

# Styrene-*co*-acrylonitrile Resin Modifications of PVC/CPE Blends

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**ABSTRACT:** The effects of styrene-*co*-acrylonitrile resin (AS) on the mechanical properties, morphology, and plasticizing and rheological behaviors of poly(vinyl chloride)/chlorinated polyethylene(PVC/CPE) blends are studied. The results show that the impact strength and the tensile strength are all increased and the plasticizing and rheological behaviors are also improved when a certain amount of AS is added into PVC/CPE blends, which are different in characteristics and regularity from plastics toughened with elastomers. It is blends of brittle-ductile transition regions (i.e., PVC/CPE = 100/10, 100/15) that can obviously be toughened by AS. The analysis of the morphological structure shows that AS promotes the formation of a CPE network that embeds the primary particles of PVC. © 1997 John Wiley & Sons, Inc. *J Appl Polym Sci* **66**: 1455-1460, 1997

**Key words:** styrene-*co*-acrylonitrile resin; poly(vinyl chloride); chlorinated polyethylene; polymer blends

## INTRODUCTION

Polymer blends are of considerable importance because blending could provide a means for improving mechanical properties as well as processability. It is well known that plastics are blended with rubbery polymers to improve impact strength, thus making them suitable for marsh applications. On the other hand, incorporation of rubbery polymers lowers the tensile strength, modulus, resistance to heat, and processing behavior of plastics, so it is highly important for theory and practice to look for new and better methods of plastics toughening.

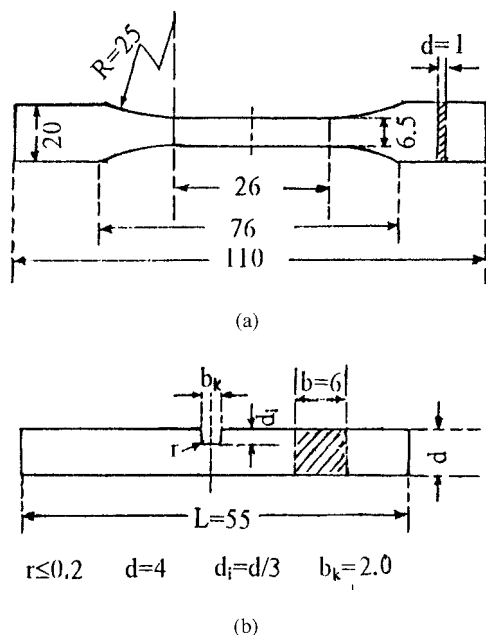
In 1984 Kurauchi and Ohta discovered that styrene-*co*-acrylonitrile resin (AS) or acrylonitrile-

butadiene-styrene (ABS) could toughen polycarbonate (PC),<sup>1</sup> and the blends have good tensile strength and processability. From 1985 to 1988 a number of researchers repeated and developed this work.<sup>2-4</sup> These studies aimed at improving the ductility and processability of engineering plastics and showed the possibility of plastics toughened with nonelastomers. In the study of the toughening of common plastics, poly(vinyl chloride) (PVC) toughening has attracted great interest owing to its low price and good resistance to aging and corrosion. PVC/chlorinated polyethylene (CPE) blends can form rigid and ductile polymer materials, so they have been developed rapidly and applied widely in recent years. In this article, the effects of AS on the mechanical properties, morphological structure, plasticizing, and rheological behaviors of PVC/CPE blends are studied. The results are different in characteristics and regularity from plastics toughened with

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**Figure 1** The geometric figure and size (mm) of samples.

elastomers, the combined properties of PVC/CPE blends are improved further.

## EXPERIMENTAL

### Materials

PVC, with an average polymerization degree (DP) of 1000, was supplied by Qilu Petrochemical Corporation (Zibo, China). CPE, with 35% of the weight content of chloride, was supplied by Weifang Chemical Factory, Weifang Factory (Weifang, China). (AS HF type) was supplied by Lanzhou Chemical Corporation (Lanzhou, China).

Acrylic resin plasticizer (ACR, 201 type) was supplied by Shanhu Chemical Factory (Shanghai, China). Other additives were industrial products.

### Preparation of Polyblends and Characterization Methods

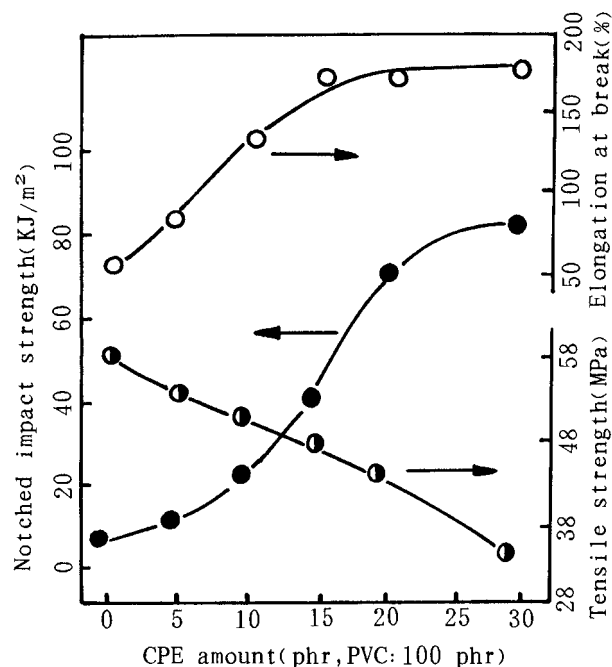
The blend components were kneaded 10 min in a high-speed kneader and then plasticized 10 min at 170°C on a double roll plasticator. Test samples were molded at 170°C with flat-plate tablet machine and prepared with a universal clipper. The tensile properties were determined according to Chinese Standard 1040-79 [T-10 type electronic tensile tester, Monsanto Co., tension rate 10 mm/min; Fig. 1(a)]. Notch impact strength was deter-

mined according to Chinese Standard 1043-79 [Charpy, XCJ-40 type tester, Chengde Machinery Factory, China; Fig. 1(b)]. Morphological structures of blends were observed by electron microscope (JEM-2000EX type, Japan Electron Co.). Plasticizing curves were measured with a Brabender plasticizing rheometer (PLE-331 type, Germany Brabender Co.). Melt flow properties were measured on a constant-pressure capillary rheometer (XLY-2 type,  $L/D = 40/1$ , 170°C, Jilin University, China).

## RESULTS

### Mechanical Properties and Characteristics of CPE Modifying PVC

Figure 2 shows that the tensile strength decreases, elongation at break increases, and impact strength varies in an S-type curve with the increase of CPE amount, a typical property of plastics toughened with elastomers. The ductility of PVC/CPE blends only increased slightly when a small amount of CPE, and a brittle-ductile mutation region of blends is formed when 10–20 phr CPE is added to PVC (100 phr). However, the tensile strength obviously decreased and the im-



**Figure 2** Effect of CPE amount on the mechanical properties of PVC/CPE blends.

duct strength did not increase when the CPE amount was increased further. These show the defects and limitations of toughening plastics with elastomers, so it is necessary to further improve their properties to find other methods.

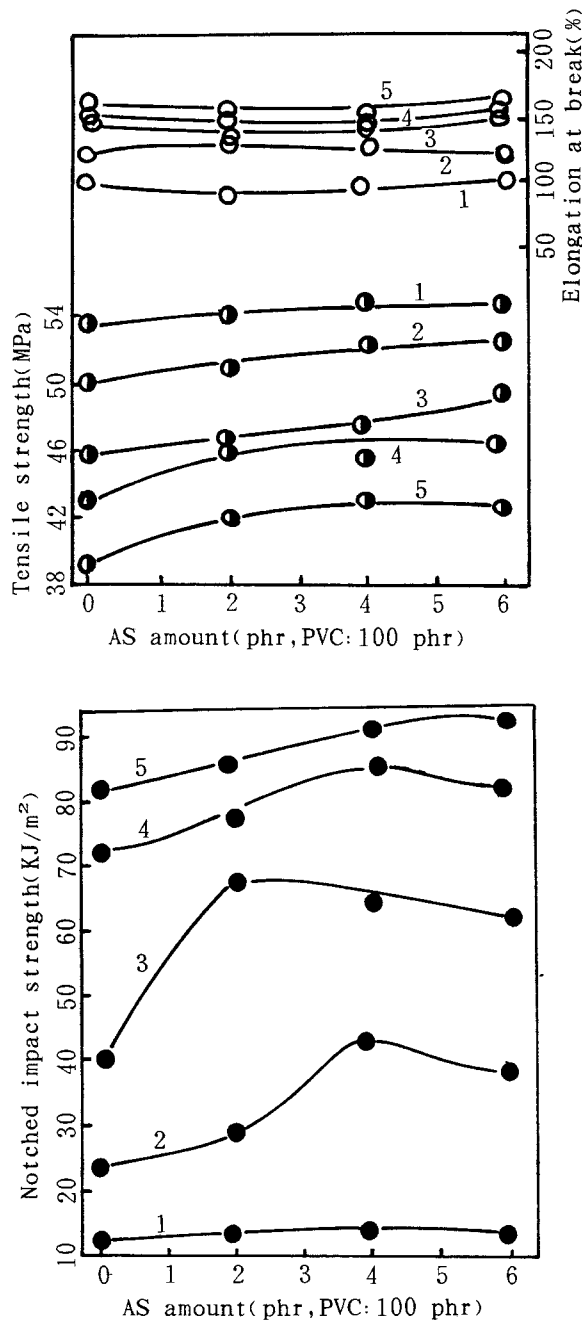
### Mechanical Properties of AS Modifying PVC/CPE Blends

Elastomers can toughen both brittle plastics and ductile plastics, while nonelastomer toughening not only demands that the toughened matrix have certain ductility but also that the brittleness of nonelastomers matches the ductility of the toughened matrix<sup>1-4</sup>; otherwise, there is no action of nonelastomer toughening. Figure 2 shows that the ductility of PVC/CPE blends can be adjusted effectively by varying the CPE amount, and various brittle-ductile matches between AS and PVC/CPE blends can be obtained.

The effects of AS amount on the mechanical properties of various blending rates of PVC/CPE blends are shown in Figure 3. It can be seen that the mechanical properties of blends are all increased, but the increasing degree is different for various PVC/CPE blends and AS amounts. The reinforcing effect of AS on PVC/CPE blends increases with CPE amounts and AS amounts, and the toughening effect of AS on the PVC/CPE blends is small when the CPE amount is low or high. This is probably because of the nonmatch of the brittleness of the AS and the ductilities of the PVC/CPE blends. It is blends of the brittle-ductile mutation regions (i.e., PVC/CPE = 100/10, 100/15) to be toughened obviously, and a good toughening effect is obtained when the AS amount is 2-4 phr. On the other hand, a high AS amount lowers the toughening effect. These are different in characteristics and regularity from plastics toughened with elastomers.

### Morphological Structure of AS Modifying PVC/CPE Blends

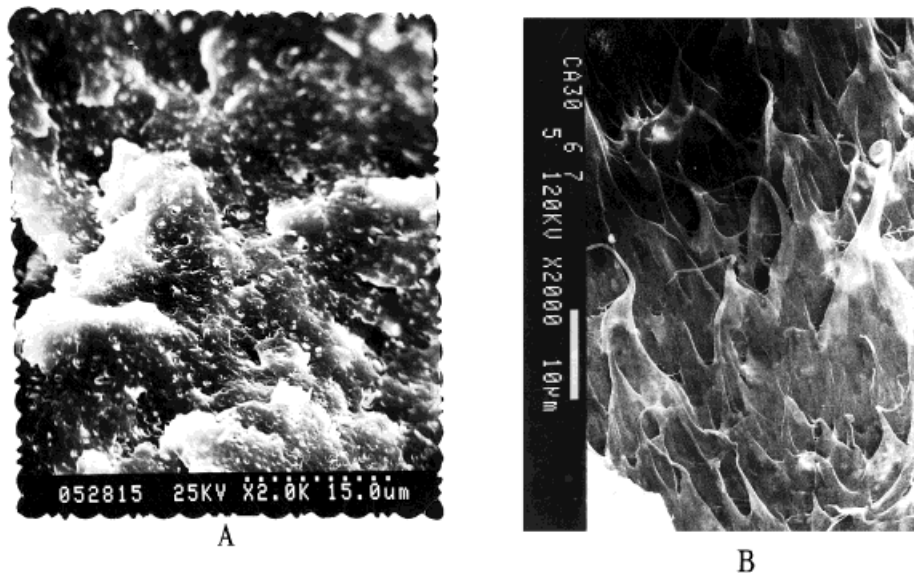
Mutation of the material's properties is relative to the change of its morphological structure. Some impact modifiers with linear structure (e.g., ethylene vinyl acetate, nitrile butadiene rubber, CPE etc.) can form a continuous network embedding the primary particles of PVC when the amount of impact modifiers and processing conditions are proper,<sup>5-7</sup> and the formation and improvement of



**Figure 3** Effect of AS resin on the mechanical properties of PVC/CPE blends. The blend ratios of PVC/CPE for curves 1-5 are 100/5, 100/10, 100/15, 100/20, and 100/25, respectively.

this special structure favorably affects the impact strength.

Figure 4 contains SEM photographs of impact sections of PVC/CPE and PVC/CPE/AS blends. The root whiskers on the impact section of the PVC/CPE blend are fewer and shorter than that

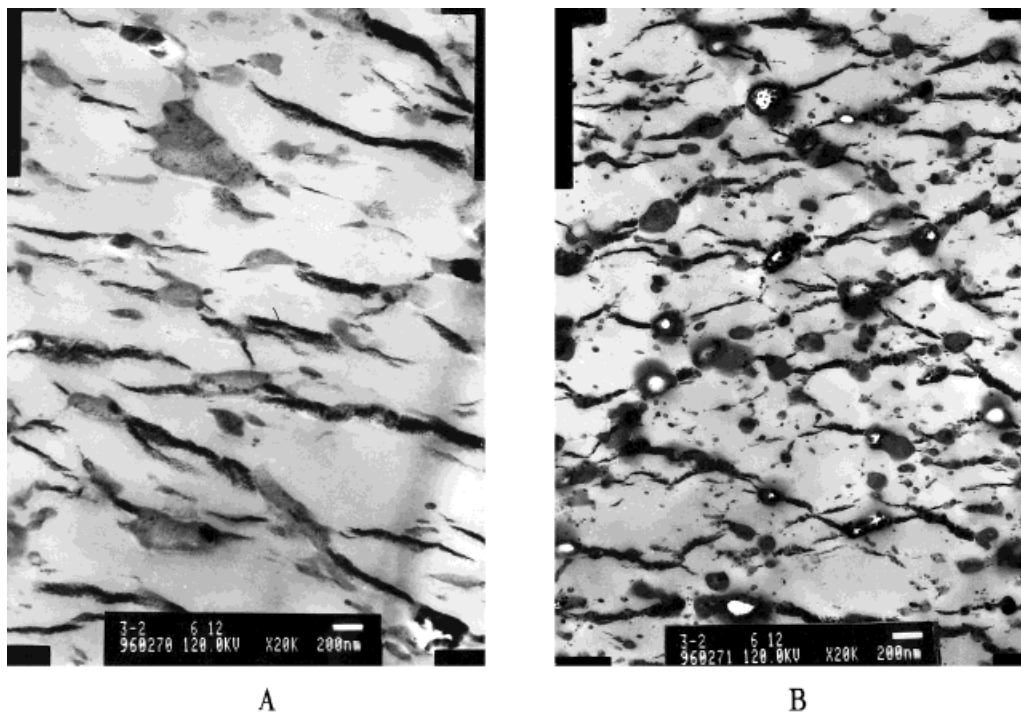


**Figure 4** SEM photographs of the fracture surface of (A) PVC/CPE (100/10) blend and (B) PVC/CPE/AS (100/10/4) blend.

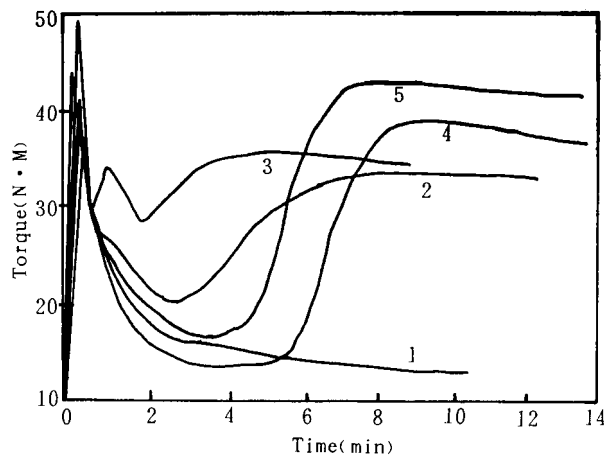
on the impact section of PVC/CPE/AS blend; the former mainly shows a brittle feature and the latter a typical ductile feature. The change in morphology of the impact section corresponds to the

obvious increase of impact strength (see Fig. 3), which shows that AS promotes the brittle–ductile transition of PVC/CPE blends.

Figure 5 shows TEM photographs of the sam-



**Figure 5** TEM photographs of the microphase structure of (A) PVC/CPE (100/10) blend and (B) PVC/CPE/AS (100/10/4) blend.



**Figure 6** The plasticizing curves of various blends (170°C, 20 rpm). Curves 1–5 are PVC/CPE (100/10), PVC/CPE/AS (100/10/3), PVC/CPE/AS (100/10/5), PVC/CPE/ACR (100/10/3), and PVC/CPE/ACR (100/10/5), respectively.

ples. The network of CPE in the PVC/CPE matrix is large and uncontinuous without AS, but the network of CPE becomes homogeneous and tiny when a small amount of AS is added into the PVC/CPE blend. The compatibility and dispersibility of blending components is promoted at the same time. The change of microspherical morphology must obviously increase the ductility of the PVC/CPE/AS blend (i.e., the rigid polymer AS boosts the toughening effect of CPE on the PVC matrix). As a result, PVC/CPE/AS blends have the tensile strength of a PVC/CPE blend with a low CPE amount and the ductility of a PVC/CPE blend with a high CPE amount; thus, the combined properties of the materials are further improved.

#### Plasticizing and Rheological Behavior of AS Modifying PVC/CPE

PVC has a complicated state of aggregation.<sup>7</sup> Its melt plasticizing and flow behaviors are relative to both processing conditions and additive materials, and these will further affect their physical and mechanical properties.

Figure 6 shows that the PVC/CPE blend itself cannot plasticize well without plasticizers, but AS can accelerate the plasticizing of the PVC/CPE blend effectively and is superior to ACR, which is a processing additive of PVC in common use. In addition, both maximum torque and equilibrium

torque of the PVC/CPE/AS blends are lower than that of PVC/CPE/ACR.

A PVC/CPE blend possesses a high viscosity that can be reduced by the addition of AS resin (shown in Fig. 7). Viscosities decrease with the increase of shear rate and AS amount in the experiment.

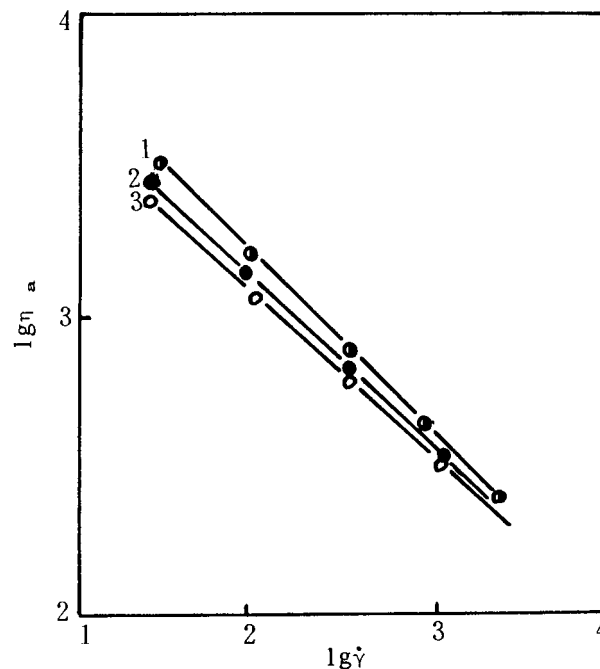
The changes of plasticizing and rheological behaviors should result in the change of morphology and the improvement of mechanical properties.

#### SUMMARY AND CONCLUSIONS

It has been seen that nonelastomer (AS) toughening is superior to and different from elastomer (CPE) toughening in characteristics and regularity in the following respects.

The property of the toughening agent has obvious differences in strength, modulus, softening temperature, deformability, and flow behavior.

Toughened matrix is different. Elastomer (CPE) can toughen both brittle plastics (pure PVC) and ductile plastics (PVC/CPE), while nonelastomer (AS) toughening demands the ductility of a matrix toughened to some extent. Otherwise,



**Figure 7** Effect of AS on the rheological behavior of PVC/CPE blends. Curves 1–3 are PVC/CPE (100/10), PVC/CPE/AS (100/10/2), and PVC/CPE/AS (100/10/4), respectively.

the toughening effect cannot be obtained or is low (see Fig. 3).

The change tendencies of the ductility of toughened matrix are different according to the variation of the amount of toughening agent. The ductility of PVC/CPE blends increases with CPE amount (elastomer toughening). However, a good AS toughening effect on PVC/CPE blends cannot be obtained unless the AS amount is proper (non-elastomer toughening).

Toughening agents have different effects on material properties. Elastomer can increase ductility but the strength, modulus, resistance to heat, and flow behavior of toughened matrix are decreased. On the contrary, these properties can be improved or remain unchanged for nonelastomer toughening.

These points show that the toughening mechanisms may be different. The CPE toughening of PVC is due to the deformation of CPE in the matrix, crazing and shear yielding of matrix toughened, which is similar to the toughening mechanism of common elastomers.<sup>8-10</sup> The formation of a network structure of CPE in the PVC matrix promotes its toughening effect further.<sup>7</sup> One of the reasons for the AS toughening of PVC/CPE blends is that AS favors the formation and perfection of a network of CPE in the PVC matrix and makes the network homogenous and tiny. Another is that AS can promote the plasticizing degree of PVC/CPE blends and the dispersibility of CPE in the PVC matrix.

The reinforcement of the matrix is dependent on the strength and amount of additives and the

compatibility among the components. AS has high strength and good compatibility with the matrix and should reinforce the PVC/CPE blends, which have relatively low strength. The plasticizing of PVC/CPE blends is promoted by AS, which should also increase the strength of PVC/CPE blends. AS should accelerate the plasticizing of the matrix effectively because AS is dispersed in the matrix in a microparticle state and has good compatibility among phase interfaces. The improvement of melt flow behavior is due to the high flowability of AS itself and the acceleration of AS on the plasticizing of the matrix and the change of supermolecule morphology caused by AS.

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