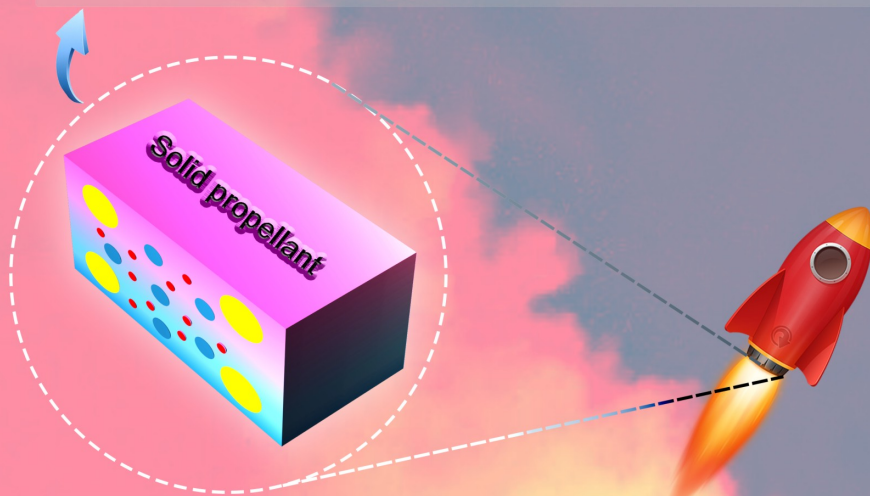
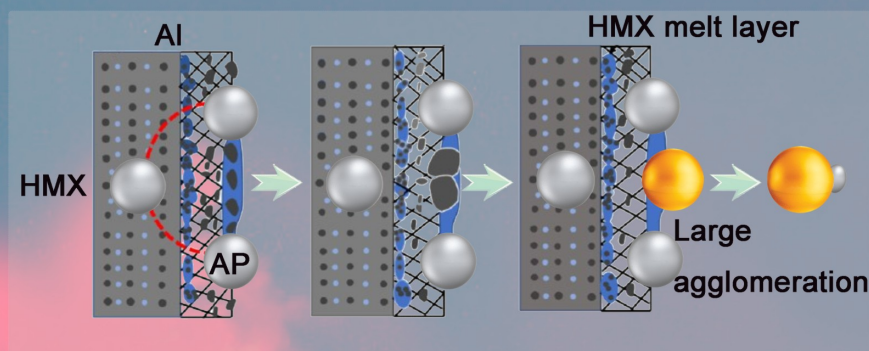


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# 含能材料

CHINESE JOURNAL OF ENERGETIC MATERIALS



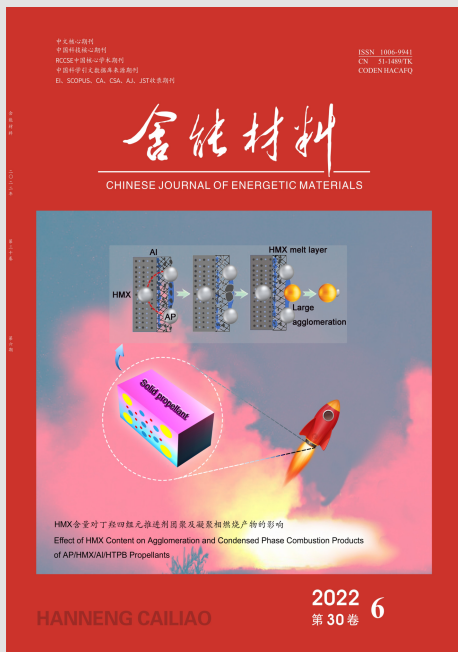
HMX含量对丁羟四组元推进剂团聚及凝聚相燃烧产物的影响

Effect of HMX Content on Agglomeration and Condensed Phase Combustion Products  
of AP/HMX/Al/HTPB Propellants

HANNENG CAILIAO

2022  
第30卷 6

HMX含量对丁羟四组元推进剂团聚及凝聚相燃烧产物的影响



为了提高固体推进剂的能量特性,推进剂中通常添加一定量的铝粉。然而,由于铝的熔点和沸点相差较大,因此推进剂在燃烧过程中,铝颗粒会在燃面发生团聚现象,所生成的大粒径团聚物对凝聚相燃烧产物的形成至关重要。目前,关于HMX影响推进剂铝团聚和凝聚相燃烧产物的研究较少,前期相关研究指出HMX会促进铝的团聚过程,然而HMX含量对推进剂燃面上铝团聚和凝聚相燃烧产物的影响规律,目前依然认识不清。西北工业大学苟东亮、敖文、刘露、吴浩明、刘佩进、何国强等研究人员采用推进剂燃面拍摄、激光点火和凝聚相燃烧产物等方法,对HMX含量为0~10%时的4种固体推进剂开展了相应的点火试验,并研究了HMX含量对推进剂点火、燃烧、团聚以及凝聚相燃烧产物的影响规律。结果表明:随着HMX含量的增加,推进剂的点火延迟时间由191 ms(含量为0)增加到286 ms(含量为10%),推进剂的燃速和压强指数均减小,凝聚相燃烧产物平均粒径由48.1  $\mu\text{m}$ 增加到138.3  $\mu\text{m}$ 。含10% HMX的推进剂燃面上铝的团聚程度最大,而含8% HMX的推进剂凝聚相燃烧产物中活性铝的含量最高。本研究为深入理解HMX对推进剂燃烧和团聚性能的影响提供了具体的理论和实验指导。

### 铝聚还赢

封面以奥克托今(HMX)推进剂在含铝(Al)的团聚和相关凝聚相燃烧产物为主体,向读者展示了推进剂燃烧过程中,AP/HMX/Al固体推进剂的关键变化过程。封面用方块表示固体推进剂的微观结构,其中AP颗粒在HMX中构成一个“口袋”的形状(图中红色虚线部分),整体推进剂由这样的一个个口袋构成,且团聚主要发生在口袋内,图中不同的团聚铝颗粒表示离开燃面的燃烧铝颗粒明显大于推进剂内部的铝颗粒。

封面效果 / @山鹰·翼筒设计

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## Energetic Express

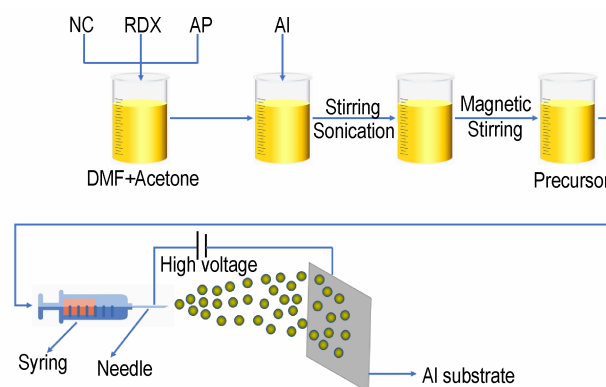
P527

### Preparation and Property

#### Preparation and Characterization of RDX/NC/AP/Al Composite Energetic Microspheres Based on Zero-oxygen Balance

Ji Wei, XU Yu-xuan

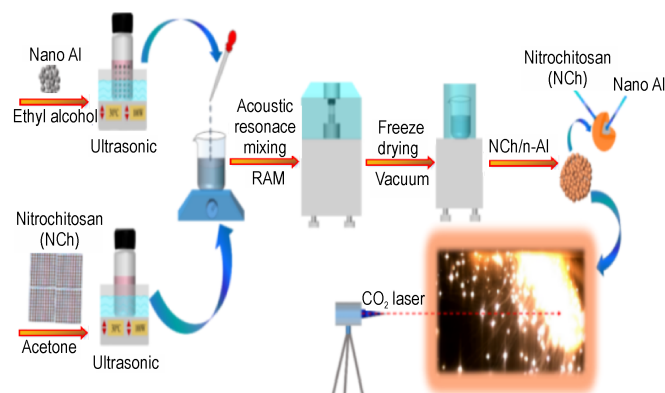
**P528** In order to take into account the mechanical properties, RDX/AP/NC/Al composite explosives based on zero oxygen equilibrium were prepared by electrostatic spray method. Scanning electron microscopy (SEM), fourier transform infrared spectroscopy (FT-IR), thermogravimetric differential scanning calorimeter (TG-DSC), mechanical sensor and high-speed photography were used to analyze the product.



#### Resonance Preparation and Combustion Characteristics of Nitrochitosan/n-Al Nanocomposite

ZHANG Wen-zhen, QIN Zhao, YI Jian-hua, LI Hai-jian, CHEN Su-hang, XU Kang-zhen

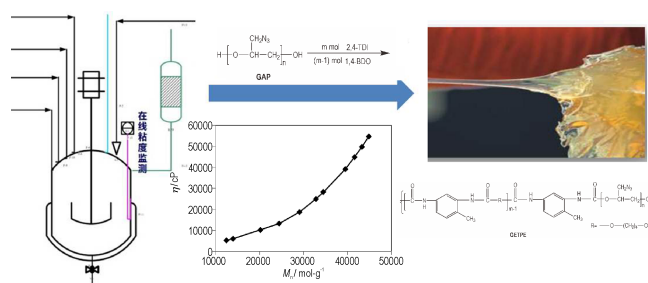
**P535** Using honeycomb network structured nitrochitosan as coating agent, a new nanocomposite NCh/n-Al was prepared by acoustic resonance method. The morphology, structure and combustion performance of NCh/n-Al were investigated by XRD, SEM, TEM and laser ignition, and compared with that of NC/n-Al composite.



#### Controllable Polymerization and Application of GAP-based Energetic Thermoplastic Elastomers

LU Xian-ming, CHEN Miao, MO Hong-chang, XU Ming-hui, LIU Ning

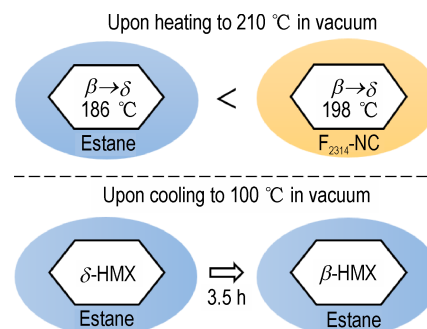
**P542** The number-average molecular weight ( $M_n$ ) of GAP-based energetic thermoplastic elastomers (GETPE) can be accurately controlled by on-line viscosity monitoring method. This work can improve the quality stability of GETPE and meet the requirements of thermoplastic elastomers with different  $M_n$  for explosives.



## Effects of Binders on the Phase Transition Behavior of HMX

SHI Jing, LI Lan, LIU Jia-hui, BAI Liang-fei, LI Xin-xi,  
DUAN Xiao-hui, TIAN Qiang

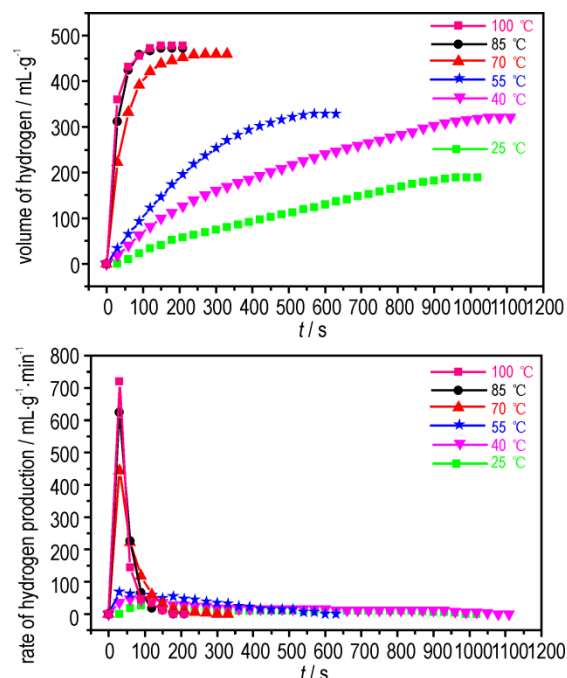
**P550** The phase transition behavior of HMX-Estane (polyurethane), HMX-F<sub>2314</sub> (fluororubber), HMX-F<sub>2314</sub>-NC (nitrocellulose), and HMX pellet, prepared by compression molding, was studied by variable temperature wide-angle X-ray scattering. Addition of a small amount of NC to the binder significantly inhibited the  $\beta \rightarrow \delta$  phase transition. However, Estane promoted the  $\beta \rightarrow \delta$  phase transition and its inverse transition in vacuum. These results shed light on the importance of polymer binders on the phase transition of explosive crystals and the interactions between binders and HMX.



## Aluminum/water Reaction Mechanism of Aluminum-based Hydrogels

GUO Chun-yu, LI Ting-run, ZHAO Yang-yang, BAO Shu-xia,  
ZHANG Hui-juan, WU Rui-feng

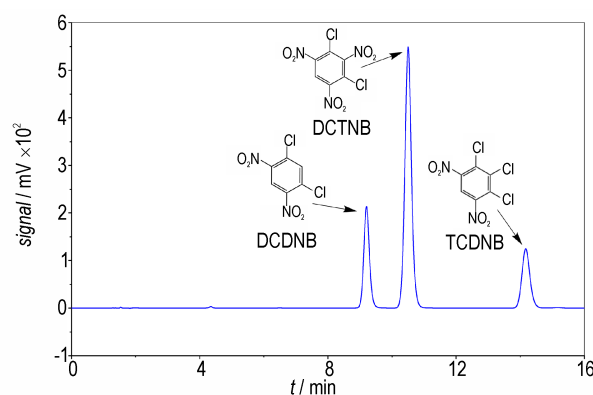
**P557** In order to study the aluminum-water reaction characteristics of PVA-nAl/HTPB, the hydrogen production and hydrogen production rate of the reaction of PVA-nAl/HTPB with 0.1 mol·L<sup>-1</sup> NaOH at different temperatures were explored. When the temperature reaches 100 °C, the maximum hydrogen production of PVA-nAl/HTPB is 478 mL·g<sup>-1</sup>, and the maximum hydrogen production rate is 720 mL·g<sup>-1</sup>·min<sup>-1</sup>.



## Purity Analysis of 1,3-Dichloro-2,4,6-Trinitrobenzene by High Performance Liquid Chromatography

LIU Yun-zhang, HE Jia-yuan, XIAO Yun, CHEN Li-zhen,  
WANG Jian-long

**P564** In this work, an HPLC method for purity analysis of DCTNB was developed and further validated by studying the influence of chromatographic conditions such as mobile phase system and ratio, flow rate, column temperature, and injection volume.



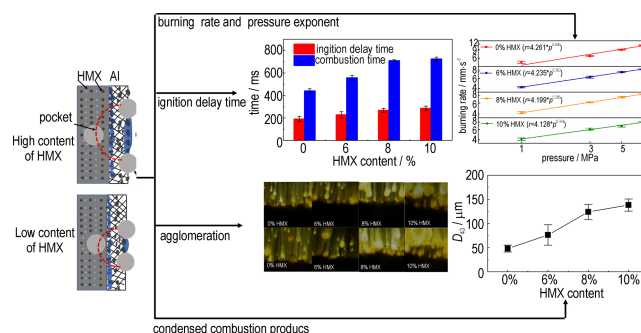


## Propulsion and Projection

### Effect of HMX Content on Agglomeration and Condensed Phase Combustion Products of AP/HMX/Al/HTPB Propellants

GOU Dong-liang, AO Wen, LIU Lu, WU Hao-ming, LIU Pei-jin, HE Guo-qiang

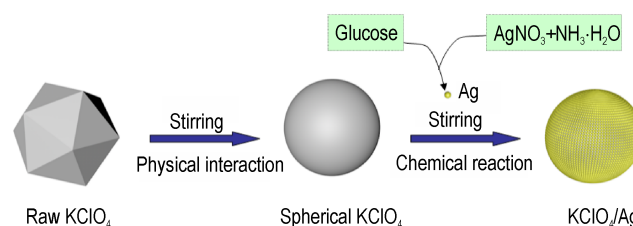
**P571** In order to comprehensively study the effect of HMX content on combustion, agglomeration and condensed phased combustion products (CCPs) of solid propellant, typical AP/HTPB/Al/HMX propellants with HMX contents ranging 0%–10% were tested through a variety of experimental methods, including burning surface photography, laser ignition and collection of the CCPs. Ignition delay time, burn rate, image of aluminum agglomeration and particle size distribution of CCPs were obtained and the mechanism of HMX on combustion and agglomeration of the propellant was analyzed.



### Preparation and Properties of KClO<sub>4</sub>/Ag Composite Particles

LU Guo-qiang, CHEN Shu-bing, CHEN Shu-fang, WU Wen-qi, WANG Xu-bo, HUANG Hong-yong

**P579** The composite particles of KClO<sub>4</sub>/Ag were prepared by modifying the surface of KClO<sub>4</sub> particles by the reaction of glucose and silver ammonia solution. Compared with the initial raw KClO<sub>4</sub>, KClO<sub>4</sub>/Ag composite particles have higher thermal decomposition efficiency and lower mechanical sensitivity.

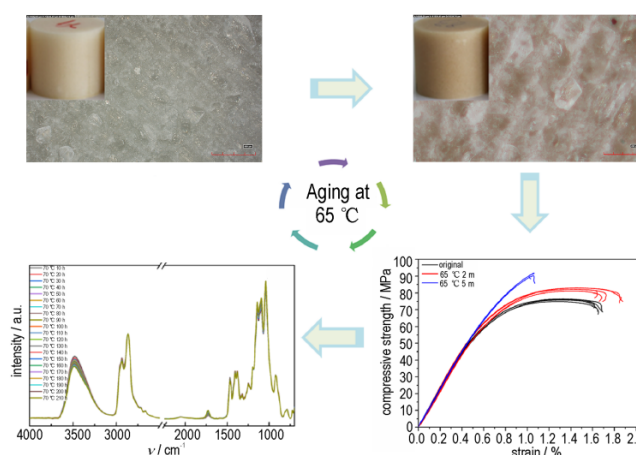


## Safety Performance and Assess

### The Aging Performance of Acrolein Pentaerythritol Resins-based Casting PBX

GONG Zheng, XIAO Qian, WANG Lin, ZHU Rong-hai, SUI He-liang, WEI Cheng-sha

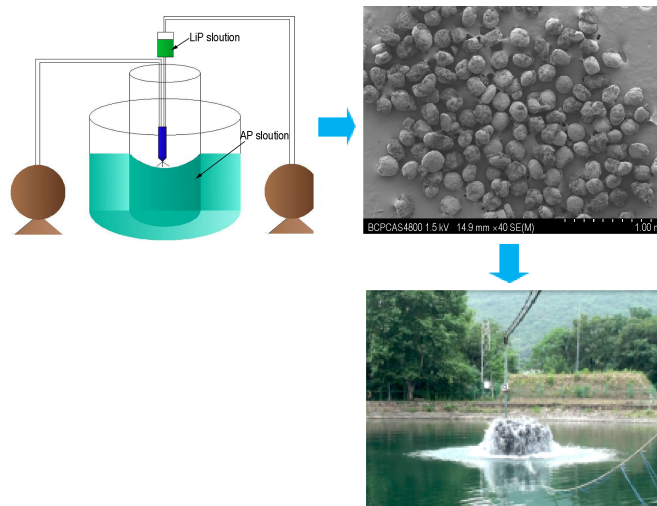
**P584** The aging properties of acrolein-pentaerythritol resins-based casting PBX were investigated by accelerated aging at 65 °C, and were characterized via various analysis methods, including *in-situ* Infrared Spectroscopy (IR), 3D-Super Depth of Field Digital Microscope, Scanning Electron Microscope (SEM) and Universal Testing Machine for mechanical properties. Through experimental design, the mass loss, dimensional stability, microstructure and mechanical properties were firstly studied. Subsequently, the mechanisms of the weight loss and the improvement of mechanical properties of the PBX columns were analyzed and discussed.



## Effects of Novel Oxidant Composite AP-LiP on the Energy Output Structure of Underwater Explosion

XU Yang, WANG Zhong

**P591** A novel oxidant of composite ammonium perchlorate-lithium perchlorate was prepared by solvent evaporation method. The power parameters of underwater explosion of three PBXs containing different oxidants were tested and compared.

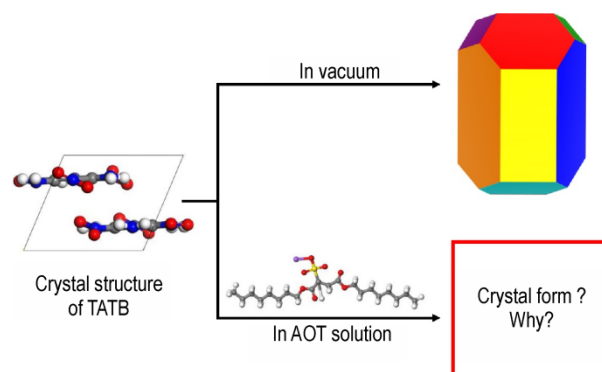


## Calculation and Simulation

### Molecular Dynamics Simulations for Interfacial Interactions of TATB with AOT

WEI Xian-feng, LIU Min, WEN Tao, YANG Guang-cheng,  
GUO Chang-ping

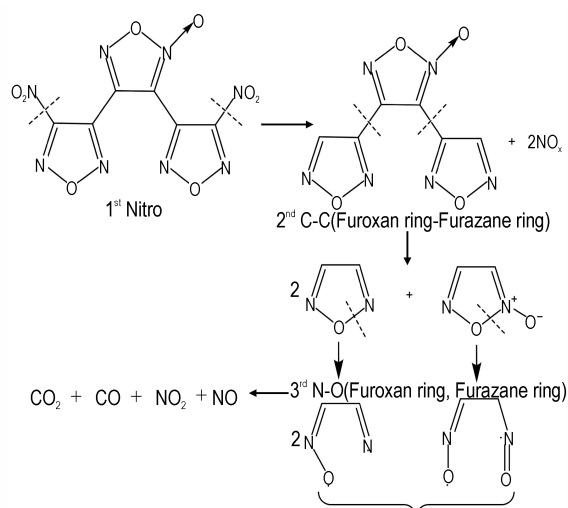
**P597** The interfacial interactions between TATB and AOT solution were analyzed through molecular dynamics simulations. Combined with the phenomenon during the experiment, the effect of AOT on the crystallization process of TATB was obtained. This work enriches the research content of TATB crystallization technology and the conclusions could become a reference for the safe development of TATB.



### Thermal Decomposition Kinetics and Mechanism of DNTF by in Situ Infrared Technology

NAN Hai, PAN Qing, JIANG Fan, WANG Xuan-jun, JIN Peng-gang,  
ZHANG Kun

**P604** Through the infrared analysis of DNTF during the heating process at room temperature, the variation law of the characteristic groups of DNTF with temperature was obtained. By using molecular dynamics method, the thermal decomposition properties and molecular structure of the characteristic groups of DNTF were modeled and calculated. Combining infrared analysis and calculation, the thermal decomposition mechanism of DNTF was speculated.

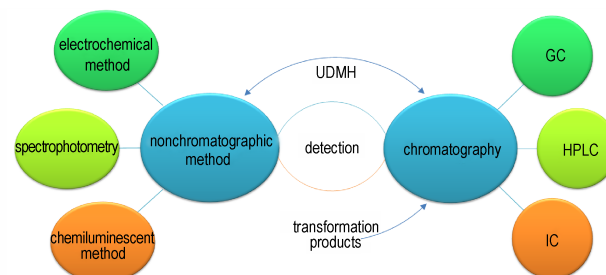


## Reviews

### Progress Progress on Detection Methods of UDMH and Its Transformation Products in Water

GAO Xin, YANG Yu-xue, LU Xin, CHENG Jin-xing, GAO Ying,  
ZHANG Tian-yi, HAN Jun-jie, YU Ai, ZHANG Yue

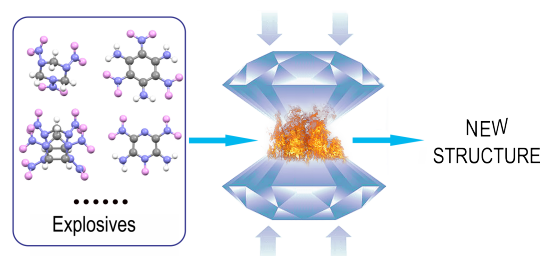
**P611** The detection methods of unsymmetrical dimethylhydrazine (UDMH) in water as well as its transformation products were reviewed.



### Progress in Structural Evolution of Explosives under High-temperature and High-pressure

DENG Zhi-ying, WANG Yi, QI Guang-yu, ZHANG Qing-hua

**P622** The structural evolution of twelve different explosives at high-temperature and high-pressure is reviewed. There are numerous studies focusing on common explosives, which still need to promote. For example, HMX takes four phase transitions upon compression.



Executive editor: GAO Yi WANG Yan-xiu JIANG Mei