PVA Used as a Soil Conditioner: Aging and Interaction Forces with Soils

LEE Yuan-chih[1], CHENG Jack-da[2], LIU Chun-ku[3], CHOU Liang-hsing[3], LEE Maw-tien[4]*
(1. Department of Water and Soil Conservation, National Chung-Hsing University, Taiwan 402;
2. Department of Resource Engineering, National Cheng Kung University, Taiwan 701;
3. Department of Civil and Water resource Engineering, National Chiayi University, Taiwan 600;
4. Department of Applied Chemistry, National Chiayi University, Taiwan 600)

Abstract: Polymers used as soil conditioners to enhance the capability for protection against erosion of soil are important topics in environmental study. Polymer soil conditioners can stabilize the aggregates of soils, increase the infiltration and reduce the runoff and erosion of soil. In this work, polyvinyl alcohol (PVA) was used. Its degradation in soils and its intermolecular interaction force with soils were studied. Pure PVA film, PVA with silica and PVA with alumina oxide were heated or treated with ultra-visible light. FTIR was used to observe the aging of PVA. The surfaces of the specimens were observed with SEM and AFM (atomic force microscope). Interaction force between PVA and the tip was measured with AFM. The effects of soils on the aging of PVA were discussed according to the experimental results. Effects of treating methods on the interaction force between soils and PVA were also discussed in this study.

Key words: soil conditioner; intermolecular force; poly (vinyl alcohol)
CLC number: S156 Document code: A Article ID: 0529-6579 (2007) S1-0262-03

1 Introduction

Poly (vinyl alcohol) (PVA) is water-soluble, biodegradable. It is attractive for environmentally friendly products. There are a large amount of studies on the adsorption of PVA onto solid surfaces. Sivlle[1] and Vishwakarma[2], studied the adsorption isotherms of PVA on to solid surfaces. The interactions and adhesive forces between PVA and different solid surfaces were measured by Atomic Force Microscopy (AFM) recently, for examples Uner et al[3], and Yoichi Kanda et al[4]. Effects of PVA on the germination of plants' seeds have been studied in agricultural applications for a long time. Barry et al[5] gave some research results. The aging of PVA in the environment was also an important topics. Emo Chiellini et al[6] studied the biodegradation of PVA. In this study experiments on PVA aging by heat and UV light were conducted and measured with FTIR. Adhesive forces between PVA and solid surfaces were measured with AFM. SEM picture were used to observe the binding phenomena of PVA and solids.

2 Experiments

2.1 materials and instruments

Polyvinyl alcohol (PVA) (Chang Chun Petrochemical CO. Ltd Taiwan), standard sand (Ottawa standard sand by U. S. Silica Company), and SiO_2 (Merck) were used in the experiments.

Fourier Transform Infrared Spectrometer (FTIR), Atomic Force Microscope (AFM), and Scanning Electron Microscope (SEM) for characterizing the reaction products.

2.2 Experiment procedure

a. Preparation of PVA film

(1) 1 Mixing 3 g PVA solid with 97 mL pure water ($R > 18M\Omega$). Heating and stirring the mixture until the PVA solid dissolves completely. (2) Cooling the solution and taking some drops of the solution on glass. The solution drops spread. The spreading film was kept in room temperature for air-drying for 24 hours.

b. Preparation of PVA-SiO_2 mixtures

(1) 1 g of PVA was added to 20 g of pure water. Heating and stirring the mixture until the PVA solid dissolves completely. (2) 4 g of SiO_2 was mixed with the PVA solution prepared in (1). (3) The mixture

①收稿日期: 2007-01-10
基金项目: 台湾自然科学基金资助项目 (NSC94—2622—E415—002—CC3)
作者简介: 李元智 (1964年生), 男, 博士生; 通讯联系人: 李茂田; E-mail: mtlee@mail.ncyu.edu.tw

was kept in room temperature for air-drying for 24 hours.

c. Aging experiments

(1) Both the samples prepared in a and b sections were heated at 50, 100, 150℃ for 1 ~ 3 hours. (2) The PVA film was further treated with UV light for 1 ~ 7 days.

d. All the samples were analyzed with FTIR to observe the change of function groups of PVA. SEM was also used in this studied. Finally, AFM was used to analyze the surface structure of PVA film and the interaction force between PVA and solid.

3 Results and Discussions

Figure 1 shows the results of FTIR analysis. In comparison with the IR spectrum of the original PVA film, PVA film heated to 150℃ for an hour or treated with 254 nm UV for 7 days shows some different absorption in 1143 cm^{-1} (within the C-O absorption range). It is believed that both treating methods will induce the aging of PVA.

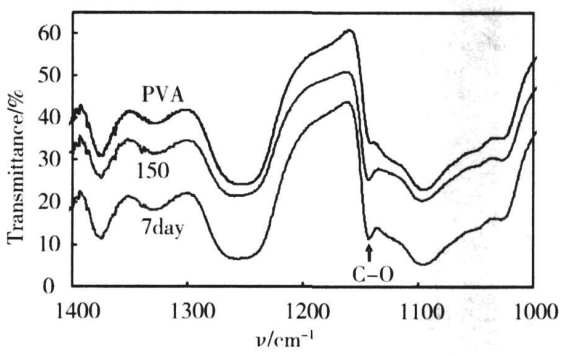
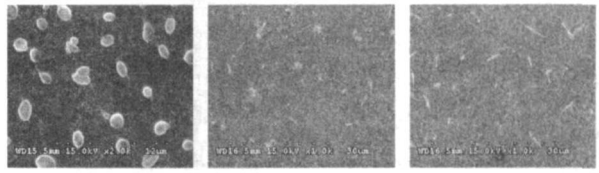


Fig. 1　IR spectrum of PVA films

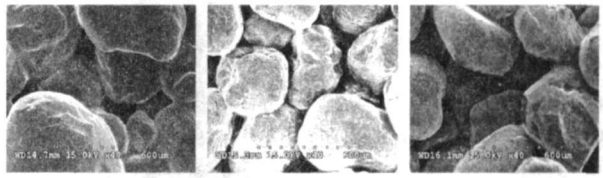
Figure 2 a is the SEM picture of original PVA film. It is clear that PVA molecules are sphere-like shape. PVA film heated to 150℃ is shown in figure 2 b. In this case PVA molecules are rod-like shape. It is believed that with high temperature, small PVA molecules will polymerize to large molecules. PVA film treated with UV gives the similar results as shown in figure 2 c.

As we know, silicon oxide is the most amount component in almost all soils. In this experiment PVA was mixed with silica to observe the interaction of PVA and silica. Figure 3 a gives the SEM picture of PVA-silica mixture. It is apparent the silica particles link together by PVA film. Figure 3 b shows the mixture after heating to 150℃ for an hour. With the loss of water and possible polymerization reaction, the PVA film shrinks and adheres to the silica surface. UV treatment gives the similar result as shown in figure 3 c.



a　　b　　c

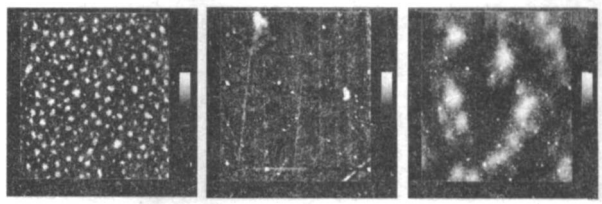
Fig. 2　a PVA film (original),
b PVA film (heated to 150℃ for 1 hour),
c PVA film (treated with UV 254nm for 7 days)



a　　b　　c

Fig. 3　a PVA + SiO_2 (original);
b PVA + SiO_2 (heated 150℃ for 1 hour);
c PVA + SiO_2 (UV-ireating for 7 days)

Figure 4 a depicts AFM pictures of the PVA films. Figure 8 a shows the scanning result of original PVA film. As depicted in figure 2, PVA molecules have spherical shape. They overlapped with each other. Figure 4 b is the AFM picture of PVA film which was heated to 150℃. PVA molecules in this case are different from the original PVA film. Some accumulation occurs in the film. It is believed that PVA molecules polymerized to larger molecules. The polymerization was not homogeneous. In figure 4 c PVA film was treated with UV light for 7 days. The polymerization of small molecules was more completely. Large molecules accumulated together.



a　　b　　c

Fig. 4 AFM pictures and depth profiles
a Original PVA film, b heated to 150℃ for a hour,
c UV (254nm) treated for 7 days

To understand the interaction force between PVA and solid, the force-distance relation was measured with AFM contact mode. Adhesive force was recorded and compared for various PVA films. Figure 6 shows the adhesive forces between PVA film and the colloidal probe. The increase of treating temperature will enhance the adhesive force. It is believed that decrease of water content and larger PVA molecules will increase the adhesive force.

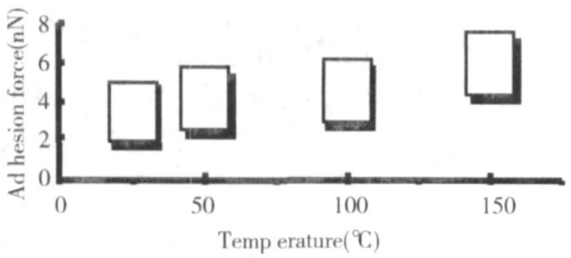


Fig. 5 Effect of heat treated on the adhesive force

4 Conclusions

PVA films and PVA-silica mixtures were prepared in this study. Both samples were treated with heat and UV to observe their properties change. Increase in temperature and treated with UV light will induce polymerization occurs. SEM pictures gave the evidence. AFM scanning showed that UV light makes the polymerization more complete. FTIR spectrum depicted that both heat and UV light would change the absorption in C—O spectrum region. It is believed that PVA will age by heat and UV light. AFM was used to get the interaction force between PVA and solid. The higher the temperature, the greater the adhesive force. Lower water content and larger PVA molecules are the possible answer for this result. Experimental results showed that PVA adhered to soils well. Soils and PVA had better bonding than that of mixtures kept in room temperature.

References:

[1] SIBYLLE P W, WALTER R F. Estimation of specific surface area of soil particles by adsorption of polyvinyl alcohol in aqueous suspension [J]. J Plant Nutr Soil Sci, 2001, 164: 441—443.

[2] VISHWAKARMA B N. Adsorption of poly (vinyl alcohol) onto Fullers earth surfaces [J]. Colloids and Surfaces A: Physicochem Eng Aspects, 2002, 2003: 117—130.

[3] UNER B, RAMASURBRANIAN M K, ZAUSCHER S. Adhesion interactions between poly (vinyl alcohol) and iron oxide surfaces: the effect of acetylation [J]. J Applied Polymer Sci, 2006, 99: 3528—3534.

[4] YOICHIK, SHIN J, KO H. Adhesive force between hydrophilic surfaces in alcohol-water solutions [J]. J Colloid and Interface Sci, 1999, 216: 394—400.

[5] BARRY P V, STOTT D E, TURCO R F. Organic polymers' effect on soil shear strength and detachment by single raindrops [J]. Soil Science Society of American J, 1991, 55 (3): 799—804.

[6] EMO C, PATRIZIA C, SALVATORE D. Liquid mulch based on polyvinyl alcohol: PVA-soil interaction [J]. Macrol Symp, 2003, 197: 133—142.

聚丙烯醇做土壤改良剂研究: 老化与作用力分析

李元智[1], 郑皆达[1], 卢俊谷[2], 周良勋[3], 李茂田[4]

(1. 中兴大学 水土保持系, 台灣 402; 2成功大学资源工程研究所, 台灣 台南 701;
3. 嘉义大学 土木与水资源工程系, 台灣 嘉义 600; 4嘉义大学 应用化学系, 台灣 嘉义 600)

摘 要: 聚烯醇可生物分解且无毒性, 可做为土壤改良剂。其在土壤中受温度、紫外线影响而老化的问题为本研究的一部份。以加热及 UV处理 PVA膜与 PVA与 SiO_2 混合物。样品以 FT-IR光谱了解其劣化情况。 PVA膜与土壤之作用力则以原子力显微镜量测其力曲线与观察表面变化。此外 PVA与 SiO_2 混合物则以 SEM观察其受热与受 UV处理的结果。

关键词: 土壤改良剂; 分子间作用力; 聚烯醇

中图分类号: S156