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Photoelectric Properties of ZnSe/ZnCdSeTe Superlattice Nanotips

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ABSTRACT

We report the growth of ZnSe/ZnCdSeTe superlattice nanotips on oxidized Si(100) substrate by molecular beam epitaxy (MBE). It was found the nanotips exhibit mixture of cubic zinc-blende and hexagonal wurtzite structures system. It was also found that photoluminescence intensities observed from the ZnSe/ZnCdSeTe superlattice nanotips were much larger than that observed from the homogeneous ZnCdSeTe nanotips. Furthermore, it was found that activation energies for the ZnSe/ZnCdSeTe superlattice nanotips with well widths of 12, 16, 20 and 24 nm were 189, 205, 292 and 240 meV, respectively.

Keywords: Quaternary ZnCdSeTe, ZnSe/ZnCdSeTe Superlattice Nanotips, MBE.

1. Introduction

One-dimensional (1D) semiconductor materials have attracted much attention in recent years [1-4]. With a significantly larger surface-to-volume ratio, 1D semiconductor materials exhibit unique properties that make them desirable for use in many novel device applications. Among the various 1D semiconductor materials, ZnO nanowire/nanotips have been extensively studied. ZnO is an n-type group II-VI semiconductor material with large exciton binding energy and wide bandgap energy. However, it is well known that p-type ZnO is very unstable. As a result, it is difficult to achieve ZnO-based p-n junction devices with good reliability. Similar to ZnO, ZnSe is also a wide bandgap II-VI semiconductor with large exciton binding energy [5-7].

In contrast to ZnO, one can achieve stable p-type ZnSe easily through proper doing. Furthermore, it is possible to form ZnSe-based heterostructures easily. With these advantages, planar ZnSe-based devices, such as light emitting diodes [8], laser diodes [9] and photodiodes [10] have all been demonstrated. With similar heterostructures, we should also be able to achieve 1D ZnSe-based nano-devices with much better reliability, as compared to 1D ZnO-based nano-devices. It is also possible to prepare ZnSe-based nanowires/tips with superlattice structure. For these superlattice nanowires/tips, the longitudinal confinement could couple with radial confinement. This should provide more functionalities for the superlattice nanowires/tips [11]. To realize ZnSe-based superlattice nanowires/tips, it is necessary to form ternary/quaternary nanowires/tips. The growth of ternary ZnCdSe nanowires/tips has already been demonstrated by Colli et al. [12].

Compared to ternary ZnCdSe, the quaternary ZnCdSeTe provides an extra degree of freedom to control the bandgap energy and lattice constant. By controlling the composition ratios among Zn, Cd, Se and Te, we should be able to grow lattice matched ZnCdSeTe on ZnSe with adjustable bandgap energy [13]. Furthermore, it has been reported that binding energy of Te bound excitons in related II-VI compound semiconductors is very large. Extremely strong room temperature photoluminescence (PL) and electroluminescence (EL) signals were detected from the ZnCdSeTe nanowires/tips. These findings indicate that ZnCdSeTe nanowires/tips are promising for novel device applications.
also observed from localized excitons bound to Te atom (Te\textsubscript{1} emission) and Te\textsubscript{n} (n\geq2) cluster (Te\textsubscript{n} cluster emission) in planar ZnSeTe films [14-16]. It has also been shown that the extrinsic self-trapping of excitons (STE) formed in Te-related emission in ZnSeTe films could provide a much higher luminescence efficiency, as compared to free excitons [17-22]. These observations suggest that Te-containing II-VI nanowires/tips are potentially useful for various photonic applications. In this study, we report the growth of ZnSe/ZnCdSeTe superlattice nanotips on oxidized Si(100) substrate. Structural, physical and optical properties of these nanotips will also be discussed.

2. Experimental Details

The ZnSe/ZnCdSeTe superlattice nanotips used in this study by a Riber 32P solid source molecular beam epitaxy (MBE) system on oxidized Si(100) substrate using vapor-liquid-solid (VLS) mechanism with an Au-based nano-catalyst. The source materials for the MBE system were elemental Zn (6N), Cd (6N), Se (6N) and Te (6N). Prior to the growth of the nanotips, Si(100) substrates were first immersed in boiled acetone for 10 min, in boiled isopropyl alcohol for 10 min, and in hydrofluoric acid solution for 30 sec. The chemically cleaned Si substrates were thermally oxidized to form a 150-nm-thick SiO\textsubscript{2} film. This SiO\textsubscript{2} film acts as a catalyst diffusion barrier [23]. A 0.6-nm-thick Au film was then deposited onto the SiO\textsubscript{2} layer by sputtering. The samples were then loaded onto the preparation chamber and annealed at 280°C to transfer Au film into Au nano-particles [24]. Subsequently, the substrate was transferred into the growth chamber to grow of ZnSe/ZnCdSeTe superlattice nanotips at 280°C for \~1 hour.

It has been shown previously that ZnSe nanowires can be grown by MBE based on Au-catalyzed VLS deposition [12]. Similar growth mechanism should be applied to the growth of ZnSe/ZnCdSeTe nanotips in this study. During the growth of quaternary ZnCdSeTe nanotips, we carefully controlled beam equivalent pressures of Zn, Cd, Se and Te so as to keep the composition ratios at Zn:Cd=87:13 and Se:Te=98:2. Figure 1 shows schematic diagrams of the VLS growth procedure and the energy band diagram of our ZnSe/ZnCdSeTe superlattice nanotips. With Au nano-particles dispersed on the oxidized Si substrate, eutectic Au-Zn alloy droplets were first formed [25, 26]. The deposited source atoms (i.e., Zn, Cd, Se and Te) were then diffused along the nanotip sidewalls to form the ZnCdSeTe and ZnSe/ZnCdSeTe nanotips. For the growth of the ZnSe/ZnCdSeTe superlattice nanotips, we carefully controlled the growth time so as to achieve the designated thickness. We prepared samples with four different ZnCdSeTe well layer thickness (i.e., \(L\textsubscript{w}=12, 16, 20\) and 24 nm) while the ZnSe barrier layer thickness was kept at 78 nm. Growth interruptions were also introduced at each ZnSe/ZnCdSeTe interface by stopping the growth for 30 seconds.

After the growth, surface morphology of the samples was characterized by a Hitachi S-4700I field-emission scanning electron microscope (FESEM) operated at 15kV. A Philips FEI TECNAI G\textsuperscript{2} high resolution transmission electron microscopy (HRTEM) operated at 200kV and a Siemens D5000 X-ray Diffractometer (XRD) system were used to evaluate crystallographic and structural properties of the as-grown nanotips. Photoluminescence (PL) property of these nanotips was also characterized by a continuous wave (CW) He-Cd laser operated at 325 nm as the excitation source. The luminescence signal generated from the samples was then recorded by a lock-in amplifier at 20K to 160K.

Fig. 1. Schematic diagrams of the VLS growth procedure and the energy band diagram of our ZnSe/ZnCdSeTe superlattice nanotips.
3. Result and Discussion

3.1 FESEM and TEM

Figures 2(a), 2(b), 2(c) and 2(d) show top-view FESEM images of the ZnSe/ZnCdSeTe superlattice nanotips with $L_w = 12$, 16, 20 and 24 nm, respectively. It was found that high density tapered nanotips were grown on the oxidized Si substrates for all four sample. It was also found that average length of these nanotips were about 1µm. It has been reported previously that the geometry of ZnSe 1D nanostructure prepared by MBE depends strongly on the growth temperature [31]. At high temperatures (i.e., 350-450°C), nanowires with high aspect ratios were formed. On the other hand, needle-shaped structures with wide base and sharp tip were formed at low temperatures (i.e., ~300°C) due to the low migration speed of adatoms. Since the samples used in this study were grown at 280°C, we thus achieved nanotips instead nanowires, as shown in Figures 2(a), 2(b), 2(c) and 2(d).

Figure 3 shows HRTEM image of one randomly selected ZnSe/ZnCdSeTe superlattice nanotip with $L_w = 24$ nm. Insets in figure 2 show Fast Fourier transform (FFT) patterns measured from three different points in this particular superlattice nanotip. These FFT patterns indicate that points 1 and 3 (ZnCdSeTe well layers) exhibit mixed zinc-blend and wurtzite structure while point 2 (ZnSe barrier layer) exhibits zinc-blende structure. From the HRTEM image, it can be seen that the interfaces between zinc-blend and wurtzite domains were sharp with very few defects. The sharp interfaces observed in this HRTEM image should be attributed to the use of growth interruption at each ZnSe/ZnCdSeTe interface.

![Fig. 2. Top-view FESEM images of the ZnSe/ZnCdSeTe superlattice nanotips with $L_w$= (a) 12 nm, (b) 16 nm, (c) 20 nm and (d) 24 nm.](image)

![Fig. 3. HRTEM image of one randomly selected ZnSe/ZnCdSeTe superlattice nanotip with $L_w$ = 24 nm. Insets show FFT patterns measured from three different points in this particular superlattice nanotip.](image)
3.2 X-ray diffraction

Figure 4 shows XRD spectra measured from the four ZnSe/ZnCdSeTe superlattice nanotips. Table 1 lists the point group II-VI semiconductors, with various crystal structures and lattice constants, using Joint Committee on Powder Diffraction Standards (JCPDS). It was found that the diffraction peaks observed in figure 6 could all be exclusively indexed by the cubic zinc-blende and hexagonal zinc-blende crystal structures. These peaks again indicate that our ZnSe/ZnCdSeTe superlattice nanotips exhibit mixture of zinc-blende and zinc-blende structures. It can also be seen that FWHMs of the observed XRD peaks were small. This suggests reasonably good crystal quality of our ZnSe/ZnCdSeTe superlattice nanotips.

![XRD spectra measured from the four ZnSe/ZnCdSeTe superlattice nanotips.](image)

Table 1. Crystal structure and lattice constants of group-II-VI semiconductors.

<table>
<thead>
<tr>
<th>Material (II-VI)</th>
<th>Crystal structure</th>
<th>a (nm)</th>
<th>c (nm)</th>
<th>JCPDF card</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-ZnSe</td>
<td>ZB</td>
<td>0.567</td>
<td></td>
<td>05-0522</td>
</tr>
<tr>
<td>w-ZnSe</td>
<td>WB</td>
<td>0.3996</td>
<td>0.655</td>
<td>15-0105</td>
</tr>
<tr>
<td>c-CdSe</td>
<td>ZB</td>
<td>0.6077</td>
<td></td>
<td>19-0191</td>
</tr>
<tr>
<td>w-CdSe</td>
<td>WB</td>
<td>0.430</td>
<td>0.702</td>
<td>02-0330</td>
</tr>
<tr>
<td>c-ZnTe</td>
<td>ZB</td>
<td>0.6102</td>
<td></td>
<td>15-0746</td>
</tr>
<tr>
<td>w-ZnTe</td>
<td>WB</td>
<td>0.431</td>
<td>0.709</td>
<td>19-1482</td>
</tr>
<tr>
<td>c-CdTe</td>
<td>ZB</td>
<td>0.6481</td>
<td></td>
<td>15-0770</td>
</tr>
<tr>
<td>w-CdTe</td>
<td>WB</td>
<td>0.458</td>
<td>0.750</td>
<td>19-0193</td>
</tr>
<tr>
<td>c-ZnSe0.95CdTe0.05</td>
<td>ZB</td>
<td>0.606</td>
<td></td>
<td>65-7966</td>
</tr>
</tbody>
</table>

3.3 PL spectra and integrated PL intensities

Figure 5 shows PL spectra of the four ZnSe/ZnCdSeTe superlattice nanotips measured at 20K. It can be seen clearly that the observed PL peak blue-shifted from 496.5 to 473.5 nm as we decreased the ZnCdSeTe well layer thickness, $L_w$, from 24 to 12 nm. This should be attributed to the quantum confinement effect [32]. The much larger PL intensities should be attributed to the effective confinement of carriers in the well layers. Figures 6(a), 6(b), 6(c) and 6(d) show Arrhenius plots of the integrated PL intensities measured from the ZnSe/ZnCdSeTe superlattice nanotips with $L_w$ = 12, 16, 20 and 24 nm, respectively. It was found that we can fit the experimental data since the temperature dependence of the integrated PL intensities could be expressed as follows [33]:
\[ I(T) = \frac{I_0}{1 + A \exp(-E_A/kT)} \]  

(1)

where \( I_0 \) is the integrated PL intensity at low temperatures, \( k \) is the Boltzmann's constant, \( k \) is temperature, \( A \) is rate constants while \( E_A \) is the activation energy, respectively. As shown in figures 6(a), 6(b), 6(c) and 6(d), it was found that the activation energies were 189, 205, 292 and 240 meV for the ZnSe/ZnCdSeTe superlattice nanotips with \( L_w \) = 12, 16, 20 and 24 nm respectively. It should be noted that these values were also larger than that observed from the previously reported homogeneous ZnSe nanowires [34]. At high temperatures, PL quenching in quantum wells is primarily due to the thermal emission of charge carriers from the confined quantum well states into the barrier states [35]. Compared with homogeneous ZnSe nanowires, the much larger activation energies observed in figures 6(a), 6(b), 6(c) and 6(d) suggest that the ZnSe/ZnCdSeTe superlattice nanowires reported in this study are potentially useful for feasible nano-photonic application.

Fig. 5.  PL spectra of the four ZnSe/ZnCdSeTe superlattice nanotips measured at 20K.

Fig. 6.  Arrhenius plots of the integrated PL intensities measured from the ZnSe/ZnCdSeTe superlattice nanotips with \( L_w \) = (a) 12 nm, (b) 16 nm, (c) 20 nm and (d) 24 nm.
4. Conclusion

In summary, we reported the growth of ZnSe/ZnCdSeTe superlattice nanotips on oxidized Si(100) substrate by MBE using VLS mechanism with an Au-based nanocatalyst. It was found that the as-grown ZnSe/ZnCdSeTe superlattice nanotips exhibit mixture of cubic zinc-blende and hexagonal wurtzite structures. It was also found PL intensities observed from the ZnSe/ZnCdSeTe superlattice nanotips were significantly larger than that observed from the homogeneous ZnCdSeTe nanotips.

References

Hybrid Organic Solar Cells Based on ZnS Nanoparticles

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ABSTRACT

We report on the realization of high-efficiency heterojunction organic solar cells (OSCs) based on P3HT/PCBM on transparent ITO substrates, and we control the concentration of ZnS nanoparticles (NPs) in the active layer of such OSCs. Furthermore, we have compared the OSCs with and without ZnS NPs, their efficiency were 0.72% and 0.45%, respectively. As a result, the efficiency of photovoltaic cells can be enhanced by using ZnS NPs as hybrids.

Keywords: Organic Solar Cells, Interfacial Layer, Nanoparticles.

1. Introduction

As a potential alternative to expensive silicon solar cells, OSCs got into the focus of research interest in the last years [1, 2]. The technology compared with silicon devices offers many advantages.

However, OSCs have attracted great attention due to the advantages of light weight, flexibility, and low cost with the possibility of fabricating large area device by cheaper liquid based process [3]. The power conversion of OSCs is limited by the low dissociation probability of excitons and inefficient hopping carrier transport [4]. Therefore, improving the performance of the solar cells has been recently resolved by mixing inorganic materials in the absorption layer. Hybrid OSCs will improve carrier mobility, light absorption and charge transport. From device point of view, regior egular poly (3-hexylthiophene) (RR-P3HT) and highly soluble fullerene derivative [6,6]-phenyl C61 butyric acid methyl ester (PCBM) blend represents the state-of-the-art system [5, 6]. To increase cell performance, nanoparticles can also be added into OSCs mixed with [6,6]-phenyl-C60-butyric acid methyl ester (PCBM) to further increase light absorption, improvement of exciton dissociation and better charge transport [7-9]. But the materials are limited to the questions of carrier transport and combination.

In this research, ZnS NPs are made to interpenetrate into the polymeric layer and used to enhance both absorption of photon and charge transport. The P3HT:PCBM used as the absorption layer of organic solar cells. Adding the PCBM with a different absorption spectrum from both the ZnS NPs and P3HT and is expected to increase absorption spectrum. Therefore, we adjust the concentration of ZnS NPs in parameter of fixing three kinds of different P3HT:PCBM, to find out the best concentration and realize ZnS NPs can reduce PCBM concentration to reach the possibility to reduce cost.

2. Experimental Details

The hybrid solar cell structure of ZnS NPs is shown in Figure 1. The samples were cleaned in the ultrasonic bath
of acetone and isopropanol, rinsed in deionized water, dried in an oven. Both the PEDOT and P3HT: PCBM layers were prepared by sol-gel technique on the ITO substrate. Then, the active layer was deposited in a glove box under controlled atmosphere by coating. Our active layer from the parameters of Table 1 mixed, and the organic solar cells were fabricated onto indium tin oxide (ITO) coated glass substrates.

Fig. 1. Schematic of the hybrid solar cell structure with ZnS NPs mixed in conjugate polymer.

In other to estimate the efficiency of the photovoltaic cell, the current-voltage (I-V) characteristics of the cells were measured by TELTEC. The data were measured under white light simulated illumination AM1.5, 100 mW/cm². In addition, we also utilize some instruments to measure and examine photovoltaic cell with Ca, including “Incident Photon Conversion Efficiency (IPCE)”, “UV-VIS-NIR Spectrophotometer” and “Scanning Electron Microscopy (SEM).”

Table 1. Hybrid solar cells for different ZnS NPs concentrations mixed in the active layer.

<table>
<thead>
<tr>
<th>P3HT:PCBM</th>
<th>ZnS (wt%)</th>
<th>0 wt%</th>
<th>15 wt%</th>
<th>30 wt%</th>
<th>45 wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:0.3</td>
<td>Standard-1</td>
<td>ZnS-1</td>
<td>ZnS-2</td>
<td>ZnS-3</td>
<td></td>
</tr>
</tbody>
</table>

3. Result and Discussion

The topography of the polymer surface was characterized by AFM as shown in figures 2 (a), (b), and (c). As shown in figure 2, the surface roughness of increases with ZnS NPs concentration is 3.9685, 2.9605, 2.3596 nm, respectively, for ZnS NPs concentration from ZnS-1 to ZnS-3. These results indicate that adding more NPs, and the surface roughness decreased. Therefore, the increase of ZnS NPs concentration will affect the density increases, and the surface will become smoother. These results will improve the surface structure of P3HT:PCBM. This will reduce the series resistance and improve the efficiency of conversion.

Fig. 2. The AFM topography of the polymer surface (P3HT/PCBM/ZnS NPs). (a) ZnS-1, (b)ZnS-2, (c)ZnS-3.
The optical absorption spectrum shows different optical properties of hybrid organic materials in Figure 3. The P3HT:PCBM material main absorption band from 430 to 680. Observation of Table 2, the absorbance spectra of standard-1 is 521 nm, the absorbance of ZnS-1 is 521 nm, the absorbance spectra of ZnS-2 is 521, and the absorbance spectra of ZnS-3 is 527 nm, respectively. The absorption spectrum reveals red shift of adding ZnS NPs in the active layer. After adding ZnS NPs, the result can increase the absorption of the residual light.

![Image](image.png)

**Fig. 3.** The absorption spectra for different ZnS NPs concentrations mixed in the active layer.

The extracted device parameters are summarized in Table 2. For the device without ZnS NPs on the active layer, the efficiency is 0.45%. When adding ZnS NPs on the active layer, all device performances improved. The efficiency of adding ZnS NPs in active layer increases from 0.45% to 0.72%. Therefore, we can clearly determine what adding ZnS NPs can improve the conversion to increase efficiency and reduce the series resistance. Because adding inorganic materials usually with very high carrier mobility to enhance both absorption of photon and charge transport [3]. Because the ZnS-3 may be agglomeration in the active layer, lead to the fill factor (FF) of the ZnS-3 decreased. Figure 4 shows the EQE spectra of the hybrid solar cell. Greatest peak of P3HT:PCBM is in 490 nm, EQE is 10.8 %. From figure 4, adding ZnS NPs can enhance both absorption of photon, charge transport, and decrease electron-hole pair recombination and much higher efficiency.

<table>
<thead>
<tr>
<th></th>
<th>Standard-1</th>
<th>ZnS-1</th>
<th>ZnS-2</th>
<th>ZnS-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jsc (mA/cm²)</td>
<td>1.840</td>
<td>1.310</td>
<td>1.800</td>
<td>3.300</td>
</tr>
<tr>
<td>Isc (mA)</td>
<td>0.073</td>
<td>0.052</td>
<td>0.072</td>
<td>0.132</td>
</tr>
<tr>
<td>Voc (V)</td>
<td>0.600</td>
<td>0.650</td>
<td>0.650</td>
<td>0.650</td>
</tr>
<tr>
<td>R (ohm)</td>
<td>956.256</td>
<td>916.200</td>
<td>352.671</td>
<td>388.623</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>0.450</td>
<td>0.460</td>
<td>0.650</td>
<td>0.720</td>
</tr>
<tr>
<td>FF (%)</td>
<td>41.290</td>
<td>54.070</td>
<td>55.300</td>
<td>40.590</td>
</tr>
</tbody>
</table>

**Table 2.** Short-circuit current density (Jsc), open-circuit voltage (Voc), power conversion efficiency (PCE), and fill factor (FF) of various PV devices.
4. Conclusion

To summarize, a highly efficient hybrid polymer solar cell has been demonstrated by adding ZnS NPs in the active layer. The achieved efficiency of 0.72 is comparable to our best result of the standard-1 structure device. The XRD studies reveal the surface of the active layer can smoother with adding ZnS NPs. This will reduce the series resistance and improve the efficiency of conversion.

References

Experimental Research on Two-stroke and Four-stroke Gasoline Engine with Alcohol Fuel

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ABSTRACT

The purpose of this research is to explore experimentally the influences of gasoline-alcohol blended fuel on the performance of single cylinder two-stroke and inline-four cylinder gasoline engines. The research was conducted within 30% of alcohol and by blending 98 unleaded gasoline and 95% alcohol to form alternative fuels of various blending ratios. The engine performances, containing: engine speed, torque, output power, driving load, fuel pressure, manifold vacuum and oxygen content variation, were tested to obtain the optimum fuel blending ratio for the purpose of energy-saving. The research is divided into two parts: firstly, the test was carried out based on the engine of single cylinder two-stroke mower with 22c.c. air displacement, whereas a test bench and a power testing equipment were developed depending on the performance of the power system. Under different speeds, the alcohol-gasoline blended fuel of different blending ratios (3%-15%) was used to explore the difference with respect to torsion, torque, output power and driving load of low horsepower engine versus that without alcohol. Secondly, the test was performed using a 1834c.c in-line four cylinder engine, which consists of an ECM control system, a sensor (input component) and an actuator (output component). Of which, ECM can control the actuator according to the signals from the sensor, so as to optimize the working status of the engine for meeting various operating demands. For alcohol-gasoline blend fuel with different blending ratios (1%-30%), the fuel pressure, manifold vacuum, oxygen content and air flow variation were researched and compared with those without alcohol. The experiment results show that, the torsion, torque, output power and driving load of two-stroke engine can achieve better performance when the proportion of alcohol is 10%; as for four-stroke engine, when the proportion of alcohol is 20%, a better efficiency of fuel pressure can be realized; when the proportion of alcohol is 15%, a better efficiency of manifold vacuum and air flow can be realized; when the proportion of alcohol is 10%, a better efficiency of oxygen content can be realized. The research results can thus provide a reference for the researchers in vehicle industry.

Keywords: Two-stroke Engine, Four-stroke Engine, Engine Performance, Gasoline-alcohol Blended Fuel.

1. Introduction

With the industrial and technological progress in recent dozens of years, fossil fuel has been extensively applied, leading to sharp reduction of oil reserve, continuous price rise of raw oil and subsequent global oil crisis. Thus, there is an urgent demand of research and development of alternative fuels, given the fact that the usage of alternative energy has greatly reduced the reliance on raw oil and gradually alleviated oil crisis.

According to the research on alcohol gasoline, the vehicles powered by alcohol-gasoline blended fuel not
only have excellent horsepower, torsion and acceleration, but also present good resistance to explosion and lower cost with sharp reduction of emission of harmful gas.

To mitigate the green house effect, it is necessary to minimize the usage of non-renewable resources. In this respect, European countries and the U.S. have developed available biomass energies through energy conversion technology, such as bioethanol, biodiesel and hydrogen, with its purpose of substituting the limited fossil energy to reduce CO2 emission [1]. Since entry into WTO, Taiwan has experienced overproduction of agricultural products, which are relatively uncompetitive. Hence, the government made attempts recently to build a mathematical planning model, so as to simulate the feasibility of extracting bioethanol from energy crops in Taiwan [2]. In 2009, Suiran and Jing [3] simulated experimentally the effects of biomass fuels on economy, energy and environment using Monte Carlo methodology. Ayhan [4] explored the influence of biofuel on economy, employment, ecological environment and pollution prevention, and endeavored to open a new avenue for the rural residents by increasing the demand and price of agricultural products.

In view of the factors related to environment protection and energy demand, a research on the combustion characteristics of (Methyl tert-butyl ether, MTBE) was conducted to make sure if bioethanol is suitable for auto engine as an alternative fuel. In 2000, Al-Farayedhi et al. [5] researched the influences on engine exhaust emission by adding MTBE into gasoline engine. The results indicate that the increase of MTBE can cut down the emission of CO and HC, but raise the emission of NOx. In 2006, Kao [6] studied experimentally the four cylinder four-stroke gasoline engine by blending alcohol and gasoline of different proportions of MTBE, so as to explore the influence of blended fuel on engine performance, oil consumption and emission-induced pollution. The experimental result shows that, the maximum combustion pressure of MTBE-blended gasoline fuel is lower than that of gasoline, but the CO emission of blended fuel will decrease with growing oil, and the emission of HC and NO is lower than that of gasoline when the rotary speed is over 2500rpm.

Alcohol-gasoline blended fuel could significantly improve the engine performance and emission pollution. In 1993, Hwang [7] explored experimentally the influence of gasoline-alcohol blended fuel on engine performance. The research result shows that, gasoline-alcohol blended fuel has following influences on the performance of engine: 1. higher thermal efficiency of engine; 2. lower fuel consumption in the event of engine speed more than 2600rpm; 3. declining emission concentration of CO and HC with the growing proportion of alcohol. In 2002, Hsieh et al. [8] experimentally researched the influence of different gasoline-alcohol blended fuels on engine performance and pollution. The result shows that, the calorific value of the blended fuel is decreased with the growing alcohol content, but the octane content is increased; and the torsion and fuel consumption of engine increase slightly, the emission of HC and CO2 declines; of which NOx emission depends on the operating condition of engine, rather than alcohol content.

In 2003, Hassan [9] studied the effect of ethanol-gasoline blended fuel on SI engine performance and exhaust emission. The research result shows that, CO and HC decline with the increase of CO2. Al-Hasan [10] studied the influence of lead-free alcohol gasoline on the performance of four-stroke gasoline engine, showing that the mixture of alcohol and lead-free gasoline can increase the brake power, torsion, brake thermal efficiency and fuel consumption; CO and HC emission decreases with reduction of CO2 concentration; and the mixture of 20% alcohol and lead-free gasoline presents optimum effect.

He et al. [11] studied the influence of gasoline-alcohol blended fuel on the emission of gasoline engine in electrical fuel injection (EFI) system. For the gasoline fuel blended with alcohol, the octane content was increased but the exhausted toxic gas was decreased. When the blended fuel contains 30% alcohol, the total emission of HC, CO and NOx can be decreased effectively during idle operation of engine. In 2004, Yükesl and Yükesl [12] analyzed the engine performance of ethanol-gasoline blended fuel by using a carburetor that enables stable blending of fluid fuels. The research shows that, with 60% ethanol and 40% gasoline blended fuel, the oil consumption and tailgas emission can be improved significantly. In 2005, Hakan [13] researched the influence of alcohol-gasoline blended fuel on engine performance and emission. The research result shows that, the engine performance and pollutant emission can be optimized when the engine speed is 1500 rpm, and the compression ratio is 7.75 and 8.25 for the blended fuel with 7.5% alcohol. Ceviz and Yükesl [14] researched the variation of engine combustion cycle and fuel injection effect when ethanol and lead-free gasoline blended fuel was used in gasoline engine. The research result shows that, effective pressure of such blended fuel is
decreased when CO\(_2\) concentration rises to 10% above, and the emission of CO and HC is decreased with the increase of CO\(_2\) concentration.

In 2007, Cheng [15] explored the influences of ethanol-gasoline blended fuel of different proportions on the engine performance, combustion characteristic and pollutant emission under different opening angles of throttle and engine speeds. The research result shows that, for the blended fuel with adding of ethanol, the maximum cylinder pressure and horsepower decrease; and the total thermal discharge is increased when a high engine speed is reached.

Under various blending proportions, the consumption of most braking fuel is increased, whereas CO and HC emission is decreased with the growing proportion of ethanol blended fuel. Hakan [16] researched the combustion process of flame when gasoline, alcohol and alcohol-gasoline blended fuel were applied, respectively. Also, the combustion characteristic was predicted from different crank angles. When the blended proportion of alcohol reached 25%, the combustion process of flame was accelerated. In 2009, Najafi et al. [17] experimentally researched and analyzed the engine performance and exhaust emission under different blending proportions of alcohol and gasoline. The research result shows that, the engine torsion and torque are increased slightly if alcohol-gasoline blended fuel is applied; and the emission of CO and HC is decreased, but CO\(_2\) and NO\(_x\) would is increased.

Mustafa et al. [18] studied the influence of alcohol-gasoline blended fuel on the engine performance and pollutant emission of single cylinder four-stroke engine. The research result shows that, the torsion and power of engine are increased with rising alcohol proportion; whereas CO, NO\(_x\) and HC emission are decreased, and a higher alcohol proportion will increase the compression ratio. Cenk et al. [19] studied the influence of methanol-diesel blended fuel on exhaust gas of diesel engine. The research result indicates that, the emission of NO\(_x\) and CO\(_2\) is increased, but the emission of CO and HC is decreased with the growing blending proportion.

Past studies on the performance and pollution with introduction of alcohol-gasoline blended fuel into two-stroke and four-stroke engine have raised great concern. Based on its potential applicability and academic value, this paper explored the influence of alcohol-gasoline blended fuel on the performance of two-stroke mower engine and four-stroke MITSUBISHI GDI (Gasoline Direct Injection). The contents of research mainly encompass engine speed, torque, output power, driving load, fuel pressure, manifold vacuum, oxygen content and air flow as well as comparison with the cases without alcohol. The results can provide a reference for the application of gasoline engines with different horse-powers.

2. Experiments Method

2.1 Experimental research on single cylinder two-stroke engine

TBC-230D/DS is a single cylinder two-stroke gasoline engine of conventional mower, with its specifications listed in Table 1. The experimental equipments are divided into fuel blending equipment and engine testing equipment, including: power testing platform, testing engine, drive system, power testing system and data extraction system. Figure 1 is a schematic view of engine testing equipment, wherein No. 95 lead-free gasoline and 95% alcohol are employed, respectively.

<table>
<thead>
<tr>
<th>Engine Model: TBC-230D/DS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
</tr>
<tr>
<td><strong>Power</strong></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
</tr>
<tr>
<td><strong>Tank</strong></td>
</tr>
</tbody>
</table>
A single cylinder engine with small horsepower was used in this experiment, and powered by a fuel blended with 5% or 10% engine oil for lubrication and heat radiation, helping to further study the influence of oil concentration on engine. Then, fuel with 4% engine oil was prepared as a base fuel using precise equipments such as electronic scale, and finally turned into a blended fuel by adding different proportions (3%, 5%, 10%, 15%) of alcohol, with only an error within ±0.05%. The blended fuel prepared by above-specified methods was tested under different speed within 100-600rpm.

2.2 Experimental research on four-stroke engine

GDI is a gasoline cylinder direct injection engine for MITSUBISHI GALANT/VIRAGE (1.8L), with its specifications listed in Table 2. The engine control system comprises air system, fuel system and electronic control system. Fuel injection control is subject to ECM (Engine Control Management) according to the operational conditions of engine, thus optimizing the blending ratio of the fuel injected in cylinder. In this experiment, MITSUBISHI GDI in-line four cylinder four-stroke engine test bench with 1834c.c. air displacement
was used, as shown in Figure 1(b). A sensor was mounted onto oil pipeline of oil pump, air inlet manifold and exhaust pipe to measure the data, and then the steel wire was driven spirally to control the opening of throttle to reach the engine speed required in the experiment; next, different concentrations of alcohol and gasoline were added, and the engine speed was extracted and displayed, with the relevant uncertainty analysis of experiment parameters shown in Table 3.

Table 2. The specifications of four-stroke engine.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Model</td>
<td>Mitsubishi Galant/Virage/4G93</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>4</td>
</tr>
<tr>
<td>Bore</td>
<td>81 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>89 mm</td>
</tr>
<tr>
<td>Capacity</td>
<td>1,834 c.c.</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>12:1</td>
</tr>
<tr>
<td>Valves</td>
<td>16 V</td>
</tr>
<tr>
<td>Gasoline pressure up</td>
<td>3.3~3.5 kg/cm²</td>
</tr>
<tr>
<td>Gasoline pressure</td>
<td>50 kg/cm²</td>
</tr>
</tbody>
</table>

Table 3. The relevant uncertainty analysis of experiment parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum errors (±%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel pressure</td>
<td>0.29</td>
</tr>
<tr>
<td>Manifold vacuum</td>
<td>0.13</td>
</tr>
<tr>
<td>Oxygen sensor</td>
<td>0.10</td>
</tr>
<tr>
<td>Air flow sensor</td>
<td>0.11</td>
</tr>
<tr>
<td>Alcohol concentration</td>
<td>0.05</td>
</tr>
</tbody>
</table>

No, 98 lead-free gasoline and 95% alcohol were measured using precise electronic scale to prepare the mixture of various alcohol concentrations, with error of alcohol-gasoline proportion less than ±0.05%. Then, 1%, 2%, 3%, 5%, 10%, 15%, 20% and 30% alcohol concentration was tested, respectively. To prevent residual oil in the oil tank and pipeline affecting alcohol-gasoline test under different concentrations, the engine was allowed to enter into an idle operation until natural extinguishment, thus ensuring the experimental accuracy and low error rate.

3. Result and Discussion

Two-stroke and four-stroke engines are commonly used in the daily life. By comparing the blended fuel of different alcohol concentrations with the gasoline fuel, the difference in engine performance and exhaust pollution can be well understood. Figure 2 is a physical diagram and layout plan of thermal image of two-stroke and four-stroke engines.

3.1 Experimental results of single cylinder two-stroke engine

This experiment employed a small-sized low horsepower mower with single cylinder gasoline engine, which wasn’t equipped with water jacket, exhaust pipe, muffler and catalytic converter. Hence, the practical operating time was no more than 30 minutes in this research, and only the engine speed, torque, output power and
driving load were considered. The maximum rotary speed that could be tested by the power test bench was only 990 rpm. When the engine speed exceeded 600 rpm during the experiment, strong vibration of mechanical parts might occur due to high engine speed, leading to obvious fluctuation of measured data against the accuracy of the experiment. Therefore, only the engine speed less than 600 rpm was considered.

Fig. 2. Physical diagram and layout plan of thermal image of two-stroke and four-stroke engines.

Firstly, gasoline was mixed with engine oil of different proportions to test the influence of blending ratio on the engine. The result shows that the speed, output power and driving load rise significantly with the increasing engine speed given a higher blending ratio (Figure 3). When the blending ratio of engine oil exceeds 10%, the consumption of engine oil is obvious, leading to generation of numerous smoke. Hence, the proportion of blended engine oil shouldn’t be over 10%, and an optimum blending ratio is 10% from the experiment data, but 4% engine oil is deemed appropriate as the exhaust pollution isn’t considered in this experiment.

Secondly, 4% engine oil was mixed with the gasoline, then the blended fuel was mixed again by different proportions of alcohol (3%, 5%, 10%, 15%) to test the influences of alcohol blending ratio on the engine. The results show that, the engine torque rises with the growing alcohol blending ratio; but when the blending ratio exceeds 10%, the engine torque is decreased; and when the speed is over 500 rpm, the increase becomes gentle as shown in Figure 4(a). Thus, the torque reaches a better status when the alcohol blending ratio is 10%.

The output power of engine rises with the growing alcohol blending ratio; however, the output power declines when the blending ratio is over 10%. When the alcohol blending ratio is less than 3% and engine speed reaches 500 rpm, the increase of output power becomes gentle; when the blending ratio is over 3% and the engine speed reaches 500 rpm, the output power decreases significantly as shown in Figure 4(b). As seen, when the alcohol blending ratio is 10% and the engine speed reaches 500 rpm, the output power of engine could reach a better status.
A higher alcohol blending ratio means a higher driving load of engine. When the alcohol blending ratio is over 10%, the driving load of the engine will decline. When the engine speed reaches 500 rpm under various alcohol blending ratios, the driving load will decrease significantly as shown in Figure 4(c). As seen, when the alcohol blending ratio is 10% and the engine speed reaches 500 rpm, the driving load could reach a better status.

To sum up, two-stroke engine of simple construction is widely applied in daily life, hence, the concern of research is also put on such engine for energy-saving purpose. The experimental results indicate that, 10% is a critical reference point of engine oil-gasoline blended fuel. Such a proportion cannot be exceeded if environmental protection is taken into account. When the blending ratio of gasoline-alcohol blended fuel is 10% and the speed reaches 500 rpm, a better value could be acquired from the measured data, providing an important reference for future research.

3.2 Experimental results and discussion of single cylinder four-stroke engine

When four-stroke engine was added with 1%, 2% and 3% alcohol-gasoline fuel, no significant difference with
pure gasoline fuel was observed. So, the fuel pressure, manifold vacuum, oxygen content and air flow were discussed experimentally under the condition of 5%-30% alcohol gasoline fuel:

(a) Relationship between the engine speed and the torque
(b) Relationship between the engine speed and the output power
(c) Relationship between the engine speed and the loading

Fig. 4. The experiment results of using different alcohol-gasoline fuels on two-stroke engine.

Figure 5 shows the variation of different alcohol-gasoline fuel and the speed of 800-3000rpm. It is imperative to maintain a certain fuel pressure in gasoline injection engine. In the event of higher fuel pressure, this will lead to high CO content in exhaust gas and air pollution. The fuel pressure/efficiency is fairly low when 15% and 20% alcohol-gasoline fuel is added into the engine, without resulting in high CO content; a better fuel pressure/efficiency could be realized when 5%, 10% and 30% alcohol-gasoline fuel is added, and the engine speed reaches 1600, 2000 and 3000 rpm, respectively.

Figure 6 shows the variation of manifold vacuum under different proportions of alcohol gasoline and rotational speeds, wherein a higher inlet manifold pressure means larger warping degree of silicon diaphragm. A larger warping degree will affect air volume, fuel injection quantity and time in every stroke. The highest pressure in manifold exists when the speed reaches 1600rpm; the pressure curve approaches pure gasoline mode when 5%, 10% and 15% alcohol-gasoline fuel are added, respectively, resulting in small warping degree of silicon diaphragm; when 30% alcohol-gasoline fuel is added, a high warping degree of silicon diaphragm will be caused.
Fig. 5. Relationship between the engine speed and the fuel pressure of using different alcohol-gasoline fuels on four-stroke engine.

Fig. 6. Relationship between the engine speed and the manifold vacuum of using different alcohol-gasoline fuels on four-stroke engine.
Figure 7 shows the oxygen content variation under different proportions of alcohol gasoline and rotational speeds. O₂ concentration (oxygen content) in exhaust gas pumped from the cylinder was measured, and then the signal was sent back to the computer for changing the injection time of the nozzle and adjusting the blending ratio. If adding 10% alcohol-gasoline fuel within 800~3000 rpm, an equivalent oxygen content/efficiency can be maintained as compared with pure gasoline mode; if adding 30% alcohol-gasoline fuel, the extremely low oxygen content indicates that the blended gas is too dense and the concentration of HC and CO in exhaust gas will be increased; if adding 5% alcohol-gasoline fuel, high oxygen content indicates that the blended gas is too thin, leading to higher combustion temperature and NOₓ concentration in the exhaust gas.

Fig. 7. Relationship between the engine speed and the voltage of oxygen sensor of using different alcohol-gasoline fuels on four-stroke engine.

Air flow/efficiency variation was further analyzed under different proportions of alcohol-gasoline and rotational speeds. In Figure 8, air volume absorbed in every stroke is close to the benchmark of pure gasoline mode if adding 10% and 15% alcohol-gasoline fuel within 1600-2000 rpm; and it’s unnecessary to adjust the fuel injection volume in such case; otherwise, the fuel injection volume shall be adjusted under other proportion of alcohol. Hence, the efficiency of air flow could be optimized by adding 10% and 15% alcohol-gasoline.

Fig. 8. Relationship between the engine speed and the voltage of air flow sensor of using different alcohol-gasoline fuels on four-stroke engine.
4. Conclusion

From above-specified experiments, the influences on the torque, output power and driving load of two-stroke engine, as well as the fuel pressure, manifold vacuum, oxygen content and air flow variation of four-stroke engine could be concluded, and the following conclusions are made:

(1) As for two-stroke engine, the torque, output power and driving load of the engine increase significantly with the growing speed and higher blending ratio of engine oil; when the blending ratio reaches 10%, a better result could be acquired.

(2) As for two-stroke engine, the torque of engine will increase with growing speed and higher blending ratio of alcohol; when the blending ratio is more than 10%, the torque of the engine drops markedly; when the engine speed reaches 500 rpm, the increase becomes gentle. So, the torque of engine could reach a better status when the alcohol blending ratio is 10%.

(3) As for two-stroke engine, the output power and driving load of the engine increase with the growing speed and higher blending ratio of alcohol; when the alcohol blending ratio is over 10%, the output power and driving load decrease significantly; when the speed exceeds 500 rpm under different blending ratios, the output power and driving load drop markedly. Thus, when the alcohol blending ratio is 10% and speed of engine reaches 500 rpm, both the output power and driving load of the engine could reach a better status.

(4) As for four-stroke engine, the fuel pressure can be kept stable if adding 10%-15% alcohol-gasoline blended fuel; and then the pressurized fuel is injected properly based on air intake manifold vacuum and computer-aided detection, avoiding extremely high CO content in the exhaust gas and subsequent air pollution.

(5) As for four-stroke engine, the manifold vacuum varies under different proportions of alcohol-gasoline and engine speed; when adding 5%, 10% and 15% alcohol-gasoline blended fuel, the pressure curve is close to pure gasoline mode with the growing speed, hence the warping degree of the silicon diaphragm is relatively small; but adding 30% alcohol-gasoline will lead to extremely high warping degree of silicon diaphragm.

(6) As for four-stroke engine, if adding 10% alcohol-gasoline fuel within 800~3000 rpm, an equivalent oxygen content/efficiency can be maintained as compared with pure gasoline mode; if adding 30% alcohol-gasoline fuel, the extremely low oxygen content indicates the blended gas is too dense and the concentration of HC and CO in exhaust gas will be increased; if adding 5% alcohol-gasoline fuel, high oxygen content indicates the blended gas is too thin, leading to higher combustion temperature and NOx concentration in the exhaust gas.

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References


Determinants of the Box Office Performance of Motion Picture in China - Indication for Chinese Motion Picture Market by Adapting Determinants of the Box Office (Part I)

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ABSTRACT

This paper aims to examine the determinants of box office revenue in Chinese motion picture industry. The testing sample consists of 60 films released during 2005-2010. By using regression method to examine those relevant factors of the box office revenue, there came out results with three primary predictors - the promotion cost, ticket price and the copies that play significant roles while concerning profitable investment for investors as well as producers in the motion picture industries. The paper is divided into two parts; part 1 explains current situations and researches on the determinants of box office revenue worldwide; part 2 uses regression method to demonstrate the significant influence of box office revenue to Chinese motion picture industry.

Keywords: Box Office, Predicting Model, Influencing Determinants, Financial Success.

1. Introduction

1.1 Statement of problem

As De Vany and Walls addressed views that producing and marketing motion pictures is notoriously risky \cite{1, 2}; and the fact indicated by Vogel that three out of ten movies break even and one becomes profitable\cite{3}, the determinants of box office appear to be complicated. In general, a particular movie of its “Value Chain” has to get through four phases: (a) Film Manufacturing, (b) Distribution, (c) Film Playing, and (d) Related Products Research and Development (See Figure 1). Though this process, Film Quality, Marketing Issues and Rating by the 3rd party would affect the production outcome of a motion picture.

\begin{center}
\includegraphics[width=\textwidth]{film_value_chain.png}
\end{center}


Fig. 1. Film value chain perspective.

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Nowadays, Chinese film industry is in its booming era, it is very curial for any movie investment to consider on how to acquire higher box office receipts? While looking into such concern there appears the issue that is at what extent determinants would influence the box office in Chinese market? However, the western country has already formed a formula testing how a film can receive higher box office through the control to its affecting determinants and the formula succeed in predicting film market in the West. This paper tries to borrow the formula and apply into Chinese film market to test whether it is workable to various market situations in China.

2. Definitions and Literature Review

2.1 Box office

Box office is an important index to measure motion picture success [5]. From western film studies relating to the test of box office, the most applicable study in predicting financial success of motion picture is firstly done by [6]. His model provides evidence that the independent variables for production costs, critic ratings, science fiction genre, major distributor, Christmas release, Academy Award nomination, and winning the Academy Award are all significant determinants for achieving success. Based on the Litman’s model, several scholars have conducted further studies on the factors influencing the box office. For example, Hennig-Thurau, Houston and Walsh discussed influences among film itself, marketing and non-production factors on the impact of the box office [7].

In comparison with the West, Chinese studies take a broader approach. Chinese scholars generally center on successful outcome of motion picture which is relatively lacks of rigorous theoretical system and depth in the specific variable-focused studies. Recent researches emphasis more on factors by standing on audiences' perspective and looking at the prediction problem through analyzing consumer behavior [8, 9]. To be pointed out from the movie “Wuji”, Jiang indicated four predictors influencing the movie box office [10]. (See Figure 2)

![Fig. 2. Model of factor interrelations and factors’ impact on movie box office shows how approaches of determinant influence the box office adopted from Jiang - Analysis the success determinants of the box office: from Wuji, a particular film; retrieved on 4th March and used with permission of the author [10].](image-url)
Zhao employed mathematical methods to estimate the amount that box office can receive. Based on audiences’ viewpoints, Yu analyzed the motivation of audiences’ views and preferences about film market in China since 1995 [11, 12]. Zhang and Zhang attempted to develop models for forecasting the financial success of motion pictures [13]. They used data acquired from the box office to demonstrate that film investment and “Film Brand” (Genre, Actors, Directors, and Sequels) both have positive correlation with the box office.

2.2 Box office and genre

Movie genre has been given attention for predictions of box office performance from several researchers. Anast was the first to look at film genre and how it relates to film attendance. For instance, comedy as a popular genre was studied widely [14, 15, 16, 17], so did science fiction, fantasy, horror, and other genre studies [18].

2.3 Box office and actors

Effects of actors or star power have received considerable attention in the literature [7, 19, 20]. Some researchers found significant contributions from star power, while several other studies did not come out with any significant effect [1, 18, 21]. Chinese study of star power is still in awareness of the commercial value [22, 23]. Chinese study is under developing and should learn from the west [5]. Another researcher Zhao mentioned about that the success of a Chinese film needs essentially more than three famous actors or actresses [11].

2.4 Box office and directors

Like the superstars, directors can be understood as ingredient for branding. That is, who contributes to the box office by attracting a personal-based audience, renowned directors are assumed to have a similar attracting power [24]. However, most of previous studies appeared that the effect of directors was not that significant [16, 21]. Li’s study about directors is in particular pointing out this viewpoint [25]. She employed one famous director-Feng Xiao gang as an example to explore the importance of movie box office. Li found that director Feng has becoming a well-known brand that enable his movies to receive a stable box office even in the depression period of movie industry in China. Yet, Duan said the majority of researches about Chinese directors are still in text researches for the effect in commerce, especially, the relationship between directors and box office should have more quantitative analysis [26].

2.5 Box office and sequels

No matter what the box office is a sequel or adapted from other media, it is relevant to the economic success of the film, several researchers showed that whether or not a film was a sequel, it is important in predicting the financial success of the movie [18, 27, 28]. However, researchers such as Litman did not find out any significant effect.

2.6 Box office and word of mouth

Word of mouth is the integrated effect by audience rating, critic rating and awards. Henning-Thurau, Houston and Sridhari [29], Liu (2006) conclude the negative or positive reviews about word of mouth [30]. Eliashberg, Jonker, Sawhney, and Weirenga apply Markov’s random process to analyze the “word of mouth” effect [31]. Some researchers specialized in the influence of online WOM to the box office have come out with the similar point of view on supporting the “word of mouth” effect too [32].
2.7 Box office and audience rating

Audience rating reflecting the degree of preference by movie-goers and function as an influencer is one of the most under-studied variables in the research relating to the success of a movie [33, 34]. Several movie information websites such as IMDB ask their visitors to evaluate the movies that they have already watched. The results were released to the public indicating that function can be a good proxy if a sufficient number of participants were secured.

2.8 Box office and critics rating

The effect of critics rating has been widely tested by previous researches [18, 21, 27, 35]. With the exception of a few studies, most of them have been supported typically [27]. Joseph pointed that for instance, the blockbuster movies, the critic’s viewpoints are not able to become the power of raising the market sales volume [36]. However, for the most of ordinary movies, the critic’s opinion will be a part of promotion strategy. As a result, it affects the consumption of the film industry. Ainslie’s finding supports the prediction effect is not that significant [37].

2.9 Box office and awards

Awards play an important role to motion picture industry. A couple of researches have shown that winning a major category Academy Award will contribute to the box office success [6]. Nelson, Donihue, Waldman, and Wheaton have estimated that an Academy Award nomination in a major category could increase box office revenue [38].

2.10 Box office and MPAA rating

Film ratings given though the MPAA (Motion Picture Association of America) will influence the performance of box office because the rating tends to determine the potential size of the audience [39]. Considering movies rated G, PG, and PG–13 have largest amount of potential audience, previous research suggested these movies should be positively related to commercial success at the box office whereas R, X, and NR films should be negatively correlated [40]. The research excludes this variable since there is no such film classification in China.

2.11 Box office and production cost

Production cost has been considered as an important predictor because of the converting into lavish sets of the big budget and costumes, expensive digital manipulations, and special effects that lead to heightened attractiveness to audiences. “Blockbuster theory” states movie production companies should spend vast amount of money in the creation of a particular film [21]. Clearly, the more expensive film, however, does not always guarantee its financial success at the box office.

2.12 Box office and market power of the distributor

Although quite a few of researches have shown that market power of the distributor is a positive indicator of box office success [41]. Movie conglomerates such as Disney, Lions Gate and Fox have their own niche in the motion picture industry in which they can rely on the targeted loyal audience who want to watch the latest picture as earlier as possible [21].
2.13 Box office and number of copies

The number of copies also greatly influences the box office outcome [42]. Research findings have supported this point for the potential of distribution opportunities while possessing a good number of copies.

2.14 Box office and advertising cost

Advertising and marketing strategies also have a significant impact on the Motion Picture. Elberse and Eliashberg looked at a simulated market of motion pictures and determined the effectiveness of pre-released advertisement in the movie industry [19]. Laurichesse concludes that as a marketing strategy for the motion picture industry [41].

2.15 Box office and release date

Date and season of a released film also have their impacts on the success of the box office [21, 43]. Since a movie is going to launch in the summer season or the last two weeks of December have the advantage when compare to other seasons [44]. Moreover, to release a movie during a particular holiday could have the initial advantage over the other time periods. One of Chinese researcher Zhao stated that the Release date is an important index to evaluate box office receipt, although there are some differences between Chinese and US holidays [45].

2.16 Box office and competitive forces

Substitute goods to movies are the options that are available for consumers other than those who are going to see a particular movie. Some of the previous studies centered on the topic of forecasting motion picture box office results also indicate the influencing parameter of representing the competitive forces.

2.17 Box office and ticket price

Two researchers, Wen found out the theater factors will influence customers experience of watching movies, for example services, environment, promotion, convenience and facilities provided by the theater [46]. A previous research by Yang, Chen, Deng, Zhang, Wang showed that above all the theater factors such as number of screens, the scale of the theater, the service quality, ticket price take the most important roles (R²=78) [47]. Chinese researcher Chen claimed when the ticket price is stable, the number of audience has positive correlation with the ticket price [3]. However, when the ticket price is unstable, the number of audience has negatives correlation with the ticket price. Ticket price seems to be the directly influence on the box office. Lin indicated that ticket price rest with the quality of the film, condition of the theater, consumption level and related movies price [48].

2.18 Summery

In short, predictions for box office are very complicated and need to be further discussed. Generally, studies in this field are separated into two approaches: (a) Communication Approach examining why audiences choose to watch a movie in a theatre, as opposed to all other available options of entertainment. Furthermore, related studies have to be conducted on why audiences choose a particular movie over another. The data set is generally composed of surveys of individual self-reporting on watching movie practices. (b) Economic approach investigating economic factors that affect collective movie attendance as a whole. This approach relies on a data set which is generally composed of market information on film financing, scheduling, advertising, etc. The economic approach takes some ideas created and suggested in the communication theory approach, such as the effect of star power on movie-goers, as well as the test of those ideas of statistical significance [21]. To conclude the studies above, this paper tries to apply the economic approach. The estimated whole picture of the
determinants is drawn as below. (See Figure 3)

![Diagram](image)

**Fig. 3.** A Whole Picture of factors and box office shows how approaches of determinant influence the box office.

### 3. Objective of this Study

#### 3.1 Purpose

Film investment is a risky business and sometimes unpredictable. “Hollywood is the land of hunch and the wild guess” [21]. Research results from western researchers may not be adapted to the situation of Chinese film market entirely. Thus, this research focuses on the forecast to Chinese films’ box office of affecting factors that is appropriate to Chinese situation. The movies producers and managers could employ this result as a reference to better predict the box office in China, whereas they can have a better decision-making and well management for their production, distribution, promotion; and reducing the risk of film production. However, film, as a commodity, shares the universality as other business. This research would help to figure out the principles of how to produce a film with successful box office in china. Consequently, results of this paper will benefit: (a) Film investors (to alleviate or avoid box office catastrophes); (b) Film industry (to recognize, analyze and apply capital film asset as strategic level - box office can be predictable); (c) Whole society (to educate the audience with better knowledge about film operations).

#### 3.2 Trains of thought

The first two parts are statement of problem, literature review which including researches in the West and former Chinese researches. The third part is the purpose of study which gives a direction of this paper. It follows by the conceptual framework- a whole picture with independent variable included in this study. Research methodology is at the fifth part describing the way of collecting sampling method data and the explanation of methods this paper employed. The sixth part is the analysis and discussion. From year 2005 to 2010, 60 released films will be used in the statistical analysis in order to validate parameters such as Actors, Directors, Sequels, Genre, Award, Critics Rating, Audiences Rating, Production Cost, Market Power of Distributor, Number of Copies, Promotion Cost, Ticket Price, Release Date and Competitive Forces for articulating their relations to the film box office. The last part is the conclusion and suggestions to the usage of predicting box office in China.
3.3 Differentiations

The approach of this study is unique because: (a) it is a quantitative study of box office for the Chinese market; (b) it cares about the financial success of the motion picture rather than judging whether a movie is good or bad; (c) it contains a plenty of literature reviews which enhances the building of frame work; (d) it brings about a creative thinking on how to measure immeasurable variables; (e) it is a secondary data-based study; (f) it is the further study based on previous research results.

4. Conceptual Framework

The figure below demonstrates the conceptual framework of this paper. (See Figure 4)

![Conceptual Framework Diagram]

Fig. 4. The conceptual framework shows the three processes of film from production, promotion to play in theater.

Among these three processes, there are clearly relationship shows in the figure that 14 variables affect the box office in China separately. As a result, it indicates the linear relation to influence the box office while considering the usage of regression method to demonstrate those determinants in the motion picture industry. The second part of this paper will continue with the hypotheses where those determinants are to be considered.
References

[43] L. Einav, Seasonality and Competition in Time: An Empirical Analysis of Release Date Decisions in the


Information for Authors

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The Journal of Science and Innovation (JSI) is published by the Taiwanese Institute of Knowledge Innovation (TIKI). The Journal is the quarterly journal devoted to advancing the understanding and practice of information and design innovation. It serves the needs of researchers as well as practitioners and executives involved in science and innovation. The review process is double-blind.

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