Supplementary Information for

Strain hysteresis and Mullins effect of rubber vulcanizates with reversible sacrificial network

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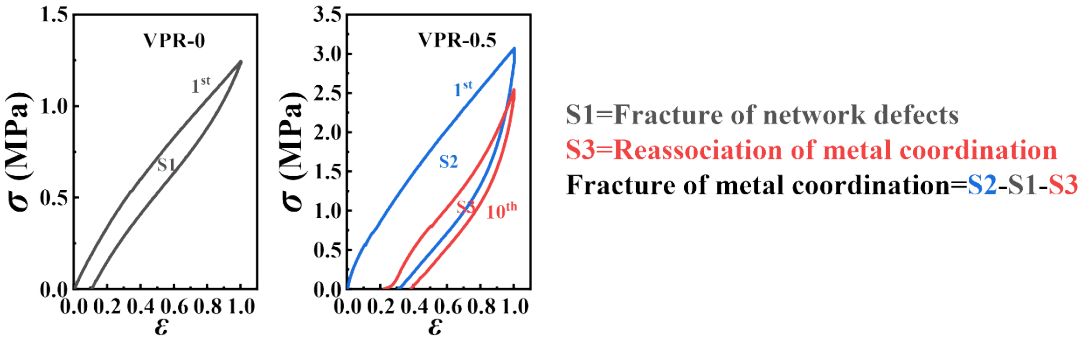

Scheme S1. Schematic diagram of area division.

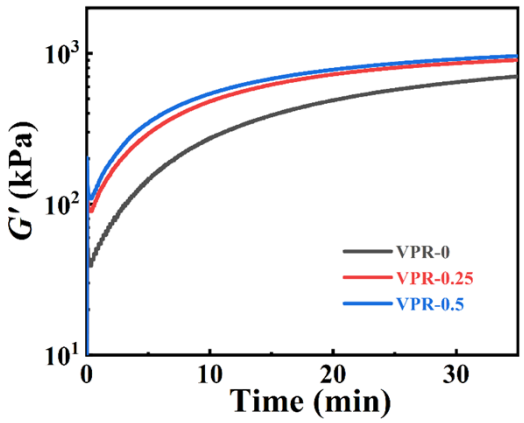

Fig. S1. Vulcanization curves of VPR-*x* at 150 ˚C.

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Due to the absence of effective observation techniques for the sacrificial bond region, its existence can only be inferred through the distribution of $ZnCl_2$. The following figure presents the TEM images of VPR-0.25, VPR-0.5, and VPR-0.67. Individual ions are not easily distinguishable. The dark regions in the TEM images represent aggregates of nanoparticles of different dimensions, suggesting the formation of sacrificial bond regions with varying sizes.

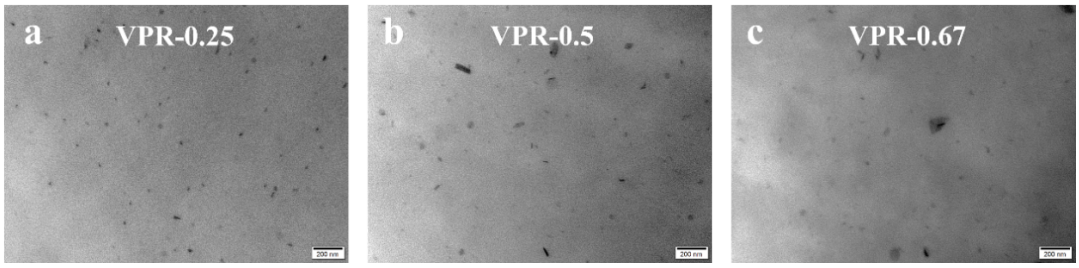

Fig. S2. TEM of (a) VPR-0 (b) VPR-0.5, and (b) VPR-0.67.

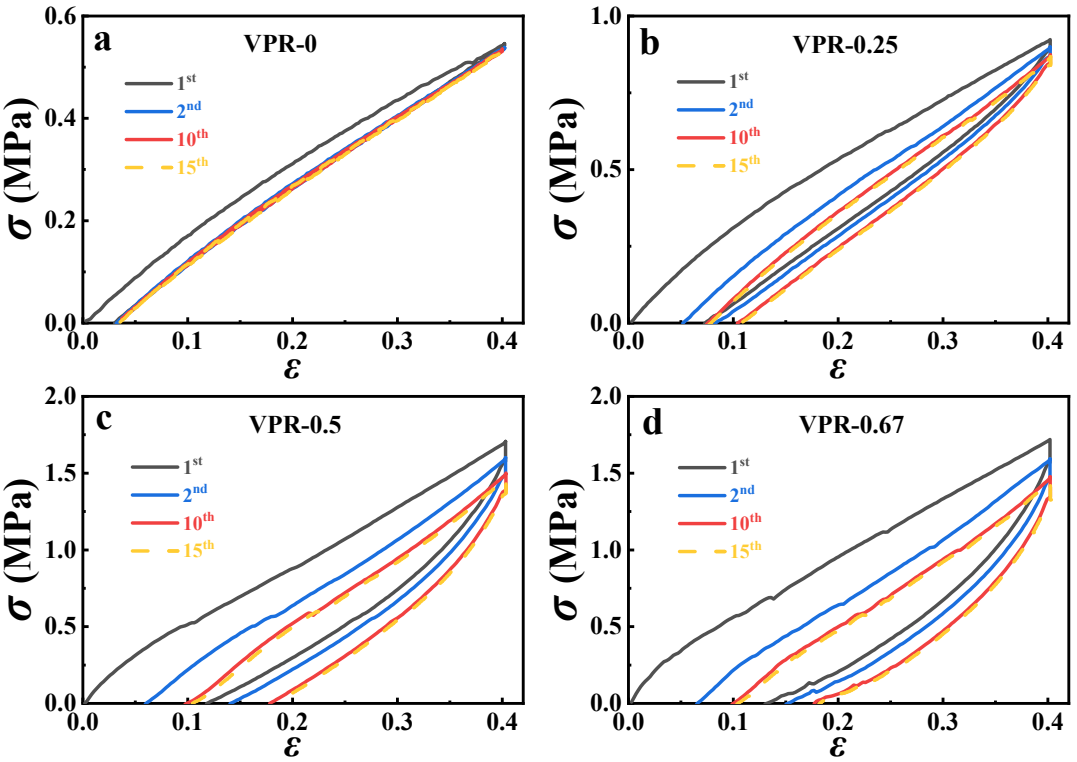

Fig. S3. Stress-strain curves of multiple cycles for (a)VPR-0, (b)VPR-0.25, (c) VPR-0.5 and (d) VPR-0.67 at ε=0.4.

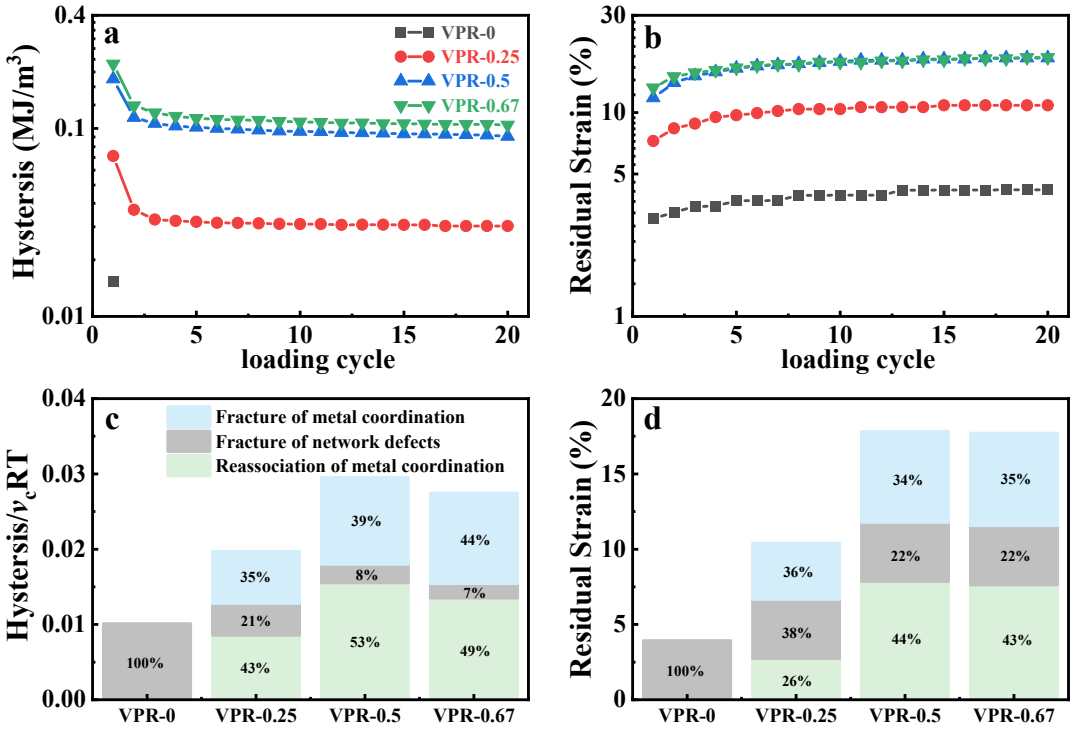

Fig. S4. (a) Area of hysteresis and (b) residual strain of multiple cycles for VPR-*x* at ε=0.4.

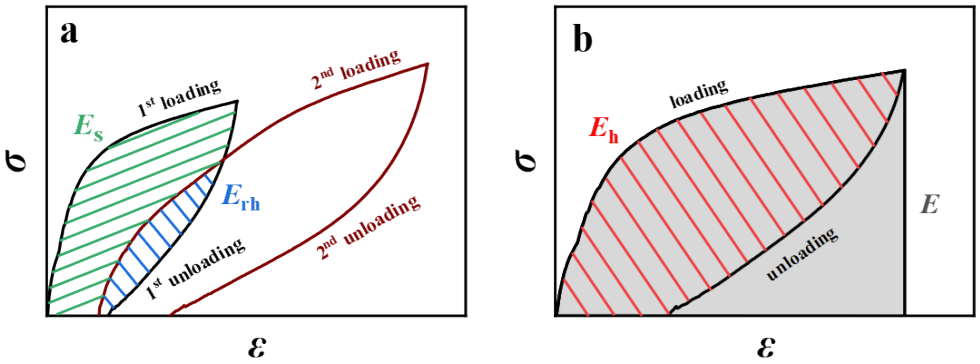

Fig. S5. Definition of energy losses.

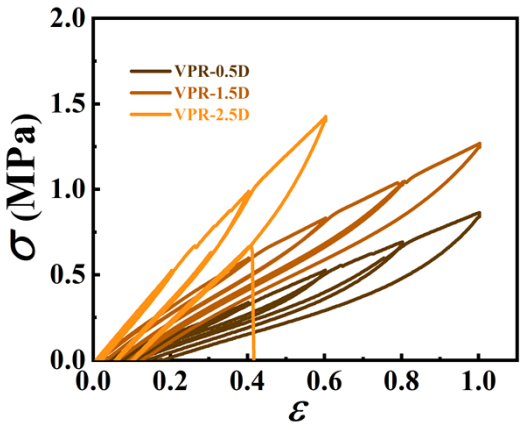

Fig. S6. Stress-strain curves of VPR-0 with covalent crosslinking density during sequential loading-unloading tensile tests at a series of different maximum applied strains.

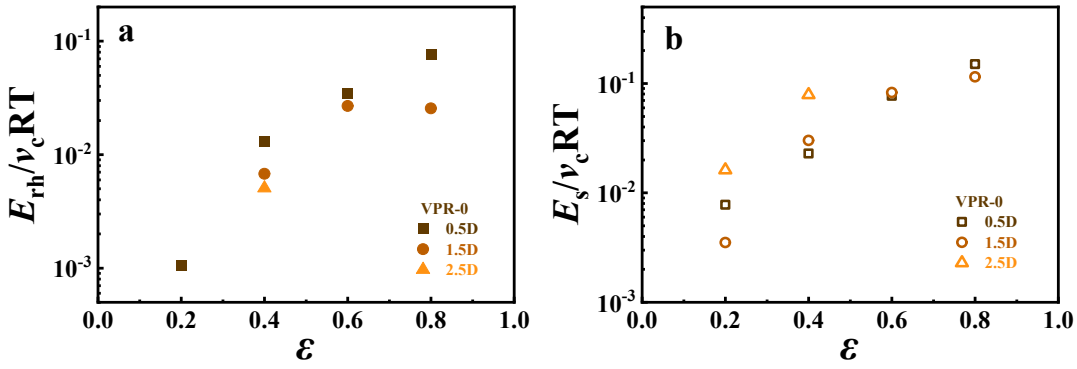

Fig. S7. Energy losses of recovery hysteresis (E_{rh}, a) and softening (E_s, b) as a function of prestrain.