Properties of Nano Calcium Carbonate Reinforced Polypropylene/Poe Nanocomposites

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Abstract: *PP-based nanocomposite was prepared by blending POE elastomer and introducing nano-calcium carbonate to improve the mechanical and thermal properties of the composite. The content of POE was optimized first to achieve a suitable balance between strength and elasticity. Then the nano-CaCO3 was modified with silane coupling agent KH-570 to improve the compatibility with the resin matrix and dispersed into the matrix. The addition of nano-CaCO3 can compensate the sacrifice of strength brought by the elastomer but keep the elasticity in a considerable extent. The influence of the nano-filler content was systematically investigated. The resulting nanocomposite have a tensile strength of 22.5 MPa, with the elongation at break of 370% and the impact strength reached 41 KJ/m2. Finally, a nucleating agent was introduced to further adjust the mechanical and thermal properties of the nanocomposite. The themostability can significantly enhanced by the nucleating agent.*

Keywords: *Polypropylene, Polyolefin elastomer, KH-570, nano-CaCO₃, PA-10*

I. Introduction

Compositing is aneffective and widespread way to improve the properties of materials. This method keeps developing with the emergence of new material and new technology. Composite with nanoscale content, termed nanocomposite, is a rather new way with high potential to enhance the property of new and traditional materials.[1]Nanocomposite, which introduce nanofillers such as nanoparticles,[2]nanorods[3], nanoplatelets[4], nanoflakes[5], nanofibers[6] into the matrix material, have developed and applied a lot. Polypropylene is one of the most widely used thermoplastic polymer in various domains such as packaging, labeling, textiles, stationery, laboratory equipment, etc., thanks to its outstanding properties includingthe low-price,ease of processing, resistance to fatigue, heat and corrosion, non-toxicity, etc.[7]However, with the increasing demand of high-quality and cheap material, PP are expected to be improved to expand the area where it is able to apply. There have been reports trying to improve the properties of PP by introducing nanofillers and make nanocomposite. Vengatesan et al. mullitenanofiber to reinforce the mechanical behavior of PP.[8] Peng et al. composited cellulose nanofiber to PP resin and improved the impact strength by 23% with the amount of added cellulose nanofibril was only 1 wt.%. [9]

Calcium Carbonate (CaCO₃) is a widely used filler in polymer industry because of its outstanding mechanical properties, thermal conductivity, and importantly its economical price. The nano-CaCO₃ particles is a highly potential candidate for nanocomposite. Prusty et al. imprinted CaCO₃ to a starch hybrid PEHA thin film. The tensile strength, thermal stability and thermal conductivity of films are increased with increase in concentrations of CaCO₃nanopowder. The growth of bacteria and fungi in starch hybrid PEHA film is reduced substantially with imprint of nano CaCO₃.[10]Chafidz et al. studied the effect of nano-CaCO₃ on rheological/viscoelastic and mechanical properties of the nanocomposites.[11]

Under the aforementioned background we prepared and studied a elastomer-composited PP resin and introduced nano-CaCO₃ filler to form nanocomposite. Finally, a nucleating agent were used to to study the possibility to further adjust the properties of the nanocomposite.

II. Experimental

2.1 Raw Materials and Equipments

PP copolymer produced by the Yanshan petrochemical, POE, DF610 contents 40 % octene produced by the American Great Lake Corporation, Antioxidant 1010, pentaerythritoltetrakys 3-(3,5-ditert-butyl-4-hydroxyphenyl) propionate produced by Shanghai Macklin Biochemical Co., Ltd. β-nucleating agent PA-10 and nano-CaCO₃ were bought from Shanghai ZhuoYue chemical technology co., LTD. Silane coupling agent KH-570 (γ-methacryloxypropyltrimethoxysilane) produced by Nanjing Neng De chemical co., LTD.HAAKE PolyLab QC manufactured by Germany Thermo Fisher Scientific, Curing press manufactured by Shanghai zhuo scientific instrument co., LTD, Universal system prototype manufactured by Chengde city branch bearing

testing machine co., LTD. Material Tensile universal Testing Machine manufactured by American Instron corporation, Charpy Impact Tester of XCJ-50 manufactured by ChengdeKechengTestingmachine co., LTD, High speed mixer manufactured by Nanjing Jieente, mechanical and electrical co., LTD, Laboratory Electronic Balance FA2004N, temperature drying boxes DHG-9123A manufactured by Shanghai jing macro sample equipment co., LTD, X-radial Diffractometer XRD-6000 manufactured by Shimadzu Japan, the thermal deformation vicat softening point temperature tester, manufactured by ChengdeKechengTestingmachine co., LTD.

III. Preparation

Nano-$CaCO_3$ was modified with silane coupling agent KH-570 before being composited with resin. The modification process is described as follow: The 20 g nano-$CaCO_3$ was added into 100 ml solution of anhydrous ethanol/deionized water with a volume ration of 9:1, and the mixed solution ultrasonic dispersing for 1 hour, then 2 g silane coupling agent KH-570 was added into the mixture in boiling flask-3-neck with condenser tubes and the temperature was maintained at 80 °C for 3 hours through constant temperature oil bath with motor stirrer of 250 r/min. Then, the mixed solution was purified by suction filtration and the cake was washed by anhydrous ethanol for 3 times and the cake was drying off in the 70 °C electric dry oven for 12 hours and the dried cake was grind with mortar to obtain the KH-570 modified nano-$CaCO_3$.

Allcomposites with different contents were fabricated by means of melt blending. In brief, all the contents were dried at 80 °C under vacuum condition for 24 hours before use. Then, the contents were blended at 60 rpm, 180-190 °C for about 10 minutes by Haake torque rheometer (Rheocord 300 P/Rheomin 600 P, Thermo Hakke, USA). The mixed composites were dried at 80 °C under vacuum for 24 hours, and the sheet material were prepared by reuse plate vulcanizing machine. The reuse plate vulcanizing machine was preheating for 10 min at 190 °C, and the sheet material of Φ 12 x 2-4 mm samples were prepared by hot compression molding at thepressure of 10 MPa. The standard tensile impact tests splines were made for the specimens according to the China National Standard GB1040-79 and GB1843-96. All the specimens were notched and impacted on Izod impact testing machine.

IV. Characterization

The WXRD of PP and 0.3 wt. % PA-10/PP was tested by the X - ray diffraction analyzer (X-radial Diffractometer XRD-6000 manufactured by Shimadzu Japan). The disk samples with flat surface were tested by Cu-Kα (40Kv, 450mA) and the scanning range from 5° to 20°.The tensile test is in accordance with the provisions of GB/T 1040-1992, the standard tensile spline with the stretching rate is 10 mm/min.The impact test is according to the provisions of GB/T 1843-1996, test the standard impact samples of the notched impact strength, standard spline with 2 mm thick, 8 mm wide.The thermal deformation vicat softening point temperature test is in accordance with the provisions of China national standard GB/T1634-2001, and the temperature test range from room temperature to 150 °C.

V. Results and Discussion
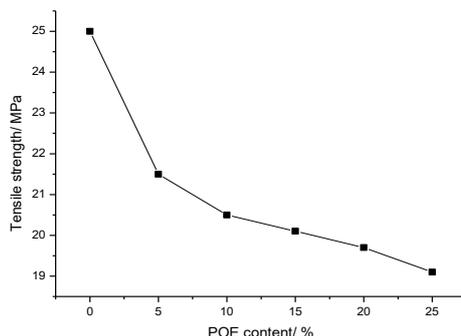
2.4.1 Tensile strength of POE/PP composite

Fig. 1The tensile strength of POE/PP with different content of POE

Fig.1 summarizes the tensile strength of pure PP and PP/POE composites with 5 wt.%, 10 wt.%, 15 wt.%, 20 wt.% and 25 wt.% of POE. An overall tendency that the tensile strength of the POE/PP composites reduces with the increase of POE proportion can be observed. A sharp decrease of tensile strength of the resin occurred when POE was applied, then the strength dropped mildly. This change is predictable since POE is an elastomer with rather low strength.

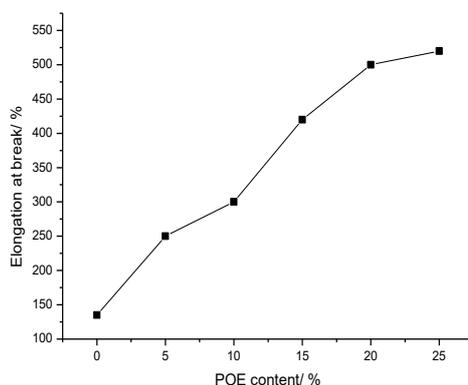### 2.4.2 Elongation at break of POE/PP composite

Fig. 2 The elongation at break of POE/PP with different content of POE

Fig. 2 exhibits the correlation of elongation at break and POE proportion of POE/PP composites. It can be seen that the elongation at break of the POE/PP composites rose significantly with the increasing fraction of POE/PP, from 135% of pure PP up to 520% of composite with 25% of POE. This result can be attributed to the addition of POE which can endow its elasticity to the composite. Further, the increasing rate of elongation is significant till the proportion of POE reached 15%, but it became milder afterwards. This implied that the influence of POE on the structure of composite become less significant after the proportion of 15-20%.
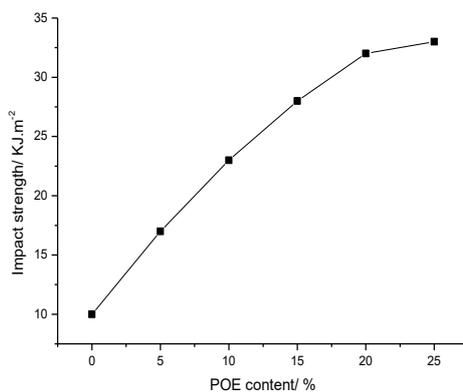
2.4.3 Impact strength of POE/PP composite

Fig. 3 The impact strength of POE/PP with different content of POE

Fig. 3shows the impact strength of POE/PP composites with different fraction of POE. The impact strength of pure PP is only 10 $KJ \cdot m^{-2}$, while that of the 5 wt.% POE/PP increased significantly to 17 $KJ \cdot m^{-2}$ and then gradually reached 32.5$KJ \cdot m^{-2}$when the proportion of POE reached 25%.The tendency of impact strength of the POE/PP composites is consistent with the elongation at break. This agreed with the hypothesis of influence of POE on the structure of the composite. In accordance with the elongation results, one can say that the POE can significantly improve the toughness of PP.

2.4.4 Melt index of POE/PP composite
Fig. 4 is the melt index of POE/PP composites. The melt index of the POE/PP composites is consistent with the tensile strength at break, which decreased markedly with the increase of POE. The melt index of pure PP is 8.6 g/10 min, and the melt index of the 5 wt.% POE/PP decreased gradually to 7.9 g/10 min. The melt index of the 5-25 wt.% POE/PP composites decreased gently and the melt index of the 25 wt.% POE/PP reduced to 6.0 g/10 min. The curves show that the POE can significantly decrease the fluidity of PP. It is mainly because the POE has lower flow rate than PP, which increased the internal friction of the POE/PP system.

2.4.5 Shorehardness of POE/PP composite

Fig. 5 is the shore hardness of pure PP, 5 wt.% POE/PP, 10 wt.% POE/PP, 15 wt.% POE/PP, 20 wt.% POE/PP, 25 wt.% POE/PP composites. The shore hardness of the POE/PP composites is consistent with the melt index, which decreased markedly with the increase of POE. The shore hardness of pure PP is 72, and the shore hardness of the 5 wt.% POE/PP decreased to 70. The shore hardness of the 5-25 wt.% POE/PP composites decreased gently and the shore hardness of the 25 wt.% POE/PP reduced to 64. As an elastomer, POE with better suppleness than PP can decrease the hardness of PP. In the matrix resin of PP, POE has good compatibility and dispersibility with a small elastomer particles dispersed in the resin matrix, which can remarkably influence the POE/PP system. Table 1 is the properties of POE/PP composite.
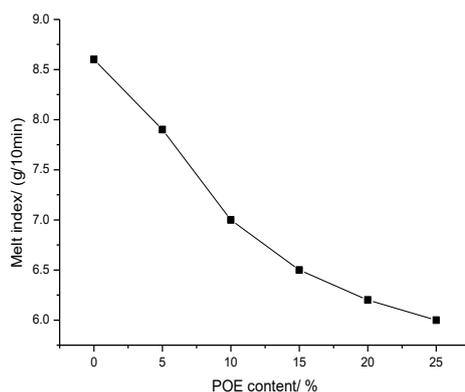

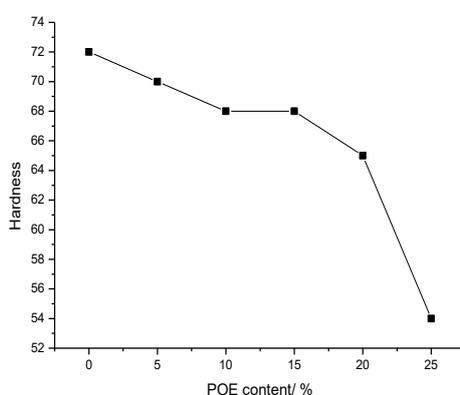**Fig. 4**The melt index of POE/PP with different content of POE

Fig. 5 The shorehardness of POE/PP with different content of POE

Table 1 Properties of POE/PP composite

Content of POE/%	0	5	10	15	20	25
Tensile strength/MPa	25	21.5	20.5	20.1	19.7	19.1
Elongation at break/%	135	250	300	420	500	520
Impact strength/(KJ·m^{-2})	10	17	23	28	32	30
Melt index/(g/10 min)	8.6	7.9	7.0	6.5	6.2	6.0
Shorehardness	72	70	68	67	65	64

2.4.6Thermal properties of POE/PP composite

Fig.6 shows the thermal properties of pure PP (a), 10 wt.% POE/PP (b), and 20 wt.% POE/PP (c) composite. The melting point temperature of pure PP (a) is 150.9 °C, the melting point temperature of 10 wt.% POE/PP (b) is 146.5 °C, and the melting point temperature of 20 wt.% POE/PP (c) is 139.3 °C. And the DSC curves of the POE/PP composites show that the melting temperature decreased with the increment of POE.Based on the results of POE/PP composite tests, the optimizedproportion of POE in the composite resin was thought to be 15-20 wt.%, and the following experiments were performed with a POE proportion of 20 wt.%.

2.4.7FT-IR spectrum of KH-570 modified nano-CaCO₃

The FT-IR spectrum ofunmodified $CaCO_3$ (curve a) and KH-570 modified nano-$CaCO_3$(curve b) were showed in Fig.7. Comparing the two curves of before and after modification, it can be seen that two significant peaks appeared at 2979 cm^{-1} and 2871cm^{-1}, representing the involvement of –CH3 and –CH2–. Further, the peaks occurred at 1720 and 1640 implied the existence of C=O and C=C respectively. The changes of stretch vibration absorption spectra in the FT-IR spectrum shown that the silane coupling agent KH-570 was successfully coated to the surface of the nano-$CaCO_3$.
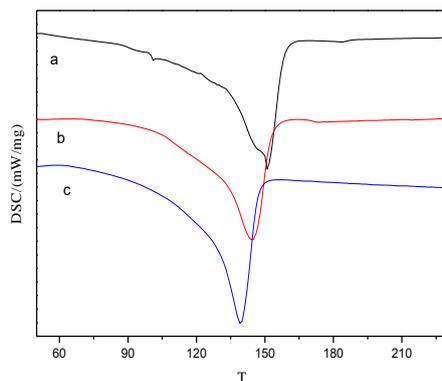

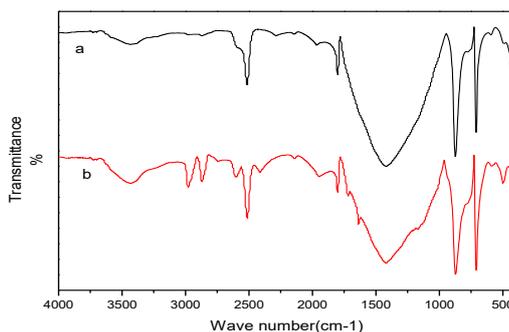**Fig.6**The DSC curve of of pure PP (a), 10 wt.% POE/PP (b), and 20 wt.% POE/PP (c) composites

Fig. 7 The FT-IR spectrum, a-nano-CaCO3, b-KH-570 modified nano-$CaCO_3$

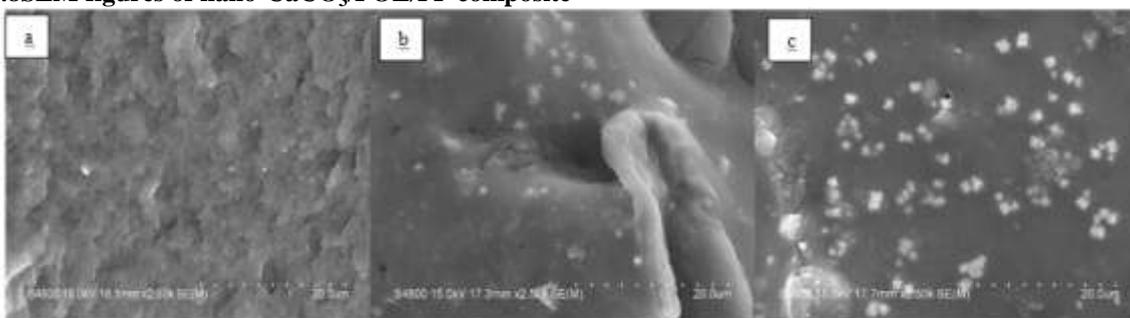**2.4.8SEM figures of nano-CaCO₃/POE/PP composite**

Fig. 8 The fracture SEM fig.s, a-POE/PP composite, b-10 wt.% KH-570 modified nano-$CaCO_3$/POE/PP composite and c-20 wt.% KH-570 modified nano-$CaCO_3$/POE/PP composite

Fig. 8 shows the fracture SEM figures, a-nano-$CaCO_3$, b-10 wt.% KH-570 modified nano-$CaCO_3$/POE/PP composite and c-20 wt.% KH-570 modified nano-$CaCO_3$/POE/PP composite. The SEM figures shown that the content of KH-570 modified nano-$CaCO_3$, small white particles, in the fracture of the composite increased with the increase of the KH-570 modified nano-$CaCO_3$ and the nano-$CaCO_3$ distributed evenly in the nano-$CaCO_3$/POE/PP composite.

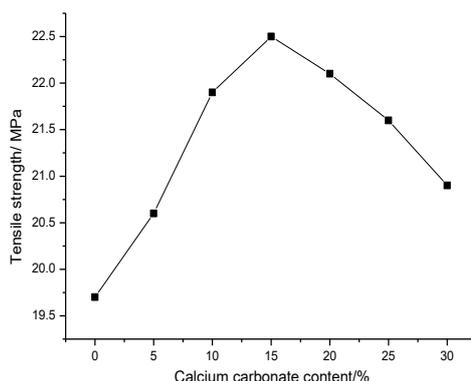**2.4.9Tensile strength of nano-CaCO$_3$/POE/PP composite**

Fig. 9 The tensile strength of KH-570 modified nano-CaCO$_3$/POE/PP composite with different content of modified nano-CaCO$_3$

The change of tensile strength of nano-CaCO3/POE/PP composite with the content of modified nano-CaCO$_3$ was exhibited in Fig.9. It can be seen that the addition of nano-CaCO$_3$ significantly increased the tensile strength of the composite. This increase is especially remarkable before the content of nano-CaCO$_3$ reached 15 wt.%. The quantity of increase peaked at 15 wt.% and dropped afterwards. This can be attributed to the structure altering with the content of the composite: the nano-CaCO$_3$ particles can concentrate the stress from the matrix to the neighboring of the particles, and the matrix would yield to generate large deformation under strength to absorb the deformation energy. This effect was enhanced with the increase of nano-CaCO$_3$ particle content. However, when the content reached 15 wt.%, further addition of nano-CaCO$_3$ particles will decrease the integration of the continuous resin phase, which will lead to the decrease of tensile strength.Comparing the tensile strength of nano-CaCO$_3$/POE/PP composite with that of the PP/POE resin, it was found that the addition of nano-CaCO$_3$ can improve the strength of resin up to 22.6 MPa, while the tensile strength of pure PP resin was 25 MPa, and highest PP/POE tensile strength was 21.5. With this comparation under consideration, one can say that the addition of the nano-CaCO$_3$ counteracted the tensile strength loss brought by the elastomer POE. To further confirm this conclusion, the elongation at break and impact strength of the composites were tested.

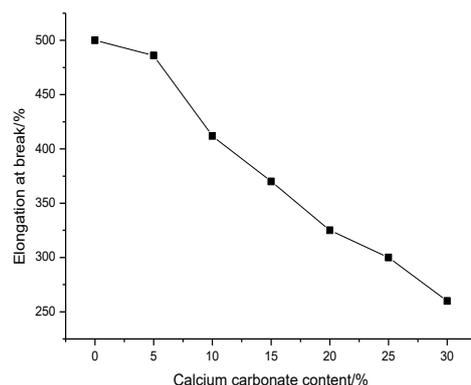**2.4.10Elongation at break of nano-CaCO$_3$/POE/PP composite**

Fig.10 The elongation at break of KH-570 modified nano-CaCO$_3$/POE/PP composite with different content of modified nano-CaCO$_3$

Fig. 10 shows the elongation at break of nano-CaCO3/POE/PP composite with different content of KH-570 modified nano-CaCO$_3$. It is expectable that the elongation at break of the KH-570 modified nano-CaCO$_3$/POE/PP composites reduced gently with the increasing content of modified nano-CaCO$_3$ since the particles endowed strength to the composites. When the content of nano-CaCO$_3$ arrived 15 wt.% which conferred highest tensile strength to the composite, the elongation at break remains nearly 400%. Tough the elongation was reduced from 500% of pure PP/POE resin, the elongation was remained in a great extentcompared to 140% of pure PP resin. This results was consistent with the hypothesis mentioned above.

2.4.11 Impact strength of nano-CaCO₃/POE/PP composite

The impact strength of KH-570 modified nano-CaCO₃/POE/PP composite was characterized and the results was exhibited in Fig.11. The impact strength of the KH-570 modified nano-CaCO₃/POE/PP composites firstly increased significantly with the increasing content of nano-CaCO₃, from 32 $KJ·m^{-2}$ of pure PP/POE resin to 42 $KJ·m^{-2}$ of composite with 15 wt.% KH-570 modified nano-CaCO₃. Then the increasing ratewas lowered after 15 wt.% and the impact started to drop after 30 wt.%. The overall tendency is similar to that of the tensile strength, implying that the hypothesis of the mechanism how nano-CaCO3 particles enhance the properties of the composite resin was reasonable. Compared with the impact strength of pure PP/POE resin (30 $KJ·m^{-2}$), this number of 15 wt.% nano-CaCO3 modified composite reached 41.5 $KJ·m^{-2}$, which is a significant improvement. Considering the enhancement of further increased content of CaCO₃ is rather slight, 15 wt.% is considered to be the optimized content of nano- CaCO₃to improve the properties of PP/POE resin.The properties of KH-570 modified nano-CaCO₃/POE/PP composite were summarized in table 2.
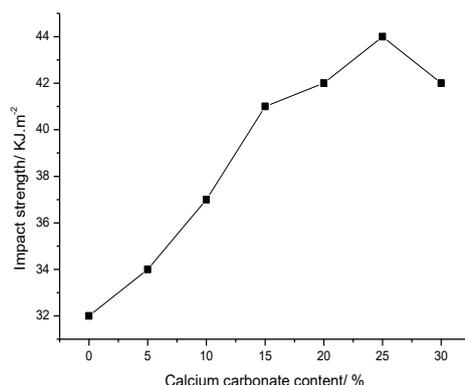

Fig.11 The impact strength of KH-570 modified nano-CaCO₃/POE/PP composite with different content of modified nano-CaCO₃

Table2 Properties of KH-570 modified nano-CaCO₃/POE/PP composite with different content of modified nano-CaCO₃

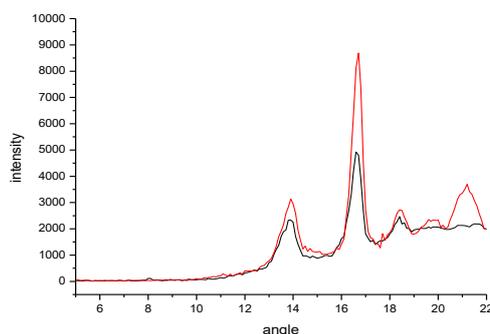| The content of modified nano-CaCO₃/wt. %	0	5	10	15	20	25	30
Tensile strength/MPa	19.7	20.6	21.9	22.5	22.1	21.6	20.9
Elongation at break/%	500	486	412	370	325	300	260
Impact strength/(KJ·m⁻²)	32	34	37	41	42	43	42

2.4.12 WXRD tests of PP and 0.3 wt. % PA-10/PP

Fig. 12 The WXRD tests of PP and 0.3 wt. % PA-10/PP

Fig. 12shows the results of WXRD tests of pure PP(curve a) and PP modified with 0.3 wt. % PA-10(curve b). α (110) 2θ=14.2°, α (040) 2θ=17.0°, α (130) 2θ=18.8° are corresponding to the three diffraction peaks of the α-modification, while β (300) 2θ=16.2° and β (300) 2θ=21.2° are corresponding to the two diffraction peaks of the β-modification. As the WXRD curve shown, a-pure PP with obviously diffraction peaks at 14.2°, 17.0° and 18.8°, which corresponding to the α-modification. While the b-0.3 wt. % PA-10/PP with obviously diffraction peaks at 14.2°, 18.8°, and 16.2°, which indicated that the b-0.3 wt. % PA-10/PP was with perfect β-modification, and the α-modification still existed.

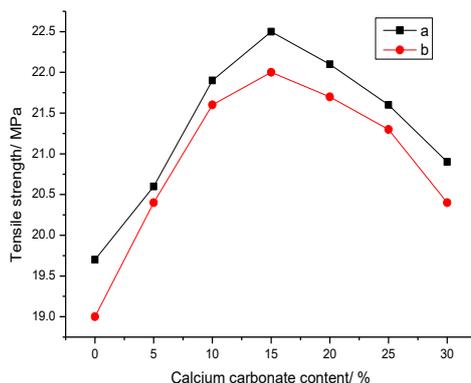**2.4.13Tensile strength of PA-10/nano-CaCO$_3$/POE/PP compositee**

Fig. 13 The tensile strength of a-KH-570 modified nano-CaCO$_3$/POE/PP composite and b-PA-10/nano-CaCO$_3$/POE/PP composite with different content of modified nano-CaCO$_3$

Tensile strength of KH-570 modified nano-CaCO$_3$/POE/PP composite(curve a) and PA-10/nano-CaCO$_3$/POE/PP composite (curve b) with different content of nano-CaCO$_3$ (0 wt.%, 5 wt.%, 10 wt.%, 15 wt.%, 20 wt.%, 25 wt.%, 30 wt.%) was summarized in Fig 13. The tensile strength of the nano-CaCO$_3$/POE/PP with or without nucleating agentshowed similar tendency, which firstly increased before arriving peak and then decreased with the increase of KH-570 modified nano-CaCO$_3$. As is clearly revealed, the addition of nucleating agent slightly lowered the tensile strength of KH-570 modified nano-CaCO$_3$/POE/PP composite. This result is predictable since the involvement of nucleating agents can introduce crystallization unit which usually increase the strength and stiffness of materials.

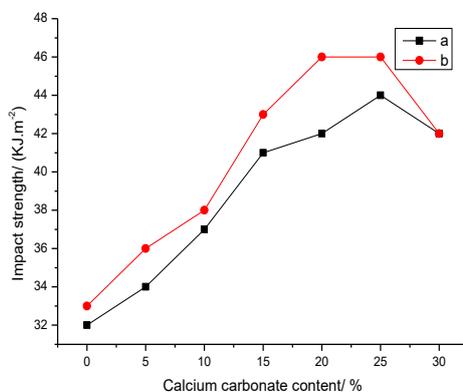**2.4.14Impact strength of PA-10/nano-CaCO$_3$/POE/PP composite**

Fig.14 The impact strength of a-KH-570 modified nano-CaCO$_3$/POE/PP composite and b-PA-10/nano-CaCO$_3$/POE/PP composite with different content of modified nano-CaCO$_3$

The impact strength data of the nucleated nano-CaCO$_3$/POE/PP composite was exhibited in Fig.14. Again, the overall tendency of impact strength changing with content of nano-CaCO$_3$ was similar, and consistent with former data: the impact strength rose with the content of nano-CaCO3, while the increasing rate was significant before the CaCO$_3$ content reached 15% and the rate became gentle. Contrary to the tensile strength, the addition of nucleating agent improved the tensile strength, and the extent of this increase became larger after 15 wt.%. The highest impact strength reached 46 KJ·m^{-2}, which increased nearly 10% compared to the non-nucleated nano- CaCO3/POE/PP composite and around 40.6% with the pure PP/POE resin. This increase can also be attributed to the crystallization endowed by the nucleate agent. The impact strength data showed that the PA-10, as an effective β-nucleating agent, can further improve the impact strength of KH-570 modified nano-CaCO$_3$/POE/PP composite just with the additive amount of 0.3 wt. %.

2.4.15HDT of PA-10/nano-CaCO$_3$/POE/PP composite

Fig. 15 shows the thermal deformation vicat softening point temperature of KH-570 modified nano-CaCO3/POE/PP composite(curve a) andPA-10/nano-CaCO$_3$ and b-PA-10/nano-CaCO3/POE/PP composite (curve b) with different content of modified nano-CaCO$_3$. The thermal deformation vicat softening point temperature gradually increased with the increase of KH-570 modified nano-CaCO$_3$in both case. Also, there is a significant and stable increase with the addition of nucleating agent regardless the content of nano-CaCO$_3$ particle. Compared with the POE/PP composite, the thermal deformation vicat softening point temperature of 30 wt.% KH-570 modified nano-CaCO$_3$/POE/PP and 0.3 wt.% PA-10/nano-CaCO$_3$/POE/PP composite is about 100.3 and 108.6 °C respectively, increased about 12.70 % and 10.37 %. The thermal deformation vicat softening point temperature curves showed that the PA-10, as an effective β-nucleating agent, can bring a decent improvement to the thermotolerance of KH-570 modified nano-CaCO$_3$/POE/PP composite. This increase can be ascribed to the crystallization enhanced by the nucleating agent. The crystal part is well-ordered compared to the amorphous part, thus the energy that crystal part needed to soften, that is to say to confer energy for moving of the molecule, is higher that the amorphous part. Since the nucleating agent can facilitate the crystalizing process thus increase the proportion of crystal part, the thermo property of the composite was significantly improved.The properties of PA-10/nano-CaCO$_3$/POE/PP composite with different content of modified nano-CaCO$_3$ were summarized in table 3.
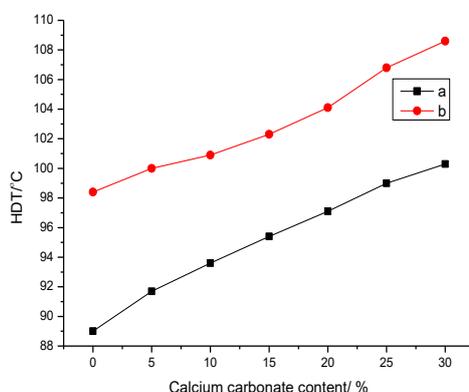

Fig.15 The thermal deformation vicat softening point temperature of a-KH-570 modified nano-CaCO$_3$/POE/PP composite and b-PA-10/nano-CaCO3/POE/PP composite with different content of modified nano-CaCO$_3$

Table 3 The properties of PA-10/nano-CaCO$_3$/POE/PP composite with different content of modified nano-CaCO$_3$

The content of modified nano-CaCO$_3$/wt. %	PA-10/wt. %	0	5	10	15	20	25	30
Tensile strength/MPa	0	0	19.7	20.6	21.9	22.5	22.1	21.6	20.9
	0.3	19	20.4	21.6	22	21.7	21.3	20.4
Impact strength/(KJ·m^{-2})	0	32	34	37	41	42	43	42
	0.3	33	36	38	43	46	46	45
HDT/°C	0	89	91.7	93.6	95.4	97.1	99	100.3
	0.3	98.4	100	100.9	102.3	104.1	106.8	108.6

VI.   Conclusion

In this paper the POE/PP composites with different POE content were first studied. As an excellent elastomer, POE toughened copolymerized PP can significantly improve the impact toughness, and elongation at break of the POE/PP system, while the flowability, tensile strength, impact strength, melt index and shore hardness decreased with the increase of POE. On the basis of the POE/PP system test data, the best adding quantity of POE should be controlled between 15-20 wt.%.Then different content of KH-570 modified nano-CaCO$_3$was added to the POE/PP resin to form nanocomposite. As an excellent surface modifier, the silane coupling agent KH-570 can effectively improve the dispersibility of nano-CaCO$_3$ in the POE/ PP resin matrix. And the KH-570 modified nano-CaCO$_3$, as a rigid inorganic filler can significntly improve the tensile and impact strength, at the same time the elongation at break property of the composite can be reasonably maintained. The tensile and impact strength of the KH-570 modified nano-CaCO$_3$/POE/PP composite, especially with 15wt. % KH-570 modified nano-CaCO$_3$, can reach 22.5 MPa and 32 KJ·m^{-2}, which increased about 14 % and 31 % respectively compared with the optimized pure POE/PP resin with 20 wt. % POE.

The β-nucleating agent PA-10 was introduced to further enhance the mechanical and thermo properties of nano-CaCO₃/POE/PP composites. As an excellent β-nucleating agent, PA-10 can improve the crystallinity of the PP resin, and the mechanical properties and thermostability of the nano-CaCO₃/POE/PP composite can correspondingly change with the PA-10. The results showed that 0.3 wt. % PA-10 can endow perfect β-modification without sacrificing the α-modification. PA-10 can slightly lower the tensile strength of KH-570 modified nano-CaCO₃/POE/PP composite with the additive amount of 0.3 wt. %, while the impact strength and thermal stability of PA-10/nano-CaCO3/POE/PP composite were increased by 10.37 % compare with the POE/PP composite.

Acknowledgements

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