Legal Supervision of the Educational Administration: From the Perspective of Studentship at the School
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After the interpretations of the Grand Justices of the Constitutional Court and the enactment of the Basic Law of Education, the relationship between students and schools transforms from a special power one to a legal one. After the transformation, it gives rise to two logic questions. One is what rights and obligations schools and students have? The other is how and what protective procedures students may employ to seek for remedies when their rights are infringed by school administrations and the state? To answer these two questions and to truly realize the preservation of students’ rights, the starting point is the legal supervision of the educational administration. This article is the first one in Taiwan starting from the legal relationship between schools and students to further discuss and review the educational administrations of Taiwan’s high schools and elementary schools. Through the discussion and review, this article is expected to furnish a description and facilitate the understanding of the scope and content of the legal supervision of the educational administration and to endeavor to build the legal framework of the educational administration in Taiwan.

The legal relationship between schools and student begins with the grants of students’ admissions and ends at students’ graduations. Because public schools are treated as public facilities by law, traditionally the relationship between public schools and their students are deemed as one of special power relationships under administrative law. However after the Judicial Yuan Interpretation No. 382 which affirmed the fundamental right for education, the then dominating view of the special power relationship was gradually replaced by the legal relationship as so do in other countries under the rule of law. The legal relationship between schools and students can be analyzed into two prongs. One is that students’ right for education falls under the constitutional guarantee of fundamental rights which in turn makes it applicable the principle of reservation of law. The other is that students may seek for judicial remedies, especially under the administrative procedure, when their rights are infringed.

If one simply looks at the language of Article 162 of the Constitution, he may come to a conclusion that every education related matters are subject to governmental supervision as prescribed by law. But such a broad reading does not reflect the contents of the law. Article 162 of the Constitution mandates the establishment of legal system of governmental supervision and does not mandate the exact scope. To fill the gap under Article 162 of the Constitution, this article begins with the constitution mandates of Article
21 of the Constitution to explore the constitutional basis of legal supervision of educational administration and to delineate the contents of state’s legal supervision of educational administration.

In countries under the rule of law, the relationship between schools and students shall be developed toward the realization of student’s self-fulfillment under the constitutional guarantee of fundamental right for education and toward the facilitation of student’s personality freedom. Therefore, the contents of legal supervision of education administration as so prescribed by Article 21 of the Constitution shall be constructed for the benefits of students’ personality freedom and with a view to students’ self-fulfillment. State’s legal supervision of educational administration shall be limited to students’ self-fulfillment and personality freedom. That is to say, Article 21 of the Constitution not only prescribes the contents of state’s legal supervision of educational administration, but also provides the boundaries of state’s legal supervision of educational administration as well.

The phrase “supervision under law” prescribed by Article 162 of the Constitution means the government’s supervision over educational administration as so authorized by law. This article contends that the meaning of the phrase “supervision under law” consist of three parts, legal supervision, professional supervision and personnel supervision. These three parts will be discussed in turn below.

Legal supervision represents state government’s formal legal control over other organizations. Government’s legal supervision of educational administration means the government may exercise control over school affairs, which can be divided into two aspects, internal school affairs and external school affairs. Internal school affairs include affairs related to curricula, such as the goal of education, and so forth. Such affairs shall be left exclusively to the state government. On the other hand, the external school affairs, such as the construction of school buildings, and so forth, shall fall into the administration of local government self-autonomy and only subject to state’s government supervision in form, not in substance.

Professional supervision represents the supervision of all curricula related affairs performed by professional organizations formed by the state government. As discussed above, though internal school affairs fall into the state government’s authority, the state government is not suitable for detailed enactments by state legislature. Therefore, state can only lay out principles by legislation and perform the substantive review of examining whether the principles and goals are met.

Personnel supervision represents that the administration and management of school personnel related matters shall be supervised by state government’ s supervisory branches. It is settled that state government may exercise personnel supervision of public schools; however, state government can only intervene and exercise personnel supervision over private schools only when the private schools conduct behaviors which are not educationally suitable under the Private School Law.

Generally speaking, this article is the first one in Taiwan starting from the legal relationship between schools and students and from the constitutional law to administrative law to further discuss and review the educational administrations. Namely, this article attempts to link between Article 162 and Article 21 of the Constitution in order to explore the scope and content of legal supervision of educational administration. The formation of a state is for its people, and the state exists for this very purpose. From the constitutional guarantee of the right for education, it is perceived that students’ self-fulfillment is the utmost guiding principle of educational administration and it is also the scope and limit of the state government’s legal supervision of educational administration. The author wishes this article will serve as stepping stone to enabling the development of Taiwan’s educational administration to move toward the goal of centering upon students’ self-fulfillment. In sum, state government’s employment
and exercise of legal supervision, professional supervision and personnel supervision over educational administration are all with a view to realize students' self-fulfillment.
Temperature effect on impact ionization characteristics in metamorphic high electron mobility transistors
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Recently, the metamorphic high electron mobility transistors, MHEMTs (InP based layers on GaAs substrate), have attracted considerable attention for high power and low noise microwave applications. From the physical point of view, the increased gate leakage current as well as decreased breakdown voltage are mainly caused by the carrier generation within the channel and carrier transport across the Schottky barrier layer. Thus, the carrier generation through effective impact ionization in channel layer is responsible for the breakdown characteristics.

Since the impact ionization is inversely proportional to the bandgap value, the narrow bandgap of InGaAs channel makes it susceptible to induce the impact ionization effect. This problem usually leads to the deteriorated device characteristics including the low breakdown voltage, high gate leakage current, and high output conductance. The extraction of impact ionization-induced gate current from the total measured gate current becomes essential to study the impact ionization effect. It is noticeable that the impact ionization effect strongly depends on the Schottky barrier height of gate contacts. The adequate determination of gate metals can suppress the impact ionizations and then improve the device characteristics. In this work, the temperature-dependent characteristics of gate-metals-related impact ionizations in MHEMTs are investigated. Different metals, including Pt/Au, Ti/Au, and Au, as the Schottky gate contacts are fabricated simultaneously to study the impact ionization effects. In order to consider the impact ionization-induced gate current, the convenient excess gate hole current model established by Webster et al. is employed. Besides, two distinct mechanisms (ionization threshold energy and hot electron population) for impact ionization, which separately dominate in different field ranges, are also presented to interpret the anomalous electric field and temperature dependences. For comparison, gate Schottky contacts were achieved by evaporating Pt/Au (20nm/130nm), Ti/Au (20nm/130nm), and Au (150 nm), three kinds of different metals, for devices A, B, and C, respectively, on the Schottky barrier layer by using the same process sequence.

Figure 1 shows the schematic band diagrams and calculated electron densities within channel layer regimes at thermal equilibrium. Due to the increase of Schottky barrier height, the electron concentrations are decreased for devices A and B. Hence, the generation of electron-hole pairs and
related impact ionization effect are effectively suppressed. The presence of large conduction band discontinuity ($\Delta E_C$) between InAlAs Schottky and InGaAs channel layers also substantially suppresses electrons injecting into the gate. This certainly further improves the carrier confinement capability at higher temperature. The measured common-source I-V characteristics at different temperatures are illustrated in Fig. 2. It should be noted that the kink effects or other degenerative behaviors caused by the impact ionization are not observed in studied devices among the temperature of 300 ~ 480K. In particular, for device A, the drain current $I_D$ is not compressed significantly even the $V_{GS}$ is increased up to +0.5 V. Furthermore, the device A shows the relatively lower drain-source saturation current $I_{DSS}$. This is because that the Pt/Au gate metals (device A) lead to the increase of Schottky barrier height. This may considerably extend the depletion region beneath the gate and result in the reduced $I_{DSS}$.

Fig. 1 Schematic band diagrams and calculated electron densities within channel layer regimes of the MHEMTs with different Schottky gate metals.
Figure 3 shows the total gate current ($I_G$) and impact ionization-induced gate current ($I_{G,ii}$) versus gate-source voltage ($V_{GS}$) under different electric field ($V_{DS}$) at 300K. Also, the evolutions of $I_G$ and $I_{G,ii}$ versus $V_{GS}$ under high electric field ($V_{DS} = +2.0 \, \text{V}$), at 300 ~ 480K, are shown in Fig. 4. Clearly, the bell-shaped behavior reflects the preponderance of the impact ionization at high $V_{DS}$ and low temperature over the Schottky gate leakage current. The existence of bell-shaped behavior is caused by the impact ionization which requires both the conditions of significantly high electron concentration and high electric field. At moderate $|V_{GS}|$ regimes, the electron-hole pairs are generated in the high electric field region between the gate and drain electrodes. Also, a portion of holes are injected across the Schottky layer and collected by the gate terminal. Therefore, the gate hole current and related bell-shaped behavior are increased and occurred simultaneously, as indicated in Figs. 3 and 4. The total gate current is composed of the hole current component, due to impact ionization occurring in the channel, and the Schottky leakage current component. According to the gate hole current model, the $I_{G,ii}$ can be expressed as:

$$I_{G,ii} = I_G - I_{G,\text{Schottky}}$$  \hspace{1cm} (1)

where $I_{G,\text{Schottky}}$ is the Schottky gate leakage current which is a function of both the gate and drain voltage. Clearly, the bell-shaped behaviors, caused by the impact ionizations, of devices A and B are significantly suppressed as compared with that of device C. This is caused by the evaporation of specific gate contacts, e.g., Pt/Au and Ti/Au. These higher Schottky barrier heights will lead to the substantial change of potential energy. This indeed extends the channel depletion region beneath the gate and
results in the decrease of drain current in the channel. Therefore, the impact ionization effect can be effectively suppressed. Especially, it is found that the peak $I_{G,ii}$ of devices A and B shift toward more positive $V_{GS}$ regimes over wide operating temperature ranging from 300 to 480K, as shown in Fig. 4. Due to the increased phonon scattering with increasing the temperature, the electron mobility and drain current are decreased. Hence, because the peak $I_{G,ii}$ is dominated by the drain current density under the identical electric field, the $|V_{GS}|$ magnitudes of devices A and B are needed to decrease to maintain the same drain current density.

![Graph: Total Gate Current and Impact Ionization-Induced Gate Current](image)

Fig. 3  The total gate current ($I_G$) and impact ionization-induced gate current ($I_{G,ii}$) versus gate-source voltage ($V_{GS}$) under different drain-source voltage ($V_{DS}$) at room temperature.
The total gate current ($I_G$) and impact ionization-induced gate current ($I_{G,ii}$) versus gate-source voltage ($V_{GS}$) at different temperatures.

Fig. 4  The total gate current ($I_G$) and impact ionization-induced gate current ($I_{G,ii}$) versus gate-source voltage ($V_{GS}$) at different temperatures.

The corresponding reverse evolutions of $I_{G,ii}$ between the electric field ($V_{DS}$) and temperature dependences are observed. This indicates that the electric field and temperature dependences of impact ionization mechanisms are different. Thus, it is important to understand and determine the dominant mechanism in different field regimes. Practically, the electric field and temperature dependences of impact ionization in device operation are mainly determined by the competition between the ionization threshold energy and hot electron population. As shown in Fig. 3, with the decrease of the electric field (lower $V_{DS}$ bias), the impact ionization is dominated by the high ionization threshold energy. Because electrons are distributed under relatively cool status, the hot electron population is substantially reduced at low electric field. This leads to the absence of impact ionization in the channel as well as the reduced $I_{G,ii}$. In contrast, since the high electric field is presented in gate-drain region at high $V_{DS}$ bias, electrons acquire enough energies and the hot electron-assisted impact ionization is easy to take place in channel layer. Subsequently, the related electron-hole pairs are generated which lead to the increase of $I_{G,ii}$. On the other hand, as shown in Fig. 4, once the temperature is increased from 300 to 480K, the ionization threshold energy and related bandgap are slightly decreased which tend to enhance the impact ionization effect. However, the mean free paths of channel electrons are significantly decreased due to the increased phonon scattering. This indicates that the lattice electrons are hard to be released with the insufficient energy. Thus, the hot electron population and the corresponding impact ionization are substantially suppressed though the ionization threshold energy is slightly decreased. Simultaneously, an overall decrease of $I_{G,ii}$ with increasing the temperature is observed.

In conclusion, the gate-metals-related impact ionizations in MHEMTs have been investigated. The influences of Schottky barrier height on the impact ionization effect and device performance are also studied. Further, two distinct mechanisms, which separately dominate the impact ionization in different field regimes, are proposed to interpret the anomalous electric field and temperature dependences. As a result, by using the higher Schottky barrier height of gate metals, both the bell-shaped behavior and
related impact ionization effect are significantly suppressed. Also, the impact ionization-induced gate current is decreased with reducing the electric field and/or increasing the temperature.

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Development and investigation of magnetic nanowire arrays in mesoporous matrices
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1. Introduction and objective

One of the most important challenges in physics and materials science today is the preparation of ordered nanostructure arrays with the controlled properties and dimensions. The most challenging nanosystems are nanowires owing to highest anisotropy parameters in them, which could certainly increase functional properties of nanomaterials. The way for preparation of nanoparticle arrays usually involves synthesis in “nanoreactors” formed by colloidal species such as reversed micelles or liquid crystals. Variation of conditions of the synthesis allows regulate the size and morphology of micellar systems and, consequently, the size and morphology of nanostructures formed. The most promising systems possessing ordered one-dimensional porous structure include MFI- and LTL-type zeolites, mesoporous silica, mesoporous aluminosilicates and anodic alumina. In the frames of the present project we intend to use these matrices as nanoreactors for formation of ordered magnetic nanowire arrays in a wide range of length/diameter ratios (the diameters will be varied from 0.5 to 100 nm).

2. Subjects

The project will address following scientific issues:
(1) Fabrication of porous templates with different pore diameters
(2) Synthesis and investigation of magnetic nanowires in porous alumina membranes
(3) Characterization of magnetic structures in (2)~(4) by TEM techniques including HRTEM, EELS, and holography.

At Moscow State University, the research will be performed by the group of Prof. Yu.D. Tretyakov, the Full Member of Russian Academy of Sciences. The team is well experienced in preparation of nanopowders and nanocomposites, synthesis of mesoporous phases; experimental characterization of nanomaterials.

At National Cheng Kung University, Department of Materials Science and Engineering (DMSE NCKU team) of Tainan, the research will be performed under the supervision of Prof. Chuan-Pu Liu. The team has a deep knowledge and experience in the fields of characterization and synthesis of nanomaterials, including quantum dots and nanowires. DMSE NCKU team would be focused on morphological characterization of magnetic nanophase particles, which is one of the major points for realization of the project and developing magnetization reversal model in one-dimensional nanostructure arrays. The DMS MSU team will focus on experimental characterization and theoretical modelling of the magnetic
properties of nanocomposites. For this purpose, computer simulations will be carried out and compared with measurements of the magnetization curve, and magnetic susceptibility. DMSE NCKU team would be focused on morphological characterization of magnetic particles by HRTEM.

3. Results

(1) Ni nanowires

Random arrays of ferromagnetic nanowires were synthesized by electrodeposition of Ni into the pores of homemade AAO templates. For the nanowire growth, a thin noble metal film was deposited by thermal evaporation on one side of the porous membranes to serve as a cathode. The filling of the pores was then performed by electrodeposition of Ni under potentiostatic control. A structural characterization of the Ni nanowire arrays was performed using transmission electron microscopy (TEM). In this work, we use AAO templates with 4 different parameters to fabricate Ni nanowires, which are 0.8V (potential), 2hrs (growth time), 0.8V, 2.5hrs, 0.8V, 6hrs and 1V, 1hr, respectively. Figure 1 shows the typical TEM image of Ni nanowires liberated from anodic films, revealing that the nanowires are cylindrical with diameter around 50nm. Table 1 shows size distribution of the nanowires. The pores of the anodic alumina were widened by immersing the as-made template in phosphoric acid for different lengths of time, and cause the fluctuation of the size distribution. In addition, there is a thin layer covered on the surface of Ni nanowire as shown in Fig.1, and the width of this layer is different from the wall width of
AAO. So that it is not from the residual AAO. Fig. 2 shows the HRTEM image and the corresponding diffraction pattern of sample 2. Ni nanowire is single crystalline as revealed by high-resolution imaging and electron diffraction. The lattice constant of nanowire is estimated from HRTEM image, which is 0.356nm. the lattice mismatch between bulk and nanowire is about 1.13%. From diffraction pattern, the nanowire structure is FCC, and the growth direction is along (110). Moreover, from the FFT results, the thin layer mentioned previously is NiO. We use EELS technique for composition analysis. Fig. 3 shows the EELS spectra for all 4 samples. The Ni L edge locates at 854 eV, and O K edge locates at 532 eV. Both Ni and O signal are detected, thus we confirm that the nanowire is composed of Ni and is oxidized.

Fig. 2 HRTEM image and corresponding diffraction pattern of Ni nanowire. the voltage is 0.8V, and the growth time is 2.5hrs. The insets are the FFT images.
For the electrical characterization, we have designed a devise to measure the resistance of a single nanowire. The schematic diagram for the device is shown in fig. 4. The lead is made by FIB. The R-T curve is obtained by PPMS. Fig. 5 shows both the SEM image of the device and the R-T curve of sample 2. After curve fitting, we calculate the activation energy of the single nanowire is 0.175meV.
Fig. 4 Schematic diagram for electrical measurement on single Ni nanowire.

(a) Au pad fabricated by photo-lithography

(b) To drop Ni nanowires on pad

(c) Pt leads are deposited by FIB
(2) Ni/Cu multilayered nanowires

The growth method for Ni/Cu multilayered nanowires is the same as that for Ni nanowires. Fig. 6 shows TEM images of Ni/Cu multilayered nanowire. TEM figures clearly show a layered structure was fabricated. It is interesting to see that there are two kinds of interfaces. One is straight (shown in fig. 6 (a)), and the other is oblique (shown in Fig. 6(b)). Fig. 7 shows the bright-field TEM image and corresponding diffraction pattern for multilayered nanowire. The structure is FCC. We use STEM-EELS to confirm the composition of the light band and dark band in the multilayered structure. Fig. 8 shows the HAADF images, the spectrum imaging, and the corresponding STEM-EELS spectra for the Ni/Cu nanowire. From the EELS spectra, the intensity of Ni signal is decreasing from point 1 to point 3, which indicated that the light layers (~10 nm) are represented by Cu, and the dark layers (~40 nm) are represented by the Ni layer. This particular wire diameter is about 100 nm.
(3) CdSe nanoparticles

CdSe nanoparticles are grown in mesoporous silica. Fig. 8 shows the HRTEM image and diffraction pattern of CdSe nanoparticles. As shown in fig. 8, the CdSe nanoparticles (marked with red circles) are embed in the matrix. The nanoparticle size is about 2~3nm. From the diffraction pattern, the structure is FCC. Moreover, the lattice mismatch between bulk and the nanoparticle is about 1.26%.
Fig. 9 HRTEM image and corresponding diffraction pattern of CdSe nanoparticles.

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Effects of In addition on the Lead-free Sn-Ag-Sb Solder
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Introduction

Tin-lead (SnPb) solders are widely used in the electronics industry due to a combination of many technical advantages, such as excellent solderability, workability, thermal and electrical conductivity, mechanical reliability, and low cost. Hazard concerns about using Pb in the electronics industry have been raised for many years, mainly stemming from occupational exposure, Pb waste from the manufacturing process, and the disposal of electronic assemblies. Pb use is being limited by stricter legislation. These factors have stimulated extensive research and development efforts to invent novel lead-free solder alloys to substitute SnPb solders in electronic applications (Tu et al. 2001).

Tin-silver based (SnAg) solder has good mechanical performances and being considered as one of the feasible candidates to replace SnPb solders. However, relatively high melting temperature and IMC (Intermetallic compound) coarsening problems at raised temperatures still restrict their usage. Recent studies (Lee et al. 2004,2005) have shown that adding antimony (Sb) can refine the IMC precipitate and hence improve the mechanical properties and thermal resistance of the Sn-Ag based solder at raised temperatures. The present study aims to investigate the influence of adding indium (In) on the melting temperature, microstructure, and shear strength of Sn-Ag-Sb solders.

Materials and Experimental Procedures

High purity Sn, Ag, Sb and In were smelted at 600℃ in a crucible protected with nitrogen to fabricate Sn-3Ag-2Sb-xIn (SASxIn, x=0, 1, 5, 10wt%) solders. Differential Scanning Calorimetry (DSC) was used to measure the corresponding liquidus and solidus temperatures of the produced solders. X-ray diffraction (XRD) technique was utilized to identify the phases formed in the solders. Single-lap tests were used to simulate actual solder joints in use and to evaluate the shear strength of the synthesized solders. The specimens for single-lap tests were prepared by joining a solder ball between two high purity copper substrates. The specimens were also isothermally stored at 150℃ for up to 625 hours to investigate their microstructure and thermal resistance. A Field Emission Scanning Electron Microscope (FE-SEM, Philips XL 40FEG) was used for microstructural analyses. Energy Dispersive X-ray Spectroscopy (EDX) was performed in the FE-SEM to analyze the chemical composition of the structures.

Results and Discussion

The corresponding liquidus and solidus temperature variations of produced solders are shown in Fig. 1. It is clear that Sn-3Ag-2Sb (SAS) has slightly higher corresponding temperatures than Sn-3.5Ag. Nevertheless, the profile starts to decline when In being added into SAS. Overall, the addition of In
decreases the melting point, but increases the range between liquidus and solidus temperature of the solder.

Fig. 1. Variation of the solidus and liquidus temperature for different solders.

The XRD profile of solders is shown in Fig. 2, in which SAS solder is consisted of $\beta$-Sn and $\varepsilon$-Ag$_3$Sn. After adding In in SAS, $\alpha$-InSb and $\gamma$-Ag$_2$In start being observed when the In addition exceeds 1 wt% and 5 wt%, respectively, and can be seen evidently in the SAS10In solder.
The microstructural evolution of solders and their interfacial structure with Cu substrate can be seen via SEM (Fig. 3). A few sheet-like Ag₃(Sn,In) compounds are observed near the Cu substrate in SAS1In (Fig. 3a). The morphology of the precipitates changed into long-strip and column-like shapes gradually with In addition, and their composition are identified as Ag₂(In,Sn) and Cu₆(In,Sn)₅, respectively (Figs. 3b and 3c).

After aging at 150 °C for 625 hours, the long-strip and column-like compounds have been found in SAS1In, and being identified as Ag₃(Sn,In) and Cu₆Sn₅, respectively (Fig. 3d). The composition and morphology of compounds changed with In addition, which can be seen in Figs. 3e and 3f, spherical Ag₃(Sn,In) and platelet InSb were observed in the structure instead.

It also can be seen in Fig 3 that the IMC layer thickness of all the as-soldered samples is about 2 µm, whereas increasing with thermal storage time. The composition of IMC layer changes with In addition, where Cu₆Sn₅ was identified in SAS1In, whereas being transferred into Cu₆(Sn,In)₅ after In addition exceeds 5wt%. The In content in the IMC layer increases with increasing of In addition in the solder. A houseleek-like compound (Fig. 4) was found in the as-soldered SAS5In, SAS10In, and aged SAS1In. It was identified as Ag₂(Sn,In) phase with size in the range of 10~35 µm. Such structure only appears between the solder and the IMC layer.
Fig. 5 reveals the shear strength evolution of the Sn-3.5Ag and SASxIn solder joints with Cu substrate after storage at 150 °C for various periods of time. It can be seen that the shear strength of the solder joints increases with increasing In addition, but decreases with increasing isothermal storing time. Since the IMC layer thickness of the as-soldered joints varies not much, the shear strength of the solder was mainly affected by the strength of solder. The solder may be strengthened by the solid-solution effect in the low In content range. By adding more and more In, the formation of InSb compounds in the solder may further increase the joint strength. However, after the heat storage processes, because of the precipitates coarsening and IMC thickening effects, the shear strength of the solders decreases with isothermal storage time. Nevertheless, the decreasing slope of the profile eventually reaches a plateau stage with time, except that of the solder with 10% In. This may be caused by the InSb compounds, whose size was dramatically increased in the solder after isothermal storage (Fig. 3f).
The fracture surfaces of the solder joints were examined after single-lap shear tests in order to investigate their fracture mechanism. Three fracture modes were found in the samples: in the solder, mixed solder and IMC, and in the IMC (Fig. 6). In the as-soldered samples, it was observed that most of the joints fractured in the solder, but mixed and IMC modes were gradually found with increasing In in the solder. Furthermore, the microstructure of the solder changes with the isothermal storage time, which directly affects its fracture mechanism. It is found that mixed and IMC fracture modes were found more frequently after aging. Most of the joints were fractured under mixed mode after aging for 625 hours.

The transition of solder joint fracture modes can be explained by the change of strength and ductility in the solder (Lee et al. 2005). The strength and the brittleness of the solder increase with increasing In content. As a result, the IMC layer may become the weakest part of the solder joint and yield plastic deformation, consequently initiating cracks in the IMC. The fracture interface changed from the interface of the solder/IMC to the interface of the IMC/Cu when In content increased from 5% to 10%.
On the other hand, the IMC layer was getting thicker and rougher after aging. This may cause local residual stress concentration and also initiating cracks in the IMC. Therefore, it was observed that the fracture behavior evolved from solder mode toward the mixed mode and finally to the IMC mode with increasing added In and isothermal storage time.

**Conclusion**

This study found that In helps to reduce the melting point but increase the shear strength of the SAS lead-free solder. Because of the alloy strengthening effects, the strength of the solder increases as the amount of added In increases. The fracture mode changes from the ductile solder mode to the brittle mixed and IMC mode. The coarsened InSb particles may cause a degradation of solder mechanical properties.

**References**

A Protection Method for Mudstone Slopes in Southwestern Taiwan

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Introduction

The exposed mudstone formations in the foothills area of southwestern Taiwan is a sedimentary rock formed in the end of the Tertiary Period to the initial of the Quaternary Period. It distributes from the County of Chiayi in the north to Kaohsiung in the south and covers an area over 1,000 km\textsuperscript{2}.

The mudstone is lithified shortly and cemented poorly. It is prone to swelling, slaking and softening with water, and has weak erosion resistance to stream flows, rainfall and surface runoffs. Severe erosion often results in bald landforms with gullies and exposed surface, like the landscape in the Moon, at the mudstone area.

Since the mudstone slopes in the area of southwestern Taiwan are particularly susceptible to erosion, a protection work on the mudstone slopes with suitable design and careful construction is needed to prevent the occurrence of geological hazards. This report presents an effective and economic slope protection method developed by the authors which was based on the characteristics of mudstone and climatic conditions in the southwestern Taiwan.

Physical and chemical properties of the mudstone

Chemical composition of this mudstones includes SiO\textsubscript{2} (63.49%), Al\textsubscript{2}O\textsubscript{3}.Fe\textsubscript{2}O\textsubscript{3} (21.53%) and CaO (2.71%) (Lin, 1943). Primary mineral components of the mudstone, based on X-ray diffraction testing results of Tsai (1984), include illite (30.54%), chlorite (28.70%) and quartz (28.45%). Secondary mineral constituents include feldspar, calcite and kaolinite. The particle size distribution of the weathered mudstone shows the average consistency is 49% of silt-size particles, 29% of clay-size particles, and 22% of sand-size particles. The index properties of the mudstone are: LL (liquid limit) = 38, PL (plastic limit) = 24, G\textsubscript{s} (specific gravity) = 2.74, \(\gamma\)\textsubscript{d} (dry unit weight) = 1.77 gf/cm\textsuperscript{3} (17.4 kN/m\textsuperscript{3}), and e (void ratio) = 0.51. The weathered mudstone in southwestern Taiwan is a low-plasticity clay, classified as CL according to the Unified Soil Classification System (USCS) (Lee et al., 1996).

Erosion Characteristics of the mudstone

Chen et al. (1984) and Chang et al. (1996) observed that south-facing slopes are more susceptible to
erosion than those facing north and that the percentage of bald slopes facing south was also correspondingly higher. The angles on these denuded slopes range from 36° to 55°, and it was observed that the longer the slope lengths, the more serious the erosion rate, with steeper slopes experiencing lower rates of erosion. The erosion depth of the bald mudstone slopes often exceeds 10 cm, while the infiltration depth of ground water may reach approximately 20 to 40 cm vertically below surfaces. Compared to bald slopes, slopes covered with vegetation generally experienced less erosion depth and land loss. In order to explore the effects of mudstone soil conservation with the vegetation method in cut slopes, Kuo and Lin (1998) used erosion pins to conduct erosion experiments on mudstone slopes. They concluded that the erosion on mudstone slopes was largely affected by the rainfall, and that the erosion depth of bald mudstone slopes (at a slope angle of 33° with a southwest aspect) averaged about 7.94 cm.

**Existing mudstone slope protection methods**

Rainfall, slope angle and slope height are considered the main factors for controlling the failure of mudstone slopes, while the slope aspect, or slant is the factor most affecting the successful growth of vegetation on these hillsides. Using the knowledge of mudstone slope failure characteristics, Lee (1992) recommended that both slope angle and slope height be considered in any mudstone slope protection and re-vegetation initiative. His research called for mudstone slopes (especially slopes with very steep and lengthy grades) to be redesigned into a “terraced” system. This new landscape design would involve cutting the larger slope into as many smaller terraced slopes as possible, each with a height of 5 m. For slopes with angles greater than 40°, sophisticated civil engineering slope protection methods must be used to ensure slope viability.

The slope protection methods commonly used by the National Expressway Engineering Bureau and other public agencies and private engineering firms include vegetation, grille beam, fabric form, shotcrete, green coating, stone masonry, gabion, prestressed rock anchor and concrete retaining wall. The following factors should be considered when selecting proper slope protection methods: the objectives and extent of protection to be achieved; the geological structure of the slope; the angle, height and length of the slope; and the constraints and advantages of various slope protection methods in terms of erosion protection, geological stability, ecological considerations and natural material considerations.

**Slope protection methods and slope failure modes in National Highway No.3**

The field survey shows that the slope protection methods used in road sections of National Highway No.3 to the south of Meishan include vegetation, prestressed rock anchors with vegetation, grille beam, rock anchors with grille beam, concrete stairs with shotcrete, precast cement frame, gabion and fabric form designs. Along the National Highway No.3 to the south of Meishan, slope failures occurred mainly in the form of surface erosion, shallow slides and side ditch cracks. Surface runoff caused surface erosion of the slopes; gullies could form first and then developed into more severe erosion. Also, vegetation layers could slide easily due to severe erosion, which often occurred in the mudstone and the alternating sandstone–shale formation slopes. Shallow slides often occurred during the season of typhoons and heavy rains. The depth of slides was generally shallow (about 50 cm), and the size of the slides ranged from 5 m×4 m to 60 m×10 m.

**Requirements for effective slope protection methods**

Based on the characteristics of the mudstone and the results of the field survey, the following recommendations are essential for effective slope protection countermeasures:

1) A slope protection method must be able to resist erosion, prevent fine-grained soil loss, and facilitate
adequate drainage,
2) A surface water drainage system is required to effectively control the rainwater,
3) The slope protection facilities must have adequate strength to resist the swelling pressure of the mudstone, and
4) The slope protection facilities must increase slope stability and facilitate vegetation growth.

**A field implementation of Soil-Tire-Vegetation method**

A new slope protection method, Soil-Tire–Vegetation Method, implementing the requirements previously described, was developed for this weak-rock mudstone region (see Figs. 1 and 2 for implementation sketches). To determine its effectiveness, a field experiment has been conducted at a mudstone slope near the Tungshan Rest Station of National Highway No. 3. Fig. 3 shows the steps taken for field implementation of the Soil-Tire–Vegetation Method. The construction of the test slopes began on 17 September, 2004 and ended on 27 November, 2004. The original slope in the experimental zone consists of the upper and lower slope surfaces. As shown in Fig. 4, the test slopes are divided into original slopes (A1), contrast slopes (B1, B2 and G1, G2) and Soil-Tire slopes (C1, C2 and D1, D2; E1, E2 and F1, F2). The attitude, area and vegetative treatment of slopes of various groups are shown in Table 1. The strike of slope surfaces in the experimental zone is N40°W with a SW dip direction. The dip angles of the original slopes are about 42°, while those of contrast slopes and Soil-Tire slopes are approximately 36° and 34°, respectively. The width of the slopes of various groups is about 15 m, and the slope lengths gradually lessen from right to left. With regard to vegetative treatment for slopes of various groups, the original slopes are covered with originally vegetative species, while the contrast slopes are laid with vegetative mats after slope cut to the design specification, and the Soil-Tire slopes are placed with Soil-Tires as the base layer for vegetation. As for the vegetation on Soil-Tire slopes, four Vativeria zizanioides are planted in the central space of Soil-Tire on the slopes of C1 and C2, and the remaining slopes (D1, D2, E1, E2, F1, and F2) are covered with vegetative mats which consist of nonwoven and straw vegetative mats. In addition, the seeds of C. dactylon and P. notatum are sowed on these slopes. The total project cost was about 35,000 U.S. dollars.
Fig. 1. Sketch of a new slope protection method (Soil-Tire–Vegetation Method) that has been tested during this study.
Fig. 2. Plan view of the new slope protection method (Soil-Tire–Vegetation Method) that has been tested during this study.
Fig. 3. The field implementation of the Soil-Tire–Vegetation Method: (a) slope cut to the design shape; (b) forming multi-stage slope and platform; (c) laying the fabric drains; (d) laying the nonwoven geotextile sheet; (e) constructing transverse ditch; (f) laying the separator of the Soil-Tires; (g) laying the Soil-Tire and vegetative bags; (h) placing the vegetative mat.

Fig. 4. The arrangement of test slopes.

Table 1 Types of vegetation and slope stabilization methods at test slopes

<table>
<thead>
<tr>
<th>No.</th>
<th>Attitude</th>
<th>Area (m²)</th>
<th>Vegetation treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original slope</td>
<td>A1</td>
<td>N40°W/42°SW</td>
<td>69.38</td>
</tr>
<tr>
<td>Contrast slope</td>
<td>B1</td>
<td>N40°W/36°SW</td>
<td>112.01</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>N40°W/36°SW</td>
<td>82.50</td>
</tr>
<tr>
<td>Soil-Tire slopes</td>
<td>C1</td>
<td>N40°W/33°SW</td>
<td>31.84</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>N40°W/33°SW</td>
<td>18.43</td>
</tr>
<tr>
<td></td>
<td>D1</td>
<td>N40°W/33°SW</td>
<td>35.30</td>
</tr>
<tr>
<td></td>
<td>D2</td>
<td>N40°W/33°SW</td>
<td>20.70</td>
</tr>
<tr>
<td></td>
<td>E1</td>
<td>N40°W/34°SW</td>
<td>40.62</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>N40°W/34°SW</td>
<td>22.20</td>
</tr>
<tr>
<td></td>
<td>F1</td>
<td>N40°W/34°SW</td>
<td>38.15</td>
</tr>
<tr>
<td></td>
<td>F2</td>
<td>N40°W/34°SW</td>
<td>21.88</td>
</tr>
<tr>
<td>Contrast slope</td>
<td>G1</td>
<td>N40°W/36°SW</td>
<td>158.78</td>
</tr>
<tr>
<td>Slope</td>
<td>G2</td>
<td>N41°W/35°SW</td>
<td>121.80</td>
</tr>
</tbody>
</table>
Table 2 shows the erosion of test slopes in the first year of experimentation. During this period, there had been several typhoons and heavy rainstorms and the accumulated rainfall reached 3553 mm. As shown in Table 2, the original slopes suffered the most serious erosion (with erosion of 27665 g/m² on Slope A1). The "contrast" slopes showed significant improvement as far as the erosion is concerned. Finally, the slopes protected with the Soil-Tire–Vegetation Method drastically reduced the erosion and the mud slide potential. This preliminary result shows the promise of the Soil-Tire–Vegetation Method in the protection of the mudstone slopes in the southwestern Taiwan.

**Table 2 Soil erosion as measured at test sites**

<table>
<thead>
<tr>
<th>Date (day/month/year)</th>
<th>Cumulative rainfall (mm)</th>
<th>Slope ID</th>
<th>Erosion (g/m²)</th>
<th>Erosion (g/m²)</th>
<th>Erosion (g/m²)</th>
<th>Erosion (g/m²)</th>
<th>Erosion (g/m²)</th>
<th>Erosion (g/m²)</th>
<th>Total erosion (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/12/04</td>
<td>96</td>
<td>A1</td>
<td>860</td>
<td>232</td>
<td>1716</td>
<td>11486</td>
<td>595</td>
<td>4897</td>
<td>6393</td>
</tr>
<tr>
<td>10/04/04</td>
<td>167</td>
<td><strong>B1</strong></td>
<td>683</td>
<td>150</td>
<td>286</td>
<td>1064</td>
<td>192</td>
<td>431</td>
<td>541</td>
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<tr>
<td>22/05/05</td>
<td>252</td>
<td><strong>B2</strong></td>
<td>84</td>
<td>235</td>
<td>735</td>
<td>1322</td>
<td>133</td>
<td>186</td>
<td>166</td>
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<td>C1</td>
<td>5132</td>
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<td>2321</td>
<td>4498</td>
<td>286</td>
<td>1388</td>
<td>482</td>
</tr>
<tr>
<td>16/07/05</td>
<td>64</td>
<td>C2</td>
<td>741</td>
<td>218</td>
<td>111</td>
<td>183</td>
<td>59</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td>26/07/05</td>
<td>723</td>
<td>D1</td>
<td>424</td>
<td>58</td>
<td>178</td>
<td>193</td>
<td>276</td>
<td>86</td>
<td>55</td>
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<tr>
<td>08/09/05</td>
<td>869</td>
<td>D2</td>
<td>192</td>
<td>136</td>
<td>33</td>
<td>26</td>
<td>34</td>
<td>39</td>
<td>16</td>
</tr>
<tr>
<td>26/11/05</td>
<td>194</td>
<td>E1</td>
<td>274</td>
<td>13</td>
<td>12</td>
<td>47</td>
<td>25</td>
<td>9</td>
<td>27</td>
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<tr>
<td></td>
<td>3553</td>
<td>E2</td>
<td>146</td>
<td>50</td>
<td>52</td>
<td>61</td>
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<td>300</td>
<td>41</td>
<td>114</td>
<td>149</td>
<td>86</td>
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<td></td>
<td></td>
<td>F2</td>
<td>216</td>
<td>75</td>
<td>50</td>
<td>107</td>
<td>121</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>G1</strong></td>
<td>446</td>
<td>117</td>
<td>139</td>
<td>290</td>
<td>47</td>
<td>111</td>
<td>187</td>
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<tr>
<td></td>
<td></td>
<td><strong>G2</strong></td>
<td>77</td>
<td>363</td>
<td>1517</td>
<td>1427</td>
<td>78</td>
<td>276</td>
<td>168</td>
</tr>
</tbody>
</table>

Note: * original slope. ** contrast slope (vegetative mat); all others: slopes protected with the Soil-Tire–Vegetation Method.

**References**

Feasibility study on bioreactor strategies for enhanced photohydrogen production from Rhodopseudomonas palustris WP3-5 using optical-fiber-assisted illumination systems

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Introduction

As the petroleum price keeps rising, the demand for reliable and effective energy alternatives is increasingly urgent. Among the candidates of alternative energy resources, H₂ has been considered an ideal energy carrier because it is clean, recyclable, and efficient. Conventional H₂ production methods, such as thermochemical conversion of fossil fuels, are usually expensive and energy-intensive; they also result in production of environmental pollutants and greenhouse gases. Therefore, alternative methods for H₂ production are of great demand. In fact, biological production of H₂ is considered the most environment-friendly route of producing H₂. Hydrogen can be produced biologically from photolysis of water, and through light-dependent or independent fermentative pathways using organic materials as the substrate. Dark fermentation with mainly acidogenic bacteria (such as Clostridium sp.) produces H₂ while converting organic substrates into volatile fatty acids and alcohols. The soluble metabolites from dark fermentation could be mineralized by photosynthetic bacteria (e.g., purple nonsulfur bacteria) to produce more H₂. Thus, combination of dark and photoH₂ fermentation has been proposed to achieve the highest theoretical H₂ yield. Compared to dark fermentation, photofermentative production is relatively slow mainly due to the low growth rate of photosynthetic bacteria as well as the poor efficiency of light energy conversion. Thus, upgrading the production rate of photoH₂ fermentation becomes a pivotal step towards a successful integrated fermentative H₂ production process.

In this study, an indigenous photosynthetic bacterium Rhodopseudomonas palustris WP3-5 was used as a model H₂ producer to investigate bioreactor strategies for a novel H₂-producing photobioreactor illuminated by combination of optical fiber and other conventional light sources (see Fig. 1). Optical fiber could be an ideal light source for photobioreactors because it provides uniform light distribution and proximal contact with light-demanding microorganisms to achieve high light transmission efficiency. The goal of this work was to develop better bioreactor operation strategies with a novel photobioreactor to improve its H₂ production performance as well as operational stability. The knowledge obtained from this study could be used to assess the feasibility of utilizing the photobioreactor system in practical
applications.

![Diagram of photobioreactor system](image)

**Fig. 1.** Schematic description of the photobioreactor system equipped with internal (optical fiber) and external (halogen and/or tungsten filament lamp) light sources.

### Results and discussion

To determine which operation mode was preferable in H₂ production, batch, CSTR and F/D operations were conducted with the same initial acetate concentration (32.5 mmol/l) and culture volume (800 ml). Meanwhile, the retention time for CSTR (HRT = 48 h) was identical to the HRTavg for F/D operations. Halogen lamp was used as the light energy supply in these tests. Table 1 summarizes the overall H₂ production performance for different operation modes. The foregoing results suggest that under similar culture conditions, the F/D operation seemed to attain better overall (15.5 ml/l h) and specific (3.83 ml/g h) H₂ production rate (Table 1) than the other operation modes examined. In addition, the F/D operation also gave a higher H₂ yield of 1.71 mol H₂/mol acetate, in contrast to 1.08 and 1.30 mol H₂/mol acetate for batch and CSTR, respectively (Table 1).

In the F/D operations, acetate was used as the sole carbon source because it is known to be one of the major soluble metabolites obtained from dark H₂ fermentation. Different acetate concentrations (16.3–48.8 mmol/l) were then fed into the photobioreactor illuminated externally with halogen lamps to examine the effect of carbon substrate concentration on the performance of photoH₂ production.
According to Fig. 2 and Table 1, an acetate concentration ($C_{\text{HAc}}$) of 32.5 mmol/l exhibited the highest overall H$_2$ production rate ($v_{\text{H}_2}$) of 15.53 ml/l h. The $v_{\text{H}_2}$ increased with an increase in $C_{\text{HAc}}$ from 16.67 to 32.5 mmol/l, whereas $v_{\text{H}_2}$ decreased considerably when $C_{\text{HAc}}$ was further increased to 48.8 mmol/l. Although $C_{\text{HAc}}$ of 32.5 mmol/l gave the best H$_2$ production performance, the organic loading may need to be adjusted lower when COD removal ratio becomes a major concern. Possible approaches to maintain a low effluent COD include extension of the reaction time for each F/D operation or loading the medium at a more appropriate feeding profile (e.g., fed-batch feeding).

The concentration of glutamic acid was also adjusted to determine the optimal nitrogen source dosage for photoH$_2$ production. With acetate concentration fixed at 32.5 mmol/l, a glutamic acid concentration ($C_{\text{glu}}$) of 100–800 mg/l was applied in the F/D cultures using halogen lamp as the light source. As shown in Fig. 3, as $C_{\text{glu}}$ was increased from 100 to 400 mg/l, the H$_2$ production rate also increased from 12.8 ml/l/h to a peak value of 20.9 ml/l/h, whereas further increase in $C_{\text{glu}}$ to 800 mg/l resulted in a slight decrease in H$_2$ production rate. Moreover, the best specific H$_2$ production rate occurred when $C_{\text{glu}}$ was at 200–400 mg/l, but decreased considerably when $C_{\text{glu}}$ was increased further. All the results suggest an optimal glutamic acid concentration of 400 mg/l in all the categories used to assess the H$_2$-producing performance.

Table 1 Performance of photoH$_2$ production in photobioreactors illuminated with halogen lamp under different operation modes and different acetate concentrations

<table>
<thead>
<tr>
<th>Operation mode</th>
<th>Acetate (mg COD/l)</th>
<th>Maximum cell concentration (g/l)</th>
<th>H$_2$ yield (mol H$_2$/mol acetate)</th>
<th>Overall H$_2$ production rate (ml/l/h)</th>
<th>Specific H$_2$ production rate (ml/g/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill and draw</td>
<td>1000</td>
<td>5.58</td>
<td>1.630</td>
<td>13.2</td>
<td>3.08</td>
</tr>
<tr>
<td>Fill and draw</td>
<td>2000</td>
<td>5.70</td>
<td>1.706</td>
<td>15.5</td>
<td>3.83</td>
</tr>
<tr>
<td>Fill and draw</td>
<td>3000</td>
<td>4.33</td>
<td>0.743</td>
<td>9.7</td>
<td>2.33</td>
</tr>
<tr>
<td>Batch</td>
<td>2000</td>
<td>7.78</td>
<td>1.080</td>
<td>8.7</td>
<td>3.01</td>
</tr>
<tr>
<td>CSTR</td>
<td>2000</td>
<td>6.16</td>
<td>1.304</td>
<td>13.5</td>
<td>3.15</td>
</tr>
</tbody>
</table>
Fig. 2. Effect of acetate concentration on the performance of photohydrogen production under fill-and-draw operations: (a) overall H₂ production rate, (b) H₂ yield, and (c) light conversion efficiency.

(Glutamic acid concentration=200 mg/l; light source: halogen lamp (HL); light intensity = 95W/m²; irradiation area = 342 cm²).
We also found that addition of optical fiber as the internal light source could markedly enhance the H₂ production rate and H₂ yield. Therefore, the best illumination system for the proposed photobioreactor (PBR) would be the combination of optical fiber (OF), halogen filament lamp (HL) and tungsten lamp (TL) (i.e., OF/HL/TL). To assess the applicability of the photoH₂ production system, the PBR was operated with the fill and draw strategy under the optimal conditions (\(C_{\text{HAc}} = 32.5\, \text{mmol/l}, \ C_{\text{glu}} = 400\, \text{mg/l}, \) light source = OF/HL/TL) for a prolonged period of time (nearly 30 day). The results (Fig. 4) show that the overall H₂ production rate and H₂ yield were fairly stable with mean values of 36.8 ml/l h and 2.90 mol H₂/mol acetate, respectively. The light conversion efficiency was also stably maintained at a high value of 1.924%. These results indicate that the PBR displayed excellent H₂-producing performance and stability during long-term F/D operations. Therefore, there is a potential of using the system for practical applications in degrading organic acids (such as acetate) to produce H₂.
Fig. 4. Effect of long-term fill-and-draw operation on the performance of photo-hydrogen production (a) overall \( \text{H}_2 \) production rate, (b) \( \text{H}_2 \) yield, and (c) light conversion efficiency. (Acetate concentration = 32.5 mmol/l; glutamic acid concentration = 400 mg/l; light source: OF/HL/TL; total light intensity = 95 W/m\(^2\))

**Conclusion**

An optical fiber-illuminating photobioreactor (PBR) was effective in producing \( \text{H}_2 \) from fill-and-draw cultures of *Rhodopseudomonas palustris* WP3-5 using acetate and glutamic acid as the carbon and nitrogen substrate, respectively. The concentration of carbon and nitrogen source appeared to play a crucial role in the \( \text{H}_2 \) production efficiency and the optimal concentrations were 32.5 mmol/l for acetate and 400 mg/l for glutamic acid. The illumination system also markedly affected the performance of photo\( \text{H}_2 \) production. Using a ternary combination of optical fiber, halogen lamp, and tungsten filament lamp (OF/HL/TL system) achieved a maximum \( \text{H}_2 \) production performance with a \( \text{H}_2 \) production rate of 38.2 ml/l h, a \( \text{H}_2 \) yield of 3.15 mol \( \text{H}_2 \)/mol acetate, and a light conversion efficiency of 1.93%. This performance is superior to that of most comparable bioprocesses and can be stably maintained for nearly 30 day, indicating the potential of practical uses of the developed PBR system.