

**Hyaluronic acid/polyvinyl alcohol 블렌드의 농도에 따른
유변학적 특성연구**

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**Effect of concentration on the rheological properties of
hyaluronic acid/polyvinyl alcohol blend systems**

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Introduction

Hyaluronic acid(HA) is a water soluble glycosaminoglycan. It is a high molecular weight linear polysaccharide with the repeating disaccharide structure composed of D-glucuronic acid and N-acetyl-D-glucosamin with (1-4) interglycosidic linkages[1]. HA occurs naturally in many living substrates as synovial fluid, vitreous humour, connective tissues, rooster comb and umbilical cord. Indications of pharmacological activity have been demonstrated in the treatment of inflammatory and degenerative joint diseases[2,3]. And HA is also used as a visco-supplementation for the ophthalmic surgery treatment[4] of osteoarthritis of the knees joint. In these applications the rheological properties of HA are important, However, the short residence time of HA due to biodegradability limits the possibility to widen its range of biomedical application. To overcome this problem, many methods have been investigated; associating HA with alginate [5-6], chemically modifying HA[7], and blending HA with other polymers[8], for example.

In this paper, we designed the blend of synthetic and natural polymers that have good mechanical properties and biocompatibility[9-11], and enhanced rheological properties. We use Poly(vinyl alcohol)-borax (PVAs) as synthetic components, and Hyaluronate(HA) as natural polymer. In this paper, the concentration effect on the rheological properties and morphology of HA-PVAs blend will be reported.

Theory

Poly(vinyl alcohol) is unique as a synthetic polymer in that it has a large number of hydroxyl groups. Hydrogen bonds related to the large number of hydroxyl groups play an important role in the physical behaviour of poly(vinyl alcohol) . Aqueous solutions of poly(vinyl alcohol) form aggregated supermolecular structures. These structures contain amorphous and paracrystalline parts[12], the mutual ratio of which depends on experimental conditions

during the preparation of solutions, and predominantly on the dissolution temperature[13]. The structure and properties of aqueous solution of poly(vinyl alcohol)-borax complex has been studied. PVA-borax forms the crosslinking and may become a gel under approximate conditions of PVA and borax concentration, ionic strength, pH, and temperature. And its shear thickening behavior has been well recognized.

Experiment

This study was carried out with Hyaluronate, Poly(vinyl alcohol) and borax. HA of molecular weight (3300KDa) is used as received by LGCI(LG Chem Investment Ltd.) in Korea. PVA (Mw: 124 -186 KDa, 98-99% hydrolyzed) and borax were purchased from Sigma.

The blend preparation is as follows :

- a) 1 wt% HA aqueous solution is prepared with purified water at room temperature for one night by shaking at 300rpm
- b) 4 wt%PVA aqueous solution is dissolved at 80°C and 106°C (200rpm, 1hr)
- c) 2wt%,1wt%, 0.6wt% borax aqueous solution is made at 60°C for 30min.
- d) (a) is mixed with (b) at 70°C for 30min.
- e) (d) is mixed with (c) at 70°C for 30min. (HA/PVAs blend)

The mixed solutions (d) or (e) of polymer solutions are 20:80 ratio 1%Hyaluronate/2%PVA borax(HA/PVAs) at various concentration . We call HA/PVAs blend that is consisted of PVA which is dissolved at 80°C to HA/PVAs[N] and the case of PVA prepared at 106°C to HA/PVAs[P]. We stained blends using Alcian Blue method for morphology investigation.

Rheological experiments were performed on an RMS 800(Rheometrics Scientific, USA) strain controlled rheometer, fitted with a cone and plate geometry (50mm,0.04rad). The morphology of blends is investigated with optical microscope (OLYMPUS BX51, JAPAN).

Results and Discussion

The tendency of PVA to form microcrystalline structures depends on the temperature history. The microstructure of PVA is different depending on the dissolution temperature as reported. So it is possible to control the microstructure of HA/PVAs blends by using the PVA prepared at different temperature. Figure 1. shows different rheological behavior between HA/PVAs[P] and HA/PVAs[N] blend. The complex viscosity of HA/PVAs[P] blend is larger than HA/PVAs[N] blend for all composition range, and it shows the maximum at the composition of HA:PVAs(20:80). It indicates that the different microstructure of HA/PVAs blend is formed by changing the preparation methods. This is verified in Figure 4. In the case of HA/PVAs[P], the aggregates are connected together, forming a three-dimensional network structure. While in the case of HA/PVAs[N], HA chains are aggregated forming dispersed phases separated from each other as in Figure 3. To get more information about these interactions among HA, PVA and borax, we first focus on borax. Though HA/PVA blend without borax shows similar

behavior, the interaction was more weaker than HA/PVAs blend. Namely, the presence of borax enhances the interaction of the blends. Figure 2 shows the rheological properties of HA/PVAs(20:80) blend are enhanced, as that concentration of borax increases. For PVA/borax system, the blend has the enhanced rheological properties as the concentration of borax increases, and the blend forms gel over the critical concentration of borax. The strain hardening behavior of the blends gets stronger as the amount of borax increases[14-15].

Figure 5,6 shows that the size of HA aggregates of HA/PVAs[P] (0.5 wt%) of $10\mu\text{m}$ is smaller than the one of HA/PVAs[P] (0.3 wt% borax) of $5\mu\text{m}$. This seems to result from the charge repulsion among the borate ions bound in PVA. So intermolecular crosslinked network is formed and the network gets stronger as the concentration of borax increases. When the concentration of borax is 1.0wt%, the amount of borax seems to be excessive[16]. The excess borax affects the interaction of HA/PVAs blend so that different microstructure of the blend appears as shown in Figure4 (HA/PVAs[P](1wt%borax)).

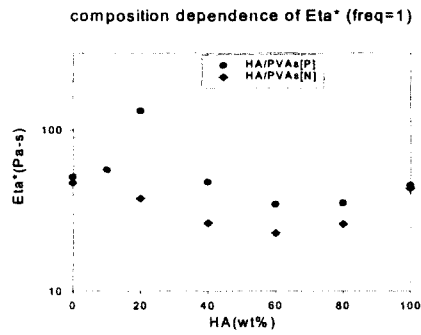


Figure 1



Figure 3



Figure 5

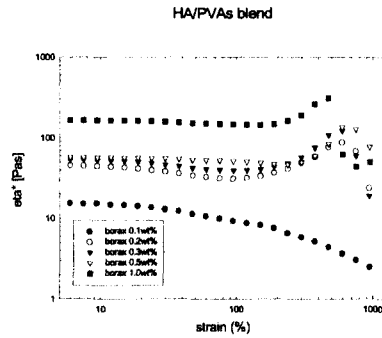


Figure 2



Figure 4

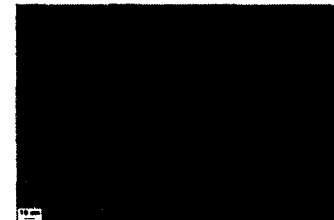


Figure 6

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