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Mechanochromic Branched Polyethylenes Synthesized through Ring-opening Metathesis Terpolymerization

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Electronic Supplementary Information

Abstract Mechanochromic polyolefins represent a novel class of functionalized polyolefins, which still remains significant challenges. Pd(II)-catalyzed coordination-insertion copolymerization is a feasible method for achieving this kind of polymers, yet with linear microstructures. Ring-opening metathesis polymerization (ROMP) offers another promising avenue for affording functionalized polyolefins. This method exhibits high polar group tolerance and the ability to precisely regulate polymer branches. In this study, we report the method for producing mechanochromic branched polyethylenes *via* ROMP. By employing the terpolymerization of a well-designed monomer containing the mechanochromic group, **NB-ABF**, with cyclooctene (**COE**) and long-chain 5-hexylcyclooctene (**COE-C6**), following by hydrogenation process, we synthesized a range of functionalized branched polyethylenes characterized by varied branching density and polar monomer incorporation. These polymers bear a structural resemblance to functionalized ethylene-octene copolymers. After crosslinking, mechanochromophores are generated, and mechanochromism is achieved in uniaxial tensile testing. A comprehensive assessment reveals that both the incorporation of polar monomers and variations in branching density significantly influence their mechanical properties. Notably, upon stretching, these materials display pronounced visible color change, confirming the successful development of mechanochromic branched polyethylenes.

Keywords Ring-opening metathesis polymerization; Polyolefin; Functionalized branched polyethylene; Mechanochromism

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INTRODUCTION

Mechanochromic polymers, which can translate mechanical events into quantifiable visualized color changes, have garnered increasing interests.[1–7] This unique property holds substantial research potential in the fields of sensing, flaw detection, and inspection.[8] In this context, mechanochromic polymers are currently undergoing rapid development, ranging from commonly utilized functional materials, such as poly(methyl acrylate),[9] poly(methyl methacrylate),[10] and polyurethanesubstrates,[11] to polyolefins.[12–14] Given the widespread application and large-scale production of polyolefins, the preparation of mechanochromic polyolefins presents a highly attractive prospect; however, there are still numerous synthetic challenges to overcome.

To fabricate mechanochromic polyolefins, blending aggregachromic dyes with polyolefins is a technically accessible and historically significant way of imparting mechanochromism to these polymeric materials.[15,16] Another reliable method involves covalently linking mechanochromophores to polymers by introducing mechanochromophores into the polymer backbone or establishing a polymer network through crosslinking.[5] An essential prerequisite of this method is the preparation of functionalized polymers containing mechanochromophores. Owing to the challenging incorporation of mechanochromophores and the compatibility between the polar mechanochromophore and the highly nonpolar polyethylene backbone,[14] only a handful of instances have successfully facilitated the production of mechanochromic polyolefins upon free radical reaction[12] and direct coordination-insertion copolymerization.[13–14] In the latter method, phosphine-sulfonate palladium catalysts are used, which generate linear functionalized polyethylenes. However, the lack of controlled branches in polymers limits the expansion of mechanochromic polyolefins. Therefore, it is essential to devise a method characterized by controllability over the branching density, which eventually provides mechanochromic branched polyethylenes.

Rapidly developed metathesis polymerization techniques offer a promising approach for synthesizing functionalized polyolefins with good controllability, which can satisfactorily fulfill the requirements. Through ring-opening metathesis polymerization (ROMP) and acyclic diene metathesis (ADMET)

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polymerization, followed by hydrogenation, polymers have microstructures similar to those of polyolefins afforded by coordination-insertion copolymerization.[17–20] Notably, typical Grubbs catalysts used in ROMP demonstrate great tolerance to polar groups,[21] enabling the incorporation of diverse functional groups into the polyolefin backbone. Another significant advantage of ROMP is its ability to precisely tune parameters, such as molecular weight, polar group incorporation, and branching length and number. This greatly enhances the ability to design tailored polyolefins, especially functionalized branched polyethylenes.

In this study, we developed a norbornene-based monomer **NB-ABF** derived from the dibenzofuranone system (Fig. 1) and presented a three-step strategy for the synthesis of mechanochromic branched polyethylenes. Based on **NB-ABF**, cyclooctene (**COE**) was used to generate polyethylene segments, and 5-hexylcyclooct-1-ene (**COE-C6)** with hexyl side chains was selected for ring-opening metathesis tercopolymerization. With further hydrogenation, a polymer microstructure akin to a functionalized ethylene-octene copolymer was achieved. The third step of crosslinking produced mechanochromic branched polyethylenes with varied polar incorporation and branching degrees. The visible color-changing properties of these polymers under force were observed and analyzed, revealing the relationship between stress and strain and color change.

EXPERIMENTAL

All the experimental details involved can be found in the electronic supplementary information (ESI).

RESULTS AND DISCUSSION

Design of the Comonomer Containing the Mechanochromophore for ROMP

The norbornene (NB) unit with suitable ring tension is an ideal candidate for ROMP because it is easily accessible and modifiable. Thus, a NB-derived comonomer **NB-ABF** based on our previously reported cross-linkable unit[14] was designed and synthesized using an improved procedure according to a previous study.[22] The structure of **NB-ABF** was comprehensively elucidated by 1D and 2D-NMR characterizations (Figs. S1–S4 in ESI). A mixture of *endo*-(78%) and *exo*-(22%) products (see ESI for details) was collected and used directly. Vinylic resonances of norbornene are clearly observed at δ = 6.12 and 5.92 ppm, and 137.15 and 132.45 ppm in ^{1}H and ^{13}C-NMR spectra, respectively (Fig. 2). The resonance at δ = 4.79 ppm (^{13}C: 49.06 ppm) is attributed to the key reactive site in the mechanochromophore for subsequent crosslinking.

Synthesis and Characterization of Functionalized Branched Polyethylene (FBPEs)

The ROMP process provides infinite possibilities for polymer designs. In this study, we used three distinct monomers to prepare FBPEs. Specifically, **COE** was utilized to generate a polyethylene backbone, while **COE-C6** was incorporated to introduce a branched structure, emulating the structure of ethylene-octene copolymers, which could bestow the material with elastomeric properties. **NB-ABF** imparts both polarity and crosslinking sites, and acts as a precursor for mechanochromophores. The copolymerization of **NB-ABF** and **COE** is indeed feasible but results in linear microstructures that are devoid of branching (see Table S3 in ESI for details). The properties of semicrystalline mechanochromic polyethylenes have been thoroughly explored.[14] Consequently, this study predominantly focused on terpolymerization to obtain branched polymers. Note that in order to achieve a polymer structure akin to branched polyethylenes, it is imperative to hydrogenate the polymers obtained *via* ROMP. By altering the feed ratio of these three components, we readily produced a variety of FBPEs characterized by varied branches and polar incorporations (Table 1). The incorporation of the functional group **NB-ABF** and branching density were determined by-NMR spectroscopy.

The initial attempt utilized a low concentration of **NB-ABF** (2%) with a moderate **COE-C6** feed ratio of 35% (Table 1, entry 1). This yields a terpolymer exhibiting a polar incorporation of 0.2 mol% and a branching density of 28.0/1000C. By maintaining **COE-C6** feed ratio and elevating the **NB-ABF** feed ratio, the branching density remains similar (Table 1, entries 2, 3 versus 1, 26.0, 32.6 versus 28.0/1000C), while the polar incorporation rises from 0.2 mol% to 0.4 mol% to 1.1 mol%. With a moderate **NB-ABF** feed ratio, varying the **COE-C6** feed ratio influenced the branching density. When elevating the **COE-C6** feed ratio (Table 1, entry 4 versus entry 2), **FBPE-4** shows a higher branching degree compared to **FBPE-2** (45.5/1000C versus 26.0/1000C), while the polar incorporation remains similar (0.6 mol% versus 0.4 mol%). With the **COE-C6** feed ratio lowering (Table 1, entry 5 versus entry 2), a reduction on the branching density in **FBPE-5** (14.1/1000C

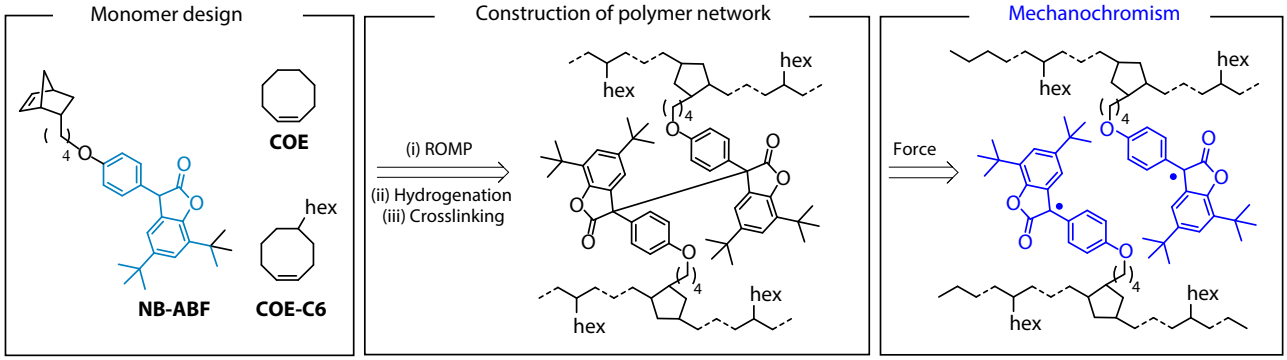

Fig. 1 Synthesis of mechanochromic branched polyethylene.

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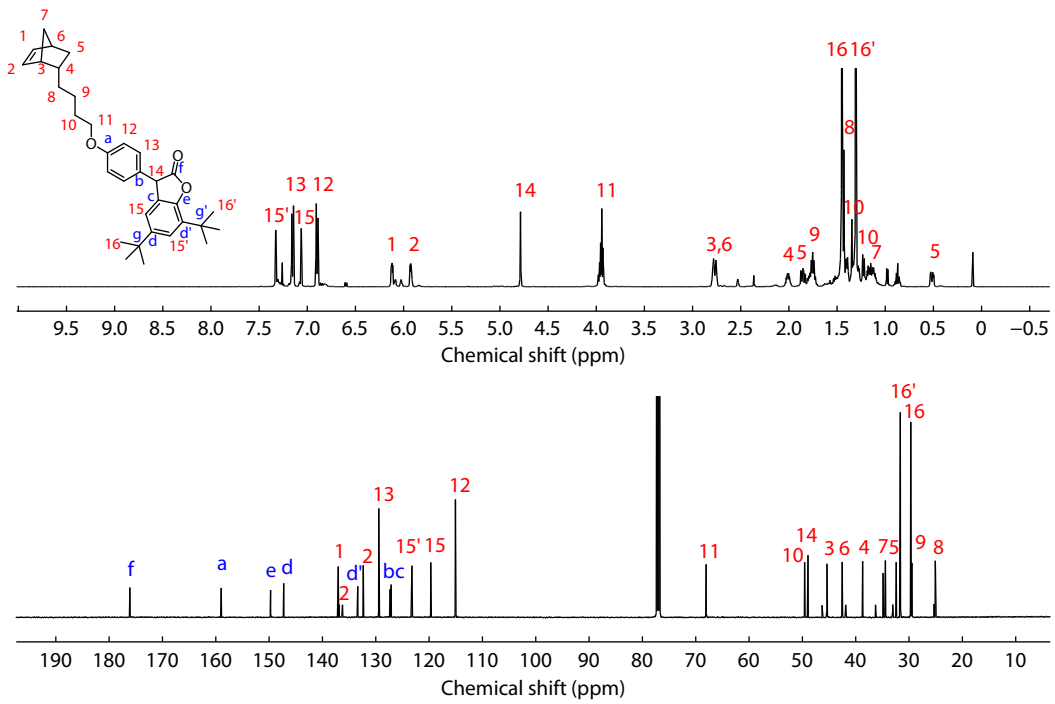
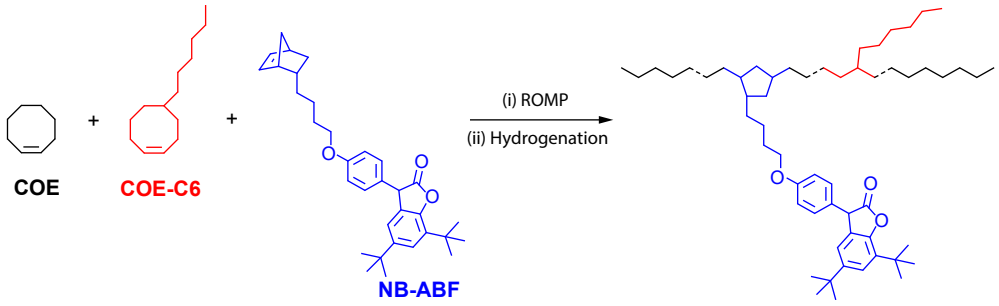


Fig. 2 ^{1}H- and ^{13}C-NMR spectra of **NB-ABF** in $CDCl_3$.

Table 1 Synthesis of FBPEs by ROMP/hydrogenation of **NB-ABF**, **COE** and **COE-C6**. [a]



Entry	$N_{NB\text{-}ABF}$ (mmol)	N_{COE} (mmol)	N_{C6} (mmol)	$M_{NB\text{-}ABF}$ [b] (%)	M_{COE} [b] (%)	M_{C6} [b] (%)	N_M [c]/HGII	Yield (g)	Brs [d]	X_F [e] (mol%)	M_n [f] (10^4)	M_w [f] (10^4)	M_w/M_n [f]	Sample
1	0.2	7.6	4.3	2	63	35	1549	1.01	28.0	0.2	2.4	4.2	1.7	**FBPE-1**
2	0.5	7.6	4.3	4	61	35	1991	1.21	26.0	0.4	3.1	6.4	2.1	**FBPE-2**
3	0.9	7.6	4.3	7	58	35	2015	1.26	32.6	1.1	2.4	4.6	1.9	**FBPE-3**
4	0.5	3.8	6.5	4	36	60	2050	1.01	45.5	0.6	1.9	2.9	1.5	**FBPE-4**
5	0.9	16.3	4.3	4	76	20	2549	1.61	14.1	0.7	3.1	5.5	1.7	**FBPE-5**
6	1.9	16.3	5.5	8	69	23	3021	2.29	23.2	1.4	2.4	6.0	2.5	**FBPE-6**
7	1.4	11.5	2.2	9	77	14	1927	1.46	16.0	2.1	3.1	5.4	1.7	**FBPE-7**

[a] Reaction conditions: Hoveyda-Grubbs II catalyst, toluene 40 mL in entries 1–4, 60 mL in entries 5–7, 25 °C, 2 h. [b] Feed ratio of the comonomers. $M_{NB\text{-}ABF} = N_{NB\text{-}ABF}/(N_{NB\text{-}ABF} + N_{COE} + N_{C6})$, $M_{COE} = N_{COE}/(N_{NB\text{-}ABF} + N_{COE} + N_{C6})$, and $M_{C6} = N_{C6}/(N_{NB\text{-}ABF} + N_{COE} + N_{C6})$. [c] $N_M = N_{NB\text{-}ABF} + N_{COE} + N_{C6}$, N_M/HGII = molar ratio of total monomers to Hoveyda-Grubbs II catalyst. [d] Brs/1000C = branching number after hydrogenation. Determined by ^{1}H-NMR spectroscopy. [e] X_F = Incorporation of NB-ABF functional monomer after hydrogenation calculated as the ethylene unit. Determined by ^{1}H-NMR spectroscopy. [f] Determined by GPC in 1,2,4-trichlorobenzene at 150 °C against a linear polystyrene standard.

versus 26.0/1000C) is observed, while the polar monomer incorporation still remains in a similar level (0.7 mol% versus 0.4 mol%). These results suggest that alterations in the polar monomer incorporation and branching density can be effectively modulated by adjusting the corresponding monomer feed ratios with minimal mutual interference. This highlights the distinct advantage of ROMP in terms of polymer customizability and affords significant convenience in regulating the polar incorporation and branching density of terpolymers. After obtaining the desired terpolymers at low and medium polar concentrations with different branches, the subsequent polymerization process focused on employing different branching densities at higher polar group concentrations. Among these terpolymers with high polar incorporations, **FBPE-6** is characterized by a higher **NB-ABF** incorporation of 1.4%, compared to the **NB-ABF** incorporation of 0.4%

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in **FBPE-2** containing similar branching degree (23.2/1000C versus 26.0/1000C). In **FBPE-7**, the branching density further decreased to 16.0/1000C and the polar incorporation was enhanced to 2.1 mol%, compared to those of **FBPE-6**.

Hydrogenation is required to obtain these FBPEs. Nevertheless, hydrogenation is usually accompanied by side reactions, which may damage the mechanochromic ABF groups. Consequently, meticulous control over the hydrogenation conditions, including temperature and duration, is paramount. We selected *p*-toluenesulfonylhydrazide in toluene with tripropylamine for hydrogenation of the obtained polymers. To ascertain the optimal conditions, a series of preliminary experiments was conducted (Table S1 in ESI). It is discerned that the hydrogenation conditions must be tailored based on the degree of polymer branching. This adjustment ensures comprehensive hydrogenation, preservation of the ABF groups, and avoidance of gel formation. Specifically, the less branched **FBPE-1**, **FBPE-2**, and **FBPE-5** to **FBPE-7** were hydrogenated at 100 °C for 2 h, whereas the highly branched **FBPE-3** and **FBPE-4** required 4 h at the same temperature for complete hydrogenation. Following these refined conditions, we were able to produce FBPEs with intact structures of the ABF group responsible for the color-change experiments.

The investigation of mechanochromic polymers involves stretching experiments, thereby imposing specific demands on their mechanical properties, which are intimately linked to the polymer molecular weight. The ROMP process enables regulation of the molecular weight of polymers by control-

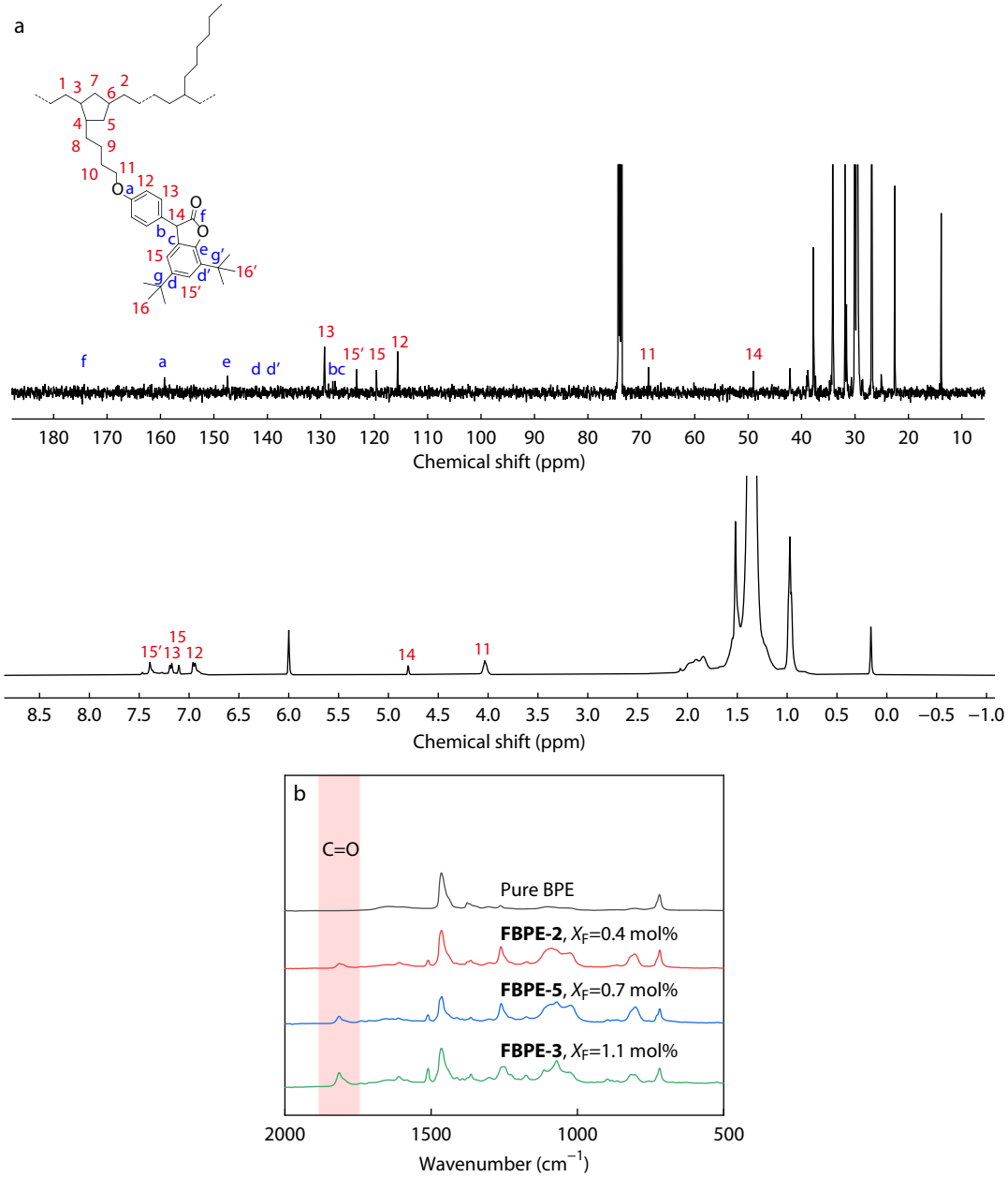

Fig. 3 (a) ^{13}C-NMR (top) and ^{1}H-NMR (down) spectra of **FBPE-3**, (b) IR spectra of the selected **FBPEs**.

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ling the monomer/catalyst ratio. Here, the ratio was carefully controlled, ranging from approximately 1500 to 3000. The molecular weights of the terpolymers were measured by high-temperature GPC, and all samples exhibited molecular weights in the range of 29–64 kg·mol^{-1}. This provides a solid foundation for our subsequent study into their mechanical properties, as well as mechanochromic properties.

The structures of the FBPEs were further characterized using-NMR and IR spectroscopy. Signals of crosslinking sites in functional ABF group are observed at δ = 4.79 and 49.01 ppm in ^{1}H and ^{13}C-NMR spectra, respectively (Fig. 3a). The resonance appearing at 175.49 ppm in ^{13}C-NMR spectrum is assigned to the carbonyl C=O group originating from the internal ester of the ABF segment. The structure of ABF was also confirmed by IR spectroscopy, in which a representative C=O stretching resonance frequency appeared at 1816 cm^{-1} (Fig. 3b). From pure branched polyethylene (BPE) to FBPEs with increased incorporations, the intensities of the C=O stretching resonance increased correspondingly. This indicates that the entire benzofuran structure of **NB-ABF** is retained in the FBPEs, which allows us to perform further crosslinking to produce mechanochromophores.

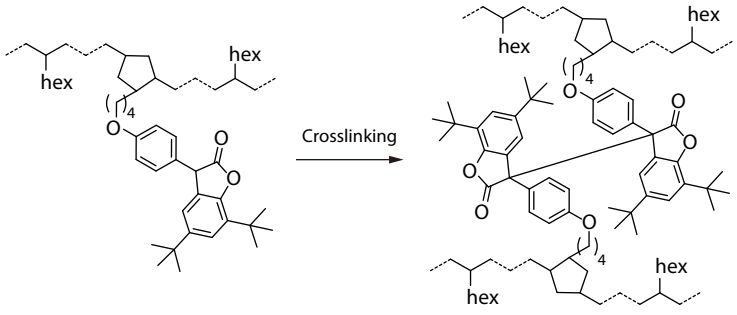
Synthesis and Thermal Properties of Mechanochromic Branched Polyethylenes (MBPEs)

The oxidant crosslinking process is performed by heating FBPEs with benzoyl peroxide (BPO), in which the H atom is abstracted by BPO upon heating to generate the ABF radical, and then two ABF radicals combine to form DABBF as the mechanochromic group (Fig. S42 in ESI). The regulation of crosslinking is achieved through the precise control of the following key parameters: heating temperature and duration, solvent concentration, and oxidant dosage.[23] After crosslinking, mechanochromophores are formed to produce mechanochromic branched polyethylenes (MBPEs). The gel fractions of the samples are listed in Table S2 (in ESI). The thermal properties of the samples before and after crosslinking were analyzed using differential scanning calorimetry (DSC) (Table 2). Typically, the remaining polyethylene chains in ethylene-octene copolymers retain a certain degree of crystallinity. In this study, distinct melting peaks in the second heating curve were observed in all samples, except for **FBPE-4,** which had the highest branching content. The lack of crystalline area in **FBPE-4** could lead to a significant decrease in strength; thus, this sample was not investigated for further mechanical and mechanochromic experiments. **FBPE-5** with medium incorporation and the lowest branching density, had the highest crystallinity of 21.3%, while those of the other samples ranged from 6.9% to 13.9%. Generally, samples with less branching and fewer monomer incorporations exhibit higher crystallinity and melting points. After crosslinking, crystallinities show slightly decrease, which aligns with former study.[24,25]

Mechanochromism and Mechanical Properties of MBPEs

After crosslinking, the selected samples were hot-pressed into dogbone-shaped specimens, and their mechanochromism and mechanical properties were further investigated *via* uniaxial stretching tests. Taking **MBPE-3** as a representative example, optical information was collected during stretching, as shown in Fig. 4(a). The original color of **MBPE-3** before the tensile test was slightly yellow, which was due to the original color of the dimer structure. At the beginning of elongation, the original color was diluted. After a certain amount of elongation to nearly 400% strain, the color began to change to blue, as anticipated. The visualized color change responsive to stress indicates that the force is conducted and the cleavage of the DABBF segment into the ABF radical species occurs, thus achieving mechanochromism. By simply mixing **NB-ABF** or **NB-DABBF** with

Table 2 Thermal Analysis of **FBPEs** and **MBPEs**.



FBPEs **MBPEs**

Entry	Brs [a]	X_M [a] (mol%)	T_{m1} [b] (°C)	X_{c1} [c] (%)	T_{m2} [b] (°C)	X_{c2} [c] (%)
			FBPEs		**MBPEs**	
1	28.0	0.2	79.4	13.9	80.5	9.4
2	26.0	0.4	67.5	6.9	74.5	5.2
3	32.6	1.1	68.9	10.2	69.9	8.8
4	45.5	0.6	n.d.	n.d.	–[d]	–[d]
5	14.1	0.7	97.6	21.3	99.1	18.6
6	23.2	1.4	81.1	10.5	81.7	6.6
7	16.0	2.1	78.7	12.6	80.5	9.0

[a] Determined by ^{1}H-NMR spectroscopy. [b] Determined by DSC (second heating). [c] Crystallinity calculated by $X_c = \Delta H/\Delta H_0$, ΔH_0 = 293 J·g^{-1}. [d] Not investigated.

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branched polyethylene, no color change was observed under force stimulation (Fig. S43 in ESI), demonstrating that mechanochromism is indeed caused by the incorporation of mechanochromophores into the polyethylene backbone. To verify the generation of the radical species, electron paramagnetic resonance (EPR) measurements of the fractured **MBPE-3** were performed (Fig. 4b). A distinct signal originating from the ABF radical was observed, which was corroborated by previous reports.[26,27]

The mechanical properties of the MBPEs were investigated by uniaxial stretching tests (Fig. 4c). Our findings indicate that both the incorporation of polar groups and number of branches significantly influence the mechanical properties of these materials. We categorized the MBPEs into two groups: **MBPE-1** to **MBPE-3**, featuring medium branches (Fig. 4d), and **MBPE-5** to **MBPE-7**, distinguished by low branches (Fig. 4e). In the medium branching group, although with the increase in the ABF incorporation from 0.2 mol% to 1.1 mol%, the samples show nearly constant tensile strength of around 15 MPa. The strain at break of the samples was also maintained at a comparatively similar level of approximately 800%. However, the situation was markedly distinct in the low-branching group. These samples generally exhibited higher tensile strengths (over 21 MPa) than the medium-branching group. In particular, **MBPE-5**, with lower branches and a moderate polar group incorporation, demonstrated a superior tensile strength of 28 MPa and a strain at break of 700%. As the polar group incorporation is escalated to 1.4 mol% in **MBPE-6** and 2.1 mol% in **MBPE-7**, slight decrease in tensile strength are observed, while the strains at break precipitously decline from 700% to 200%. In our preceding study,[14] a similar phenomenon was observed. We propose that when the polar incorporation is low, the gel component constitutes only a minor portion of the polymer, and the polymer demonstrates lightly crosslinked characteristics.

The mechanical properties of these polymers are similar to those of their non-crosslinked polar polyethylene substrate, which is consistent with our experimental results for the stretching process. In contrast, when the polar incorporation is high, the contribution of the gel component to the mechanical properties becomes significant. Owing to the crosslinking, the polymer rapidly attains a high stress value at low strains during stretching. However, the non-uniform distribution of the gel and solvable components within the polymer could lead to stress concentration, resulting in a marked reduction in the strain at break. Thus, it is imperative to meticulously regulate polar incorporation. This ensures that the polymer exhibits slight crosslinking, which is advantageous for subsequent mechanochromic studies. Furthermore, the rapid decrease in strain-at-break is not solely dependent on polar monomer incorporation; branching also plays a pivotal role. All instances of a rapid decrease in strain-at-break were observed in the low-branching group. Comparing **MBPE-3** (1.1 mol% ABF, Brs = 32.6) and **MBPE-6** (1.4 mol% ABF%, Brs = 23.2) with similar polar incorporation, **MBPE-3** with higher branches exhibited ideal mechanical properties; however, **MBPE-6** displayed a markedly reduced strain at break. It can be postulated that at a similar polar group content level, polymers with higher branching may exhibit greater resistance to the decrease in strain-at-break.

RGB Analysis of the Mechanochromic Process

To quantitatively investigate the mechanochromic process during stretching, red-green-blue (RGB) color analysis was conducted, which is widely used as an extremely fast and low-cost tech-

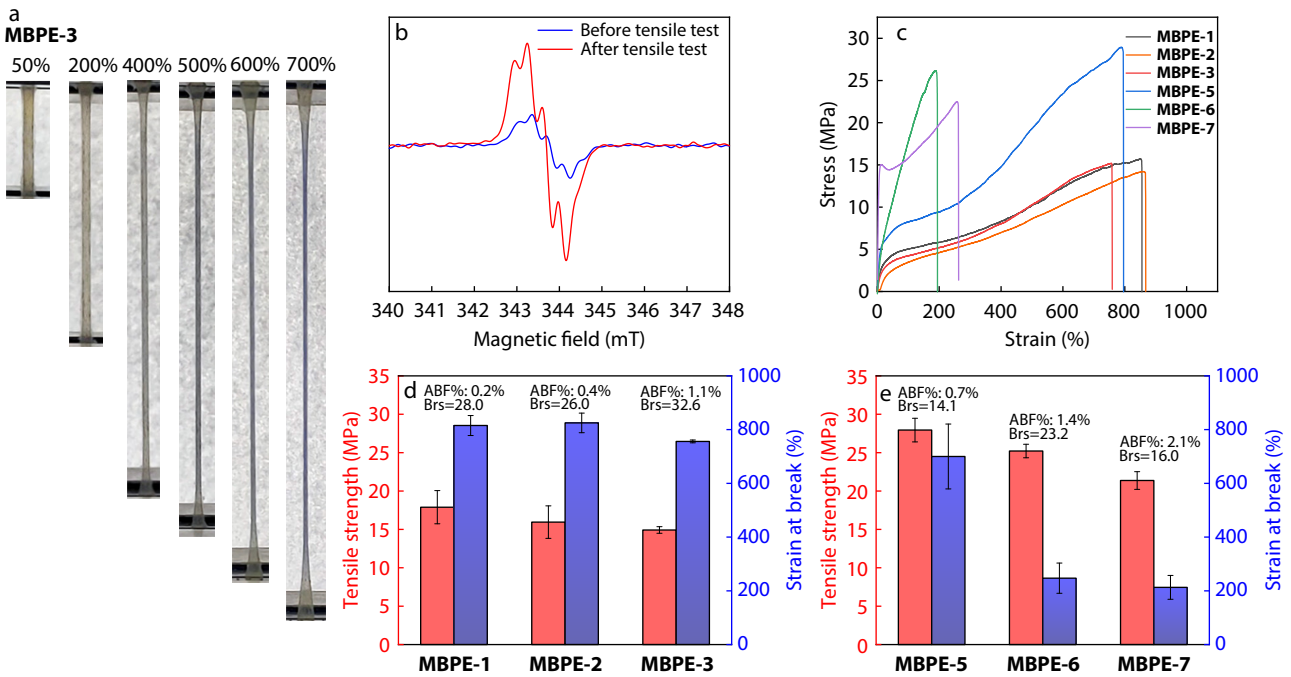

Fig. 4 (a) Optical images of stretched **MBPE-3** undergoing color changes; (b) EPR spectra of **MBPE-3** before and after a tensile test; (c) Stress-strain curves of the selected samples; (d) Mechanical properties of **MBPEs** with medium branches (**MBPE-1** to **MBPE-3**); (e) Mechanical properties of **MBPEs** with low branches (**MBPE-5** to **MBPE-7**).

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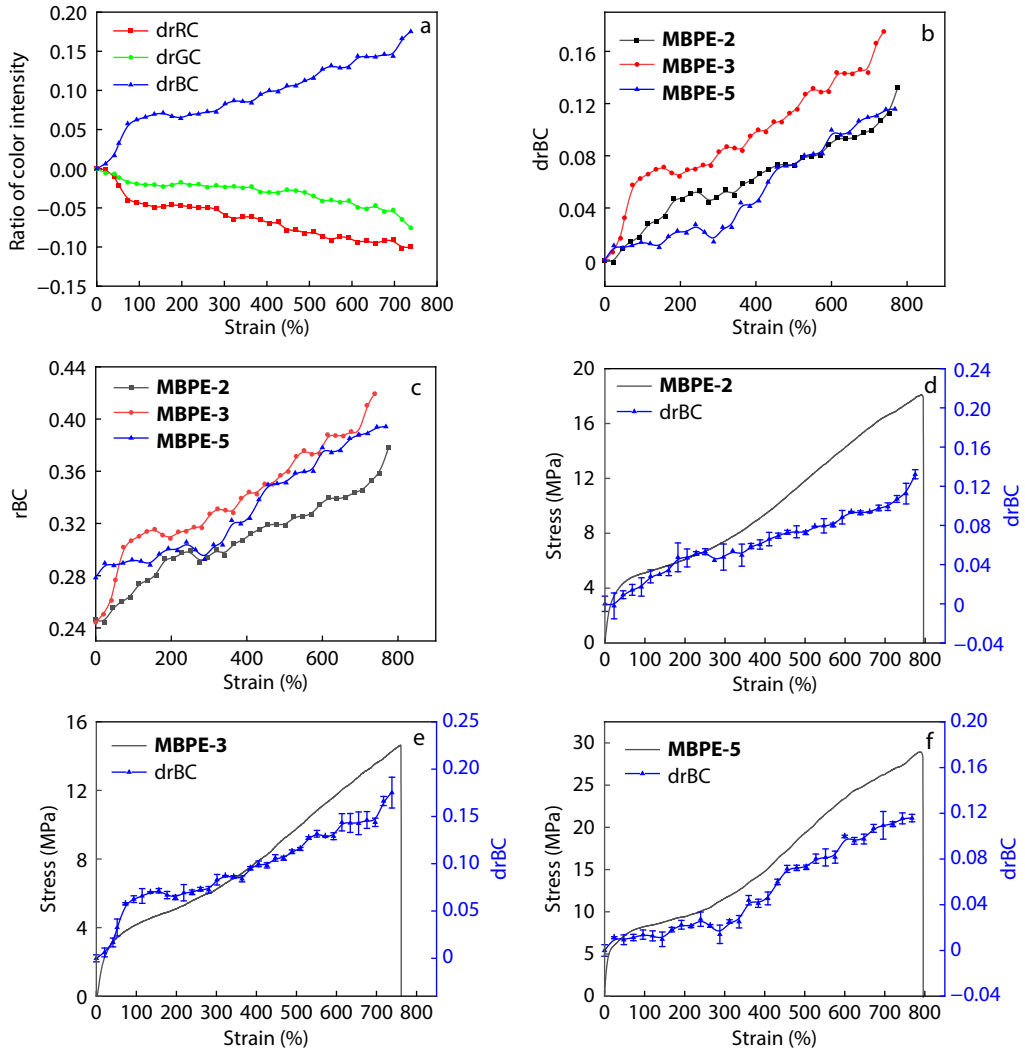

Fig. 5 (a) Color intensity changes in three channels (drRC, drGC, and drBC) as a function of strain for **MBPE-3**; (b) Intensity changes in the drBC channel as a function of strain for **MBPE-2**, **MBPE-3** and **MBPE-5**; (c) Intensity changes in the rBC channel as a function of strain for **MBPE-2**, **MBPE**-3 and **MBPE-5**; (d) Intensity changes in the drBC channel and stress as a function of strain for **MBPE-2**; (e) Intensity changes in the drBC channel and stress as a function of strain for **MBPE-3**; (f) Intensity changes in the drBC channel and stress as a function of strain for **MBPE-5**.

nique in the study of mechanochromism. Consistent with a prior study,[14] the polymer exhibited minimal or no color change when it behaved as crosslink-dominated in **MBPE-6** and **MBPE-7**, with only minor color alterations observed at the fracture site. **MBPE-1** with the least polar incorporation, can hardly form mechanochromophores, resulting in negligible color change during stretching. Thus, the primary focus of the color analysis was on the **MBPE-2**, **MBPE-3** and **MBPE-5**. The color intensity change of **MBPE-3** in the three-color channel is shown in Fig. 5(a). The blue (drBC, intensity change in blue) channel signal dominated throughout the elongation of the sample. Thus, the drBC signal channel was chosen for further quantitative color-change analysis during the uniaxial stretching process. The change in the drBC value of the three samples during elongation is shown in Fig. 5(b). During the early stage of stretching, when the strain was less than 200%, **MBPE-2** and **MBPE-3** showed rapid increases in drBC, whereas for **MBPE-5**, the change in drBC was not evident. This stage of color change is due to dilution of the original light-yellow color of the polymers.[12] Because **MBPE-5** with higher crystallinity is less yellow, less dilution effect occurs, leading to a nearly consistent drBC value. rBC (intensity in blue without subtracting the initial value, see the Supporting Information for more detail) signal change during the tensile test is shown in Fig. 5(c) to further elucidate this phenomenon. **MBPE-5** has a higher initial rBC value compared to other samples (0.28 s versus 0.24 s). After the stretching was diluted to nearly 200% strain, all three samples exhibited similar rBC values. With elongation, the color of the samples slowly changes to blue with an increase in drBC, in which the mechanochromophores in polymers are activated. Before failure, the drBC of this sample reached its maximum value. In addition, the mechanical properties and mechanochromism of the MBPEs and our previous MPEs were compared (Fig. S44 in ESI). The more pronounced mechanochromic properties of MPEs are probably due to the necking phenomenon and superior tensile strength caused by their semi-crystalline character.

For a deeper understanding of the color change in stretch-

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ing, drBC changes as a function of strain were further investigated in the stress-strain curve for these three samples (Figs. 5d–5f). Taking **MBPE-5** as an example, at 400% strain, the stress began to experience a rapid increase. At the same time, the color change of the sample experienced a synchronous leap, which contributed to the triggering of mechanochromophores. For **MBPE-2** and **MBPE-3**, similar situations were observed after nearly 400% strain, in which the stresses increased and drBC exhibited a nearly linear increase. A slight lip in the drBC immediately before the fraction was observed, which may be attributed to strength hardening, as previously reported.

CONCLUSIONS

In summary, we elaborately designed a norbornene-type comonomer, **NB-ABF** featuring the ABF mechanochromophore and incorporated it into branched polymers through ring-opening metathesis terpolymerization. Following a meticulous hydrogenation process, we synthesize a series of functionalized branched polyethylenes with varied polar incorporations and branching densities. By modulating the ratios of the three monomers, **NB-ABF**, **COE**, and **COE-C6**, it is possible to almost independently control both the polar incorporation and branching density in the resultant polymers. Notably, these terpolymers exhibit a branching structure highly analogous to that of ethylene-octene copolymers, and thus could be viewed as ethylene-octene copolymers with polar monomer insertion. The structures of the functionalized branched polyethylenes obtained were thoroughly characterized. With further crosslinking, mechanochromic-branched polyethylenes were obtained. The mechanical properties of these polymers were studied through tensile tests, in which the relationship between the mechanical properties with branches and polar incorporation was revealed. During the stretching process, the polymer exhibited significant color changes. This study demonstrates an effective approach to producing functionalized branched polyethylenes with mechanochromism.

Conflict of Interests

The authors declare no interest conflict.

Electronic Supplementary Information

Electronic supplementary information (ESI) is available free of charge in the online version of this article at http://doi.org/10.1007/s10118-025-3337-3.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The author's contact information: zbjian@ciac.ac.cn.

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