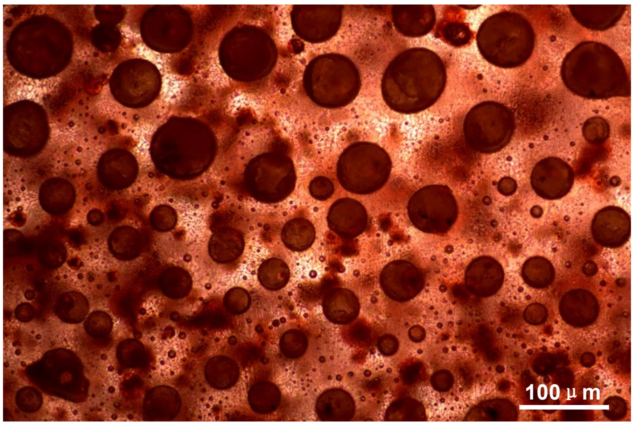


Fig. S4 OM image of composite materials

IX. Electroluminescence observation experiment

In order to characterize the characteristics of electroluminescence wavelength in the process of electrical tree development, a tree electroluminescence observation platform was built, as shown in Figure R6. The test electrode is a typical needle-plate electrode configuration, and the tip with a radius of curvature of 25 μm is used as the material defect that causes the electrical tree. The method of gradually increasing the voltage to induce the occurrence of electrical tree was used, and then voltage was lowered after the occurrence of electrical tree to record the electroluminescence characteristics during the growth of electrical tree. The whole experiment was conducted in a dark environment.

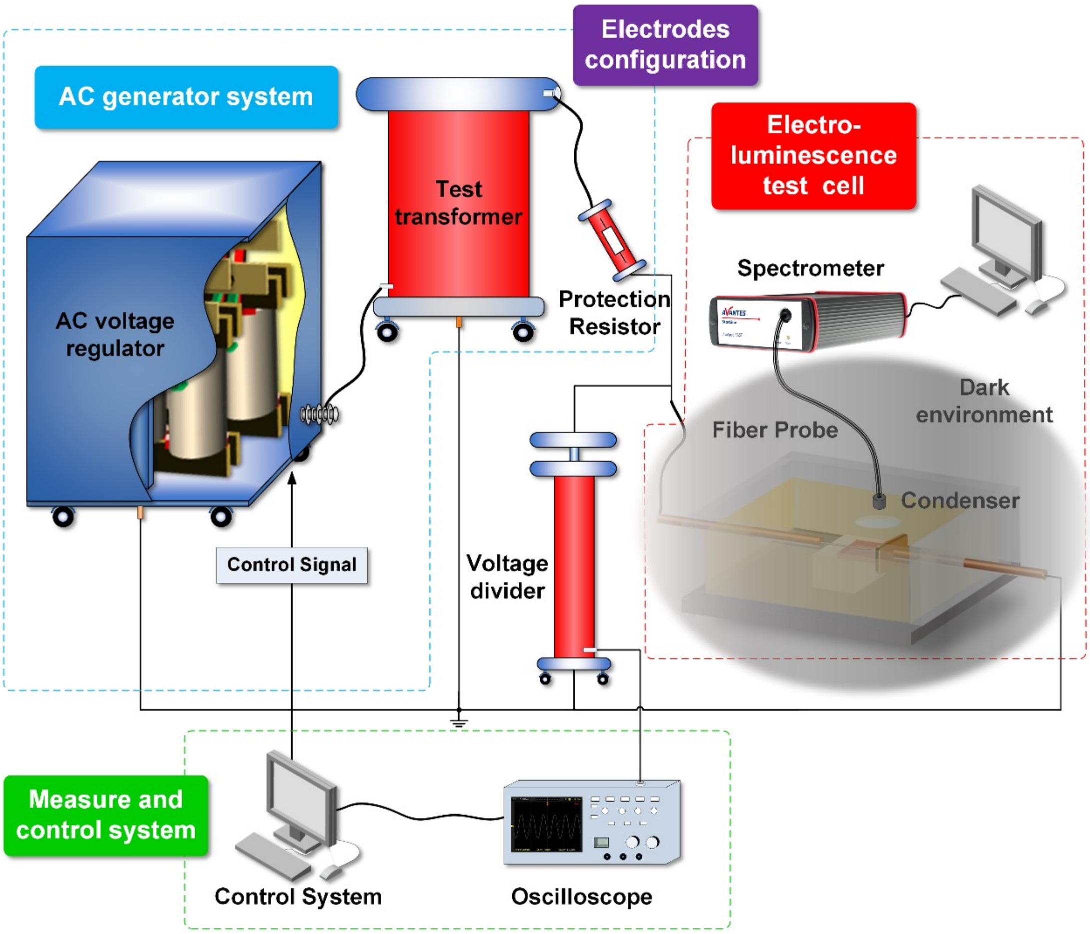


Fig. S5 Sketch of electrical tree in-situ electroluminescence observation platform.

The Avantes spectrometer was used to record the electroluminescence wavelength during the development of electrical tree in the dark environment. The test results are shown in Fig. R7.

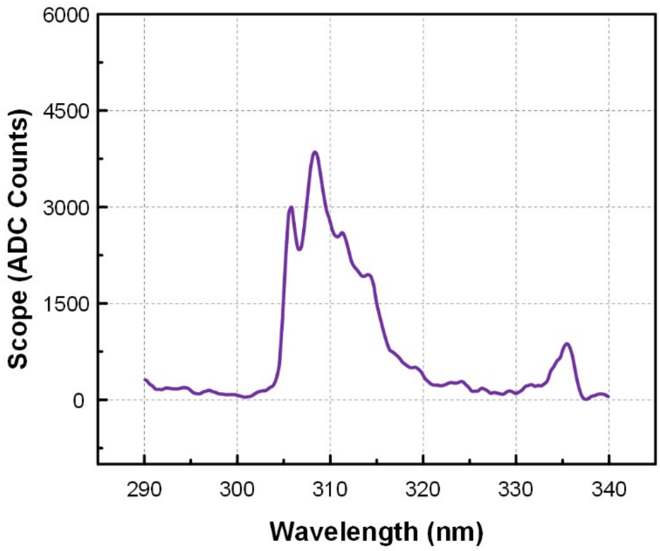


Fig. S6 Emission wavelength curve of electric tree electroluminescence

It can be seen from the figure that the electroluminescence wavelength generated by the electrical tree is concentrated in 300 ~ 320 nm, while the ultraviolet trigger wavelength of the photosensitive healing agent is 250 ~ 350 nm. Therefore, the electroluminescent wavelength of the electrical tree can effectively trigger the curing of the photosensitive core material.

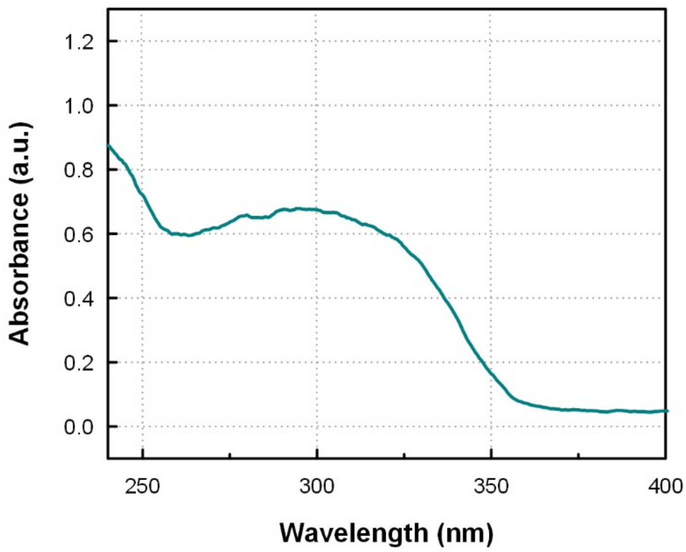


Fig. S7 UV-vis absorption spectra of PI 6992 (core materials)

Reference

[1] D. Fabiani, L. Simoni, *IEEE Trans Dielectr Electr Insul* 2005 **12** 11-16,

[2] J.R. Laghari, P. Cygan, W. Khechen, *IEEE Trans Electr Insul* 1990 **25** 1180-1182,

[3] A. Contin, G.C. Montanari, C. Ferraro, *IEEE Trans Electr Insul* 2000 **7** 48-58,