

Study on new EPDM molecular architecture

By Greg Li, Colin Li Pi Shan, Lena Nguyen, Juan Tuberquia, Sharon Wu, Ray Laakso, Tao Han, Rongjuan Cong, Dean Lee
Dow Chemical Co.

EPDM is the third largest volume synthetic rubber produced in the world¹ and is widely used in applications such as transportation, infrastructure, sports and leisure, and appliance.

Ethylene and propylene monomers are randomly polymerized into a chemically saturated, stable polymer backbone resulting in a polymer with excellent heat, oxidation, ozone and weather aging resistance. A third, non-conjugated diene monomer is copolymerized in a controlled manner to maintain a saturated backbone and provide the reactive unsaturation in a side chain available for chemical crosslinking as shown in **Fig. 1**.¹

There are several generations of catalysts operating in EPDM plants. Even though many of the existing EPDM plants still are using conventional vanadium

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Ziegler-Natta (Z-N) catalysts, an increasing number of new EPDM plants have converted to metallocene-type catalysts.²⁻⁴ The traditional vanadium Ziegler-Natta catalyst combined with diethylaluminum chloride cocatalyst is known to produce multiple active catalyst sites. Therefore the resulting products have a broad intermolecular compositional distribution and molecular weight distribution.⁴

The long chain branching structure was introduced to conventional vanadium Ziegler-Natta EPDM by coupling of chains across the enchain diene (via exocyclic double bond) through a cationic mechanism.⁴ Even though the broad molecular weight distribution and LCB are inherent in the production of conventional vanadium Ziegler-Natta EPDM, a careful control of polymerization condition is needed to avoid gel formation.⁴

There are many specific manufacturing challenges associated with EPDM manufacturers from conventional vanadium Ziegler-Natta catalyst systems that include low monomer conversion, significant catalyst deactivation, excessive reactor fouling and low production rate. Metallocene catalyst and advanced molecular catalyst technologies provides EPDM manufacturers tremendous competitive advantage compared to conventional Ziegler-Natta technology.

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Fig. 1: EPDM molecular structure.

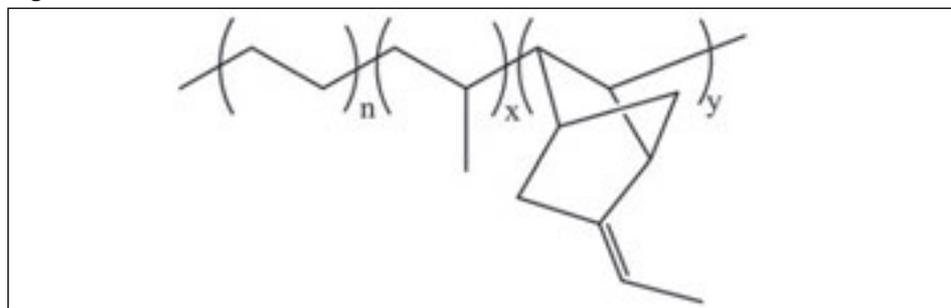


Table 1: Basic material specifications of EPDMs.

	Mooney Viscosity, MU (ML 1+4 @125°C)	Ethylene, wt%	ENB Level*	MWD***	Long Chain Branching	Catalyst
EPDM A	70	70	Medium	Medium	Medium	AMC
EPDM B	70	70	Medium	Broad	Low	AMC
EPDM C	70	70	Medium	Broad	High	Z-N

*ENB level – medium = 4-5 wt% ENB
 ***Molecular Weight Level – low = 100-150 kg/mol, medium = 150 – 200 kg/mol, high ≥ 200 kg/mol
 ***MWD Breadth – GPC Mw/Mn, narrow = 2 – 2.5, medium = 2.5-3, broad >3

Executive summary

There is an increasing need for new EPDM products that provide a balance of mixing/processability, improved mechanical properties and improved product consistency. Dow's new advanced molecular catalyst and polymerization process technology advancements enable the tailored design of EPDM molecular architecture, including composition distribution and molecular weight distribution.

The new EPDM polymers having a highly tailored architecture exhibited improved mixing/processability and improved mechanical properties. This report summarizes a newly designed Nordel-brand EPDM product and its potential applications. The EPDM polymer structure, compound formulation and mixing performance, compound rheology, vulcanization characteristics and mechanical property improvements are discussed.

AMC technology that drives increased flexibility in product and process design. AMC technologies are leading the next generation of architectural control, with breakthroughs in producing EPDM more efficiently with a better monomer incorporation, higher levels of diene, an extended range of molecular weight (high and low), broad molecular weight distribution and higher levels of homogeneous long chain branching.⁵

These tailor-designed molecular architectures ultimately enable EPDM customers the flexibility in their formulation design to achieve better EPDM compound processability and properties.

In this study, a comparison between two AMC catalyzed EPDMs and a Z-N catalyzed EPDM was conducted. The tailor-designed EPDM structure was carefully evaluated and its effects on EPDM compound processing and properties were investigated.

Materials and experiments

The characteristics of the EPDM rubbers used in this study are listed in **Table 1**. These EPDM materials were chosen to have various molecular architectures (i.e. average molecular weight and distribution, average composition and distribution) so that the effect of a tailor-designed EPDM molecular structure on compound processing characteristics and compound physical properties could be investigated thoroughly.

The other ingredients used in the formulation design are listed in **Table 2** and were used as received. These are commonly used ingredients for EPDM compounding.

EPDM polymer characterization methods

The EPDM characterization was carried on a high temperature Gel Permeation Chromatography system. The carrier sol-

vent was 1,2,4-trichlorobenzene (TCB). The GPC column set was calibrated by running narrow molecular weight distribution polystyrene standards and the molecular weights reported herein are in reference to polyethylene equivalents.

The average composition of the EPDM polymers was determined using infrared analysis. Modified versions of the standard test methods ASTM D 6047 and ASTM D 3900 were used for the infrared analysis of ENB, ethylene, and propylene content. The compositional distribution of the EPDM polymers was analyzed by HTLC.⁶

A gradient of decane and trichlorobenzene was used to elute polymer from a Hypercarb column (2.1 X 100 mm). The eluted polymer fractions were then directed to a PL-Rapide M column (10 X 100 mm) hyphenated with PD2040 light scattering detector and IR5 absorbance detector.

Melt rheology, constant temperature frequency sweeps, were measured using a TA Instruments Advanced Rheometric Expansion System equipped with 25 mm parallel plates geometry under a nitrogen purge. Frequency sweeps were performed at 190°C for all the samples at a gap of 2.0 mm and at a constant strain of 10 percent.

The frequency interval was 0.1 to 100 radians/seconds. The stress response was analyzed in terms of amplitude and phase, from which the storage modulus (G'), loss modulus (G'') and dynamic melt viscosity (η^*) were calculated.

A TA instruments Q1000 DSC, equipped with an refrigerated cooling system was

The author

Greg Li is a research scientist in Packaging & Specialty Plastics, a business unit of Dow Chemical Co. He is responsible for Nordel-brand EPDM product development, formulation, and application and processing developments.



Li

Li joined Dow in research and development in April 2011. Prior to that, he worked at Armacell L.L.C. as a research scientist and plant process chemist, where he developed elastomeric closed cell and open cell foams for the automotive industry.

He received a bachelor's of engineering from Tianjin University in Tianjin, China; a master's from the Institute of Chemistry Chinese Academy of Sciences in Beijing; and a doctorate from the University of Toronto.

Li performed post-doctoral research at Case Western Reserve University in Cleveland.

used to perform sample thermal property analysis. During testing, a nitrogen purge gas flow of 50 ml/min was used.

The thermal behavior of the sample was determined by predetermined heating and cooling of the sample temperature to create a heat flow versus temperature profile. First, the sample was rapidly heated to remove its thermal history. Next, the sample was cooled at 10°C/min cooling rate (1st cooling scan). The sample was then heated (2nd heating scan) at a 10°C/min heating rate. The first cooling and second heating curves were recorded.

Compound formulations and mixing procedures

The formulations for all the compounds in this study are listed in **Table 3**. There

Table 2: Basic information of other ingredients.

Ingredient	Chemical name	Function	Form
Cabot Sterling SO	N-550 Carbon Black	Filler	Powder
Sunpar 2280	Mixture of paraffinic mineral oil	Plasticizer	Liquid
Omya 2T-FL	Calcium carbonate	Inorganic filler	Powder
CARBOWAX™ PEG 3350	PEG	Activator/Process Aid	Powder
Desical P, 80%	CaO	Moisture Scavenger	Paste
Rubbermakers Sulfur (209)	Sulfur	Curative	Powder
Stearic Acid	Octadecanoic acid	Activator	Micro pellet
Zinc Oxide	Zinc oxide	Activator	Powder
CBS	sulfenamide	Accelerator	Powder
Rhenogran MBTS-75	MBTS	Accelerator	Pellet
Rhenogran MBT-80	MBT	Accelerator	Pellet
Rhenogran ZDMC-80	ZDMC	Accelerator	Pellet

Table 3: EPDM formulations.

ELAV	Compound-1	Compound-2	Compound-3	Compound-4	Compound-5	Compound-6
Total Phr	577.3	577.3	577.3	737.3	737.3	737.3
EPDM A	100.0			100.0		
EPDM B		100.0			100.0	
EPDM C			100.0			100.0
Sunpar 2280	150.0	150.0	150.0	200.0	200.0	200.0
Omya 2T-FL	150.0	150.0	150.0	200.0	200.0	200.0
Cabot Sterling SO	160.0	160.0	160.0	220.0	220.0	220.0
CARBOWAX™ PEG 3350	3.0	3.0	3.0	3.0	3.0	3.0
Desical P, 80%	2.0	2.0	2.0	2.0	2.0	2.0
Stearic Acid	1.0	1.0	1.0	1.0	1.0	1.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0
Rubbermakers Sulfur (209)	1.5	1.5	1.5	1.5	1.5	1.5
CBS	1.5	1.5	1.5	1.5	1.5	1.5
Rhenogran MBTS-75	1	1	1	1	1	1
Rhenogran MBT-80	0.5	0.5	0.5	0.5	0.5	0.5
Rhenogran ZDMC-80	1.8	1.8	1.8	1.8	1.8	1.8

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are two types of formulation with different level of filler loading. The medium filled formulation has total of 577.3 phr and the highly filled formulation has total of 737.3 phr. In each type of the formulations, the total phr was held constant while the EPDM rubber varied to study the effect of EPDM rubber molecular architecture on the compound mixing process.

A BR 1600 lab mixer from HF Mixing Group was used for the compounding step. A standard “upside down” one-pass mixing procedure (Table 4) was used to compound all the batches.

The carbon black, CaCO₃, PEG, stearic acid and zinc oxide were added first; followed by oil injection, and EPDM was added last in the mixer as shown in Table 4.

The batch weight was sized to have 75 percent fill factor. The rotor, mixer chamber and the drop door temperature was set at 40°C. The compound was dropped at 115°C. Then the compound was sheeted out with a two roll mill. During the mixing, the process parameters such as torque percentage, ram position, compound temperature etc. were recorded.

Uncured compound testing

Both EPDM neat polymers and compounds Mooney viscosities were measured using an Alpha Technology Mooney viscometer following ASTM D1646. The measurement conditions were 125°C (EPDM neat polymer) and 100°C (compounds) using large rotors at ML (1 + 4) conditions with a rotor speed of 0.2 rad/s.

Compound cure kinetic profiles at 180°C were measured using a rotorless cure rheometer (MDR—moving die rhe-

ometer, Alpha Technologies MDR 2000) as specified in standard test method ASTM D 5289. The test temperature was set at 180°C with a 0.5° arc. Maximum (S', MH) and minimum (S', ML) torque values were recorded for each sample. The time to reach 90 percent of maximum torque (t₉₀) was recorded and used for the curing of molded test plaques.

The green strength of the solid unvulcanized compounds were tested according to ASTM D6746.

Curing and vulcanizate testing

Plaque samples were cured on a hot press for t₉₀+5 minutes at 180°C for tensile and tear testing following ASTM D3182-15. Test specimens were cut from the cured plaques. Compression set button specimens were cured for t₉₀+12 minutes at 180°C. Cured specimens were conditioned for at least 18 hours before testing.

The Shore A hardness of solid vulcanizate was measured according to ASTM D2240.

The compression set was measured at three conditions (70 hours at 23°C, 70 hours at 70°C and 70 hours at 150°C) according to ASTM D 395 Method B.

The tensile properties of solid vulcanizate were acquired following ASTM D1708 by Use of Microtensile Specimens. Die-C tear strength of solid vulcanizate was obtained using ASTM D624.

Results and discussion

The properties of EPDM polymers are highly dependent on polymer molecular structure, i.e. average molecular weight, molecular weight distribution, long

chain branching, the average composition and composition distribution (inter-molecular chains or intra-molecular chain). These unique molecular structures can be manipulated and tailor-designed via catalyst and the polymerization processing technologies.

Dow's advanced molecular catalysts are leading the next generation of EPDM architectural control. These tailor-designed molecular architectures will enable customers to achieve better EPDM compound processability, process control consistency and superior compound physical properties.

The EPDM polymers used in this study and their molecular weight data are shown in Table 5 and Fig. 2. All three EPDM polymers have similar Mooney viscosity (ML 1+4 at 125°C=70).

EPDM C is a conventional Z-N type EPDM polymer with broad molecular weight distribution. Both EPDM A and EPDM B are AMC type EPDM with very distinct difference in average molecular weight and molecular weight distribution.

With the new AMC technology, the EPDM polymer molecular weight and molecular weight distribution can be precisely designed and controlled to achieve narrow or broad distribution.

It is illustrated in Fig. 2 that the molecular weight distribution of EPDM B is even broader than conventional Z-N type EPDM polymer (EPDM C) and exhibit a bimodal molecular weight distribution. The effect of this unique polymer structure on EPDM processing and properties will be discussed in the next sections.

The melt shear viscosity of EPDM A, B and C were measured and shown in Fig. 3. It is proven that the same Mooney viscosity of EPDM neat polymer can be achieved by carefully controlling molecular weight, molecular weight distribution and long chain branching.

At a given target EPDM neat polymer Mooney viscosity (70 MU), AMC type of EPDM (EPDM B) has a much higher average molecular weight (M_w=217k g/

mol) than the conventional Z-N type EPDM (EPDM C).

Besides the polymer average molecular weight and molecular weight distribution, the long chain branching structure affects the polymer rheological properties as well. Even with the same Mooney viscosity, both EPDM A and EPDM B exhibited less shear thinning behavior than EPDM C.

The melt elasticity (represented by Tan Δ) at low shear rate for both EPDM A and EPDM B is lower than EPDM C. It is believed the AMC type EPDM (EPDM A and EPDM B) has less long chain branching than conventional Z-N EPDM. This new technology will help to balance the EPDM polymer processing and physical properties.

The average composition and composition distribution (inter-molecular chains or intra-molecular chain) also affect EPDM processing and properties. Typically, the higher ethylene content or longer ethylene sequence length increase the total crystallinity of EPDM, therefore require higher melting temperature during mixing and impart higher green strength to the compound.

The AMC technology enables precise control of the average composition and intermolecular compositional distribution can be achieved. The average composition and intermolecular compositional distribution of EPDM A, B, and C are listed in Table 6 and Fig. 4.

From the average composition perspective, all these three EPDM polymers are very similar (Table 6). EPDM A, B, and C are all semicrystalline (~70 wt percent ethylene), medium ENB (~5 wt percent), and 70 Mooney EPDM material.

However, the subtle polymer microstructure among these EPDM materials are different. For example, EPDM C (conventional Z-N type polymer) had an extremely broad ethylene compositional distribution but the main composition peak (elution volume between 3.5 ml and 4.0 ml in HTLC separation) is very similar to that of EPDM A (AMC type) that has a narrow

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Table 4: Upside down one pass mixing procedure.

Step	Logic	Action	Rotor RPM
1		Ram up/ Open Door	50
2		Charge CB/Whiting/small Chemical	50
		Charge Oil	50
		Manual Charge EPDM	50
3		close door/lower Ram	50
4	Temp>85 C	Ram up/Open Charge Door/Add Curatives	50
5		close door/lower Ram	50
6	Temp>105 C	Isothermal for 2 minutes	Variable
7	Temp=115 C	Ram up/ Dump	50

Fig. 2: Molecular weight and molecular weight distribution of EPDM A, B, and C.

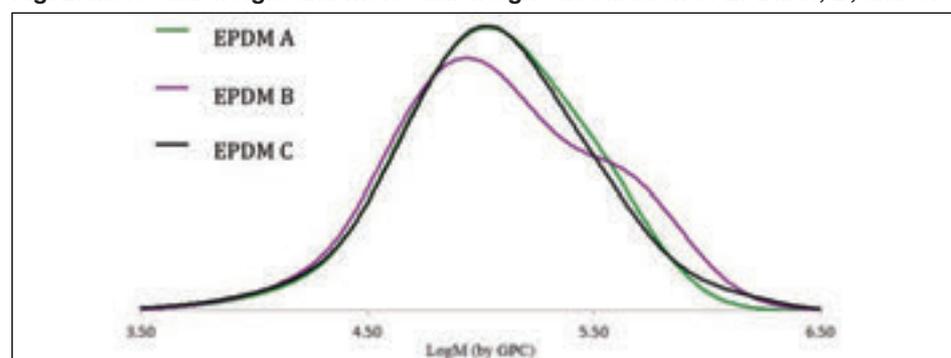


Table 5: Average molecular weight and distribution of EPDM A, B, and C.

Identification	M _n (g/mol)	M _w (g/mol)	M _w /M _n
EPDM A	68k	176k	2.6
EPDM B	66k	217k	3.3
EPDM C	64k	193k	3.1

Fig. 3: Rheological properties of EPDM A, EPDM B, and EPDM C at 190°C.

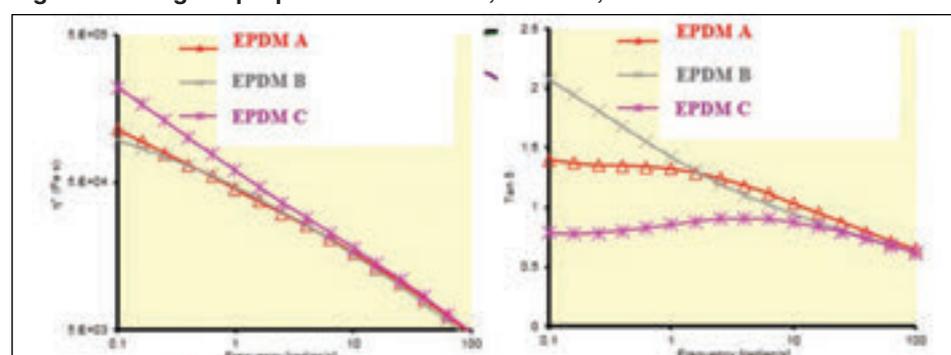


Table 6: The average chemical composition of EPDM by IR.

Polymer	Ethylene Content (wt%)	Propylene Content (wt%)	ENB Content (wt%)
EPDM A	71.0	24.1	4.9
EPDM B	70.0	24.7	5.3
EPDM C	72.2	22.6	5.2

Fig. 4: Chemical compositional distribution by HTLC.

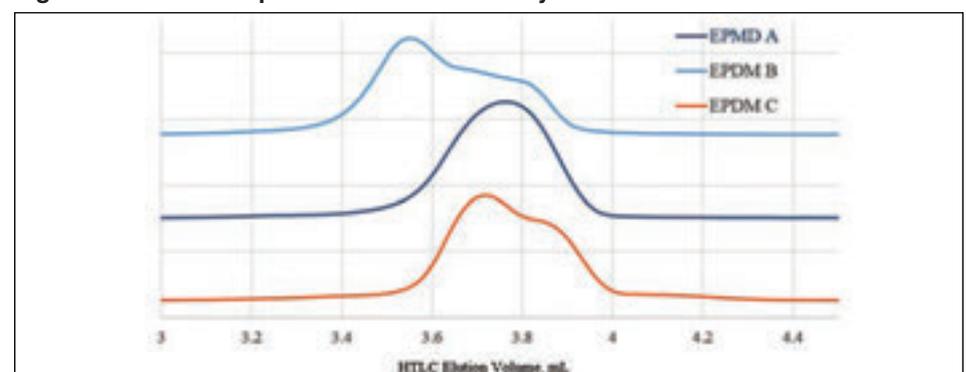


Table 7: Compositional distribution by HTLC.

	V _p (peak volume) mL	Average Propylene Content wt%	Average M _w (kg/mol)
EPDM A	3.76	29.8	162
EPDM B	3.55	31.9	193
EPDM C	3.73	30.5	176

Table 8: Thermal properties of EPDM.

	2nd heat			1st cool	
	T _g (°C)	T _m (°C)	Heat of Fusion (J/g)	T _c (°C)	Delta H cryst. (J/g)
EPDM A	-40.9	42.8	41.0	28.7	44.8
EPDM B	-43.1	34.3	37.1	17.9	40.2
EPDM C	-42.3	34.4	31.0	19.3	43.0

EPDM

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ethylene compositional distribution.

EPDM B (AMC type) structure was tailor-designed to have a much broader ethylene compositional distribution than EPDM A (AMC type). In addition, it was believed that the optimum distribution of ENB in polymer chain could be achieved with AMC technology, therefore high efficiency of crosslinking could be obtained for AMC EPDMs.

Because of this microstructure difference, their compound processing and physical properties may vary. The EPDM product manufacturers would observe difference in EPDM compound mixing, extrusion, curing and final physical properties. Those processing and property difference will be discussed in the next sections.

The composition structure of EPDM polymer affects the solid state properties profoundly, especially the thermal property. The thermal properties of EPDM A, B, and C were studied and shown in **Table 8** and **Fig. 5**. It was observed even though EPDM A and EPDM C are very similar in terms of average composition (ethylene, propylene and ENB content), the melting temperature and total crystallinity of EPDM C was lower than EPDM A.

It is believed the AMC type EPDM polymers with narrow intermolecular compositional distribution (i.e. EPDM A) tend to have a longer ethylene sequence length than Z-N type EPDM (i.e. EPDM C), therefore EPDM A exhibited a higher melting temperature and total crystallinity than EPDM C.

However with the AMC technology, the microstructure of EPDM can be tailored to achieve the desired properties. In this particular case, via the tailored-design of

the microstructure, EPDM B (i.e. AMC type of EPDM with broader compositional distribution) exhibited a very similar thermal properties as the Z-N type of EPDM (EPDM C). The T_g, T_m, and total crystallinity (Heat of Fusion) of EPDM B is the same as EPDM C.

Compound mixing behavior

The EPDM molecular structure effect on compound mixing process was studied and discussed in previous works.^{7,8} As discussed previously, due to the microstructure difference, EPDM compound processing and physical properties may vary. Low molecular weight EPDM can enhance the wetting and incorporation process during mixing.

The high ethylene content and high crystallinity EPDM rubber slowed down the filler and oil incorporation process.⁷ In this study, all three EPDM materials were mixed with the same formulation and same mixing procedures illustrated earlier. The actual mixing curves for these compounds (Compound 1-3) are listed in **Fig. 6**.

Depending on the EPDM polymer structure, the mixing behavior varied. Compound 3 with EPDM C showed a faster filler/oil incorporation rate and faster heat building up than Compound 1 with EPDM A.

It is believed that the lower total crystallinity of EPDM C enabled a faster filler/oil incorporation step and also the long chain branching structure of EPDM C imparted higher compound viscosity. Therefore a higher energy output from the rotor (high Kw) and faster compound temperature rise were achieved in Compound 3 mixing.

It took only 90 seconds for Compound 3 to reach 85°C while it took 120 seconds for Compound 1 to reach the same temperature. With the tailor-designed structure, the overall total crystallinity for EPDM B

was lowered, therefore the mixing behavior of Compound 2 was improved.

The filler/oil incorporation step was shortened for Compound 2. It took around 100 seconds for the compound 2 to reach 85°C. Also the mixing energy output for Compound 2 was higher than Compound 1.

Both green compounds and cured compounds were carefully analyzed to study the effects of EPDM molecular architecture on the processing performance and physical properties.

The compound viscosity and curing characteristics are shown in **Table 9**. All compounds have very similar Mooney viscosity due to the similar gum EPDM rubber Mooney viscosity. However, both AMC type EPDM compounds showed faster curing rate (Ts2) and higher state of cure (MH-ML) than conventional Z-N type EPDM compound (Compound 2 and Compound 5).

The uniform composition distribution and optimum distribution of the ENB along the molecular chains contributes to the excellent curing characteristics of the AMC type EPDMs. This unique feature resulted in excellent physical properties of cured compounds.⁹

The compound green strength is another critical physical property for the development of EPDM compound. The green strength of the solid unvulcanized compounds was measured following ASTM D6746 and shown in **Table 10**.

The cold compound green strength is highly dependent on the EPDM polymer ethylene content or total crystallinity. Since EPDM A has higher melting temperature and higher total crystallinity, both Compound 1 and Compound 4 exhibited higher modulus and higher tensile strength than Compound 3 and Compound 6.

With the tailored design of molecular structure, the total crystallinity of AMC EPDM (EPDM B) was lowered to match conventional Z-N EPDM (EPDM C), therefore the compound green strength of compounds made of AMC type EPDM B was very similar to that of compounds made of conventional Z-N EPDM C.

The physical properties of vulcanized compounds are dependent on EPDM molecular structure, formulations, curing properties etc. The physical properties of these compounds were measured and shown in **Table 11**.

For AMC type EPDM A, higher tensile strength and lower compression set at high temperature (70°C and 150°C) were observed due to the uniform composition distribution and high efficiency of crosslinking from ENB incorporation and distribution. However the room temperature Shore A hardness was higher and the compression set at 23°C was higher for Compound 1 and Compound 4.

It is believed the longer ethylene sequence length caused the higher crystallinity that contributed to the hardness

and compression set properties. With the tailor design molecular structure (higher molecular weight, broad ethylene composition distribution, optimum ENB incorporation and distribution), a balanced physical properties were obtained for Compound 2 and Compound 5.

A low compression set at all temperatures, low hardness, and high tensile properties were achieved. It was once again demonstrated that the AMC technology showed the flexibility to tailor design the EPDM molecular microstructure and therefore affect the final physical properties of the vulcanizates that are of great value to EPDM customers.

Conclusions

The technology based on Dow's advanced molecular catalysts enables enhanced EPDM product design capability. The AMC technology not only increased flexibility in product and process design, it also enabled fine EPDM molecular architectural control.

Optimized structure design, (i.e. high molecular weight, broad molecular weight distribution, optimized intermolecular compositional distribution and intramolecular sequence distribution) were achieved with AMC technology. The tailor-designed structures enable EPDM users more flexibility in their formulation design to achieve better compound processability and physical properties.

Acknowledgments

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Fig. 5: DSC curves of EPDM (A) Crystallization curves (B) Second heat melting curves.

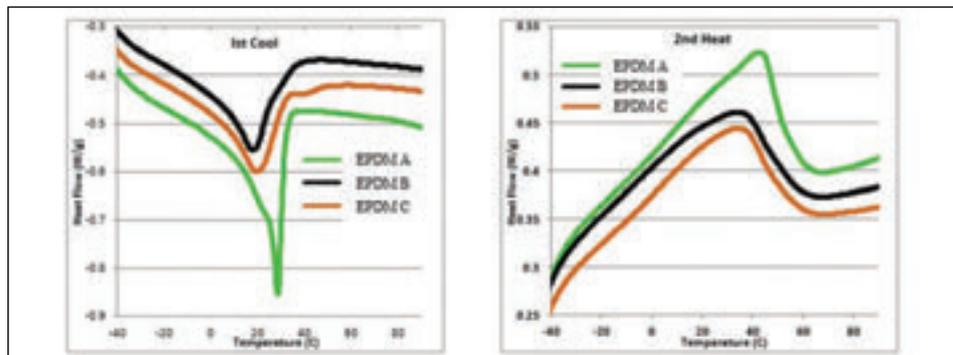


Fig. 6: Batch mixing curves of (A) Compound 1; (B) Compound 2; (C) Compound 3.

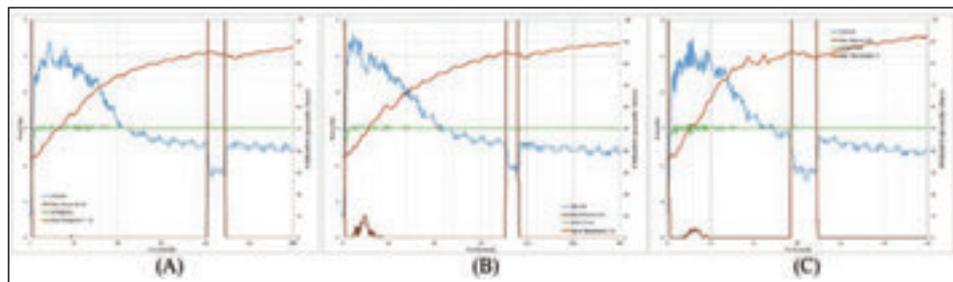


Table 9: Compound Mooney viscosity and curing characteristics.

	Compound-1 EPDM A	Compound-2 EPDM B	Compound-3 EPDM C	Compound-4 EPDM A	Compound-5 EPDM B	Compound-6 EPDM C
Total PPHR	577.3	577.3	577.3	737.3	737.3	737.3
ML1+4@100C (MU)	30.5	30.6	29.1	29.4	28.6	29.9
MDR 30 mins @140°C						
ML (dNm)	1.08	1.14	1.04	1.22	1.24	1.14
MH (dNm)	9.87	9.91	7.91	8.3	8.04	7.18
ts1 (Minute)	0.97	0.95	1.13	1.06	1.1	1.23
ts2 (Minute)	1.24	1.23	1.48	1.35	1.43	1.62
t50 (Minute)	1.9	1.95	1.98	1.97	2.12	2.15
t90 (Minute)	15.08	12.11	11.39	13.28	14.23	11.98
MDR 30 mins @180°C						
ML (dNm)	0.95	1.01	0.93	1.1	1.14	1.03
MH (dNm)	10.5	10.11	7.82	8.18	7.99	6.57
ts1 (Minute)	0.45	0.48	0.52	0.48	0.51	0.56
ts2 (Minute)	0.54	0.57	0.63	0.58	0.62	0.69
t50 (Minute)	0.8	0.89	0.77	0.77	0.82	0.8
t90 (Minute)	9.53	9.64	4.83	5.65	4.79	5.37

Table 10: Compound green strength.

	Compound-1 EPDM A	Compound-2 EPDM B	Compound-3 EPDM C	Compound-4 EPDM A	Compound-5 EPDM B	Compound-6 EPDM C
Total PPHR	577.3	577.3	577.3	737.3	737.3	737.3
Uncured Tensile						
100% Modulus (MPa)	0.81	0.5	0.57	0.9	0.6	0.59
Tensile Strength at Break (MPa)	4.19	3.09	2.91	3.44	2.72	2.05
Elongation at Break (%)	692.3	784.4	729.6	621.1	774.3	642.1

Table 11: Physical properties of vulcanizate.

	Compound-1 EPDM A	Compound-2 EPDM B	Compound-3 EPDM C	Compound-4 EPDM A	Compound-5 EPDM B	Compound-6 EPDM C
Shore A Hardness	70	67	65	68	68	66
Compression Set (%)						
70hr@23°C	36.7	28.5	30.1	42.7	33.8	33.3
70hr@70°C	14.4	15.2	17.0	11.3	13.8	16.3
70hr@150°C	72.0	72.7	75.6	72.8	74.0	76.2
Tensile Property						
100% Modulus (MPa)	2.3	2.2	2.1	2.5	2.2	2.1
Tensile Strength at Break (MPa)	7.5	7.9	7.2	5.7	5.8	5.6
Elongation at Break (%)	435.0	479.0	471.0	344.0	402.0	391.0
Tear Strength (N/mm)	27.2	24.7	23.7	20.7	21.7	19.6