Preparation of Orange-pink Glass from Recycled Materials for Jewelry Application

Ployrat Aridech and Worapong Thiemsorn

Department of Industrial Chemistry, Faculty of Science, Chiang Mai University

Chiang Mai, 50200, Thailand.

Corresponding Author E-mail address: ployrat_a@cmu.ac.th

FACULTY OF SCIENCE
CHIANG MAI UNIVERSITY

JEWEL IMPRESS
JEWELRY DESIGN STUDIO

Abstract

This research aimed to prepare orange-pink colored glass using borosilicate glass cullet and longan wood ash as the major raw materials for jewelry applications. Erbium oxide (Er2O3) was doped as a coloring agent in the range of 0.05 to 1.5 wt%. The glass batches consisted of more than 80 wt% combined borosilicate cullet and longan wood ash, cooperating with fluxing agents, and were melted in an electric furnace at 1350 °C . The molten glass was then cast into a metal mold and annealed at 550 °C for 1.5 hours, followed by furnace cooling. The structure of the synthesized glasses was characterized. Optical absorption, density, refractive index, and impurity distribution were also investigated. The results revealed that all synthesized glasses were completely melted and exhibited an amorphous structure, as indicated by the presence transparency behavior. The glasses showed an orange-pink coloration attributed to Er^{3+} ions, with characteristic absorption bands observed in the ranges of 400-490, 525-530 and 650-799 nm. The color intensity increased with increasing Er2O3 content. The density slightly increased from 2.76 to 2.79 g/cm^3. On the other hand, the refractive index remained constantly at 1.59 with higher Er2O3 content. Impurity analysis confirmed a homogeneous distribution of the coloring agent without crystallization or phase separation. After cutting and polishing, all synthesized glasses could be successfully processed into glass beads exhibiting good transparency, high gloss, and a distinct orange-pink color. The obtained glasses were suitable for incorporation with metal components for jewelry applications.

Introduction

Glass is an amorphous solid formed by melting silica and other oxides at high temperatures. The molten material becomes a homogeneous liquid and, when rapidly supercooled, solidifies without forming a crystalline structure through the melt-quenching technique. This process results in a transparent or colored non-crystalline material with a continuous glass network. In general, glass exhibits high transparency, high mechanical strength, low optical absorption, and high chemical durability.

Coloration in glass is generated by doping transition metal and rare earth oxides into a base glass. These oxides are dissolved in the glass structure and may exist in various oxidation states, which exhibit different colors. For example, Cu^{+}/Cu^{2+} produces a blue color, Fe^{2+}/Fe^{3+} produces a green color, and Mn^{2+}/Mn^{3+} produces a purple color. Redox interactions of transition metal and rare earth oxides in glass melts are controlled by their concentration, glass composition, melting temperature, and melting atmosphere [1,2].

Nowadays, glass can be produced using recycled materials such as cullet, wood ash, slag, and rice husk ash. In addition, silica-rich and alkali-rich materials can also be used as raw materials for glass production. In this work, orange-pink colored glass for jewelry applications was prepared using borosilicate glass cullet and longan wood ash as the major raw materials, doped with Er_2O_3.

Objectives

1. To prepare transparent glass using borosilicate glass cullet and longan wood ash with a combined content of approximately 80 wt%. melted at 1350°C
2. To prepare orange-pink colored glass for jewelry applications using Er_2O_3 as a coloring agent.

Glass preparation

Raw materials → Drying → Sieving through a mesh → Raw materials powder → Weighing the ingredients according to formula → Homogeneous mixing → Melting at 1350°C → Casting into a metal mold → Annealing at 550 °C for 1.5 h → Glass sample

Characterization of glass samples

Glass sample

- Polishing glass samples
  - Color intensity
  - Density
  - Refractive index
  - UV-Vis spectroscopy
- Crushed glass samples
  - Chemical composition
  - Glass basicity

Results and discussion

Table 1 Glass compositions and glass samples

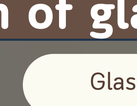
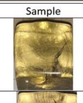
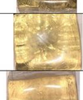
Longan Ash	Cullet	Borax	$NaCO_3$	Sample
-	100	-	-	
-	80	15	5	
20	60	15	5	
30	50	15	5	
40	40	15	5	
50	30	15	5	

Table 1 shows the glass compositions and the achieved glass samples. It was found that each composition could be completely melted to form amorphous glass. However, glass containing longan wood ash up to 50 wt% exhibited a white color, resulting from phase separation between amorphous and crystalline phases. In this work, the glass composition consisting of 40 wt% longan wood ash, 40 wt% cullet, 15 wt% borax, and 5 wt% Na_2CO_3 was selected for preparing the base glass. This composition showed good transparency, good fluidity, and good formability.

The base glass was doped with Er_2O_3 in the range of 0.05-1.5 wt%. The resulting glass samples exhibited different colors, as shown in Table 2.

Table 2 Orange-pink colored glass different Er_2O_3 contents.

Dopant Content (wt%)	Sample
0.05	
0.10	
0.20	
0.40	
0.50	
1.0	
1.5	

Orange-pink colored glass was obtained with different color intensities. The orange-pink color was generated by Er^{3+} ions, indicating that the redox interaction shifted toward the left side, as described by the following equation.

$Er^{3+} + e \leftrightarrow Er^{2+}$

The color intensity slightly increased with increasing Er_2O_3 concentration as shown in Table 3.

Table 3 The Orange-pink index and intensities of glass different Er_2O_3 contents.

Sample	Er_2O_3 (%)	Density (g/cm^3)	Refractive Index (RI)	Optical Basicity
1	No Dopant	2.65	1.57	0.74
2	0.05	2.76	1.59	0.74
3	0.10	2.76	1.59	0.74
4	0.20	2.76	1.59	0.74
5	0.40	2.76	1.59	0.74
6	0.50	2.76	1.59	0.75
7	1.0	2.77	1.59	0.75
8	1.5	2.79	1.59	0.76

The value of a* is positive, indicating that the glass tends toward a red color, while the value of b* is also positive, indicating a tendency toward a yellow color. The decrease in a* and the increase in b* resulted in the glass color changing to orange-pink with characteristic absorption bands observed in the ranges of 400-490, 525-530 and 650-799 nm.

Table 4 The properties of orange-pink colored glass different Er_2O_3 contents.

Sample	Sample	Redox equilibrium	Redox	Spectroscope Bands (nm)	L*	a*	b*	Interpreted Color
1	0.05	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Left → Er^{3+} dominant	400-475, 525-530, 650-700	-	-	-	-
2	0.10	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Left → Er^{3+} dominant	400-475, 525-530, 650-700	-	-	-	-
3	0.20	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Left → Er^{3+} dominant	400-485, 525-530, 650-700	-	-	-	-
4	0.40	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Left → Er^{3+} dominant	400-480, 525-530, 650-700	-	-	-	-
5	0.50	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Left → Er^{3+} dominant	400-490, 525-530, 650-700	32.72	1.39	1.24	yellow-pink
6	1.0	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Left → Er^{3+} dominant	400-450, 525-530, 650-700	31.12	1.44	1.15	orange-pink
7	1.5	$Er^{3+}+e^- \rightleftharpoons Er^{2+}$	Mostly left → Er^{3+} dominant	400-470, 490, 525-530, 650-700	31.62	1.07	2.35	pinkish-orange

Table 4 shows the density, refractive index, and optical basicity of the colored glasses. It was found that the density and optical basicity increased compared with the base glass due to the high molecular weight (382.5 g/mol) and high basicity (1.19) of Er_2O_3. On the other hand, the refractive index remained constant at 1.59. With increasing Er_2O_3 content, these properties changed only insignificantly due to the low concentration of Er_2O_3.
The high-intensity orange-pink colored glass containing 1.5 wt% Er_2O_3 was selected for jewelry preparation. It was found that the jewelry could be produced without defects.

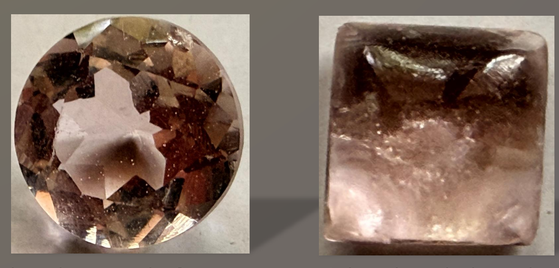


Figure 1 The jewelry glass made from orange-pink colored glass dopping with 1.5 wt% Er_2O_3.

Conclusion

The preparation of orange-pink colored glass using borosilicate glass cullet and longan wood ash as the major raw materials, doped with Er_2O_3 for jewelry applications, was successful. The glasses were completely melted and exhibited an amorphous structure. The glasses showed an orange-pink coloration attributed to Er^{3+} ions. The color intensity increased with increasing Er_2O_3 content. The density slightly increased from 2.76 to 2.79 g/cm^3. On the other hand, the refractive index remained constant at 1.59 with increasing Er_2O_3 content. Impurity analysis confirmed a homogeneous distribution of the coloring agent without crystallization or phase separation. The orange-pink colored glass could be successfully processed into glass beads exhibiting good transparency and high gloss. The obtained glasses were suitable for incorporation with metal components for jewelry applications.

Acknowledgement

The authors are greatly indebted to Jewel Impress Company for financial support and encouragement.

References

1. Kumsap J, Poowancum A, Wannagon A. Redox effects of erbium oxide doped industrial soda-lime glasses studied by UV-VIS-NIR spectroscopy. Key Engineering Materials. 2016;702:121-124.
2. Duffy JA, Ingram MD. An interpretation of glass chemistry in terms of the optical basicity concept. **Journal of Inorganic and Nuclear Chemistry**. 1976;38(6):1203-1206.