ABSTRACT

This thesis describes a scientific study on *Sāncipāt* manuscript and Hengul-Hāitāl painting traditions of early and medieval Assam for conservation of the manuscripts and restoration of original look of woodcarvings for preservation under ordinary rural conditions. The thesis is divided into four chapters, each of which covers a distinct component of the research as follows:

i. Introduction: In this chapter, the thesis has been briefly introduced.
ii. Materials and Methods: This chapter describes the materials used and methods adopted in the research work.
iii. Results and Discussion: This chapter contains the results, together with an explanation of how they were analyzed and interpreted, and relevant information that was learnt from them.
iv. Conclusions: This chapter summarizes the important findings.

Chapter 1: Introduction

This chapter describes the background of the subject, the importance of the present work, the aim and objectives, and strategies adopted to achieve them. It starts with the background of the work, an introduction to ancient and medieval manuscripts especially *Sāncipāt* manuscripts of Assam, an introduction to the traditional woodcarvings from medieval Assam along with *Hengul-Hāitāl* painting tradition and finally an introduction to the structural analysis of cellulose and lignin extracted from *Sāncipāt*. The goal and tactics of the current effort are likewise being attempted to be fulfilled in this chapter.

The scientific investigation of manuscripts and manuscript-making practices has the potential to reveal fascinating traditional knowledge, and which is expected to greatly aid in its conservation. Ancient and medieval cultures used a variety of writing surfaces, including papyrus in ancient Egypt and medieval Europe, animal leather in medieval Europe, and handmade paper in China and India, Tālpatra (Palm leaf) in south and southeast Asia and Bhurjapatra (bark of Betula utilis, Himalayan Birch) in north India. Interestingly, Assam, a northeastern state of India, had a rich heritage of manuscript writing on a unique type of writing base, *Sāncipāt*, made of the bark of the Sānci tree (*Aquilaria malaccensis* syn. *Aquilaria agallocha*), during the early and medieval period.

Tens of thousands of *Sāncipāt* manuscripts still exist in Assam, some of them centuries old, without losing the glossiness despite its harsh hot and humid climate. The first record of *Sāncipāt* manuscript is in Harshacharitam by Banabhatta, a biography of king Harshavardhana (606-647AD) of Kanouj, now in North India. A bundle of manuscripts, made of *Sāncipāt* with a reddish yellow color, was gifted to Harshavardhana by king Kumar Bhaskaravarman (595-650AD) of Kamrupa, then Assam. This unique tradition of writing *Sāncipāt* manuscript, which started by 7^{th} century and continued till the early 20^{th} century, predominated over other contemporary writing bases like Tulāpāt (hand-made paper) and Tālapatra. There are several *Sāncipāt* manuscripts written on varieties of subjects including religious, literary, historical, and medical works. The writing of *Sāncipāt* manuscripts gained popularity at the time of the Vaishnavite Saint Sankardeva. Its intriguing strengthening property, strong ink adhesion, and resistance to fungus and insects make it a more distinctive form of writing base. The preparation of *Sāncipāt* from Sānci bark involves repeated smoothening, pressing, and drying; partial degumming; polishing with fatty pulse paste; application of yellowish coating with Hāitāl (HgS, cinnabar) and a border with Hengul (As_2S_3, yellow orpiment), and punching a hole at the center for tying bundles of *Sāncipāt* which have been reported on several historical and cultural contexts. This arduous process of preparation of *Sāncipāt* through several steps involving some interesting ingredients thought to be responsible for its special properties, viz., strength, glaze, durability, and ability to retain ink and pigment. On the other hand, though a lot of reports are available on detail study of cellulose and lignin extracted from different plants, there is no such report on the cellulose and lignin extracted from Sānci bark. Understanding the structural, morphological, and mechanical features of the cellulose and lignin extracted from both new and old Sānci bark is important for a complete understanding of physical strength and longevity of *Sāncipāt* manuscripts. Special properties of cellulose and lignin of Sānci bark may also make them and their derivatives potential catalyst support. A thorough study has also been done on the changes that occurred when surface modification of cellulose and lignin, extracted from the bark of both old and new *Sānci* bark, was carried out with zirconium oxychloride.

There are well-researched methods for preventive and curative conservation of papyrus, paper, parchment, and Tālpatra manuscripts. Chemicals like isopropyl alcohol, ammonia, thymol, etc., as well as water, are used in the cleaning and treatment of papyrus, parchment, and Tālpatra manuscripts though there are recent reports about the damage done by chemicals to manuscripts. However, no research had been done on conservation

of *Sāncipāt* manuscripts which are totally different from other types of manuscripts. Since, most of these manuscripts are preserved in monasteries and villages where the passive environment for fungi and insects is impractical and since the manuscripts are also read regularly under ordinary conditions there is a need for a method of restoration cum conservation of the manuscripts for preserving them in ordinary condition for use for reading.

Traditional pigments and other materials used in paintings by our ancestors are of great importance in terms of art history and art conservation. Much interest from researchers has been drawn on the various pigments used in prehistoric cave paintings, ancient fine mural paintings in cave-like those in Ajanta Ellora, and on the walls of temples and other monuments. The history of mural painting shows that there were various painting methods such as encaustic painting, tempera painting, fresco painting, ceramics, oil painting, etc. Iron-containing earth minerals with different hues are said to be the first pigments used by the prehistoric artist in cave paintings. Evidence of the use of different colored rocks, different types of animal blood, charcoal, etc., have also been found in ancient cave paintings. There is evidence of the use of different types of red, yellow, black, blue, and green pigments as well as of using egg yolk as a binder in the paintings.

In Assam, where different types of woods are abundant, there was a great medieval tradition of woodcarvings painted with some mineral and herbal pigments. These woodcarvings included Vaishnavite mythological characters and different utility items. Mural painting for a drama, China-yatra of 1497 AD, by Srimanta Sankardeva, a Vaishnavite saint, is the oldest recorded painting work in Assam using the Hengul and Hāitāl. Records also say, Sankardeva and his disciple, Mādhavadeva used *Hengul-Hāitāl* in paintings on pillars and walls of Namghar, a kind of Vaishnavite community prayer house. Blue, white, green, brown, and black colors were also used along with Hengul and Hāitāl in Assam. Nīl, the blue herbal pigment, was cultivated in Assam towards the end of the 16th century AD. A white clay, Kharimāti, was used for the white color. Hengul and Hāitāl are still applied commercially on the handle of a traditional hand-fan of Auniati Satra, Majuli. Bael glue, obtained from Bael fruit (stone apple, *Limonia acidissima*), Outenga glue, obtained from Outenga fruit (elephant apple, *Dillenia indica*), and Dhekiya glue obtained from the gum of fiddlehead fern was used as natural glue in medieval Assam. The tradition of painting using these mineral and herbal pigments gained much

popularity in medieval Assam. These mineral and herbal pigments became popular for use in mural paintings as well as a miniature illustration in *Sāncipāt* manuscripts.

With the passage of time, the tradition of Hengul and Hāitāl painting in Assam has become almost extinct due to the increasing use of synthetic paints. Nowadays, newly made Vaishnavite woodcarvings are often colored with synthetic paints. It is disappointing to note that hundreds of such heritage woodcarvings, some of them centuries-old, which were originally painted with traditional pigments, are losing their original glare due to natural weathering and dirt as they are always kept in open condition at Namghars. Some of them are being destroyed slowly by fungus and termites as a passive air-conditioned environment is impractical in the rural set up of Namghars in villages and Satras, Vaishnavite monasteries in Assam. Unfortunately, many of such centuries-old heritage woodcarvings are often repainted by the Namghar authorities with synthetic paints destroying their antique look due to ignorance of the importance of heritage conservation or due to the easy availability of synthetic paints, with the tradition of *Hengul-Hāitāl* painting at the verge of extinction. There seems to be some interesting traditional science behind the mythical traditional color pigments commonly known as the *Hengul-Hāitāl* painting tradition which may also help in restoring old wooden sculptures.

Aim and Objectives: A careful study of the background revealed an urgent need for a detail scientific study of the traditions of *Sāncipāt* manuscripts and *Hengul-Hāitāl* painting in order to develop customized methods for their conservation and restoration. The aim of the present study was therefore to carry out the scientific study in these directions. The following objectives were set to achieve the goal:

(i) To carry out a scientific study of structure and properties of *Sāncipāt* manuscripts and folio at various stages of their preparation by the traditional method

(ii) The examine the effects of common conservative chemicals on old and freshly prepared *Sāncipāt*

(iii) To propose a customized method for conservation of *Sāncipāt* manuscripts and piloting of the same

(iv) To carry out a scientific study of the *Hengul-Hāitāl* painting tradition including study of the pigments

(v) To propose a customized method for restoration of centuries old heritage woodcarvings and piloting of the same

(vi) To study the cellulose and the lignin extracted from Sānci bark.

The strategies adopted for the work to meet these objectives have been described at the end of this chapter.

Chapter 2: Materials and Methods

The materials and procedures used in this study are described in detail in this chapter. This chapter also includes the method of preparation of *Sāncipāt*, different shades of colors, the extraction process of cellulose and lignin, and PVA casting film with cellulose and lignin.

Materials: Sānci bark was obtained from Mr. Gogoi from Golaghat, Assam, who grows Sānci tree crop for extracting a valuable perfume oil from its stem. A bunch of century-old *Sāncipāt* manuscripts, including some in good condition and some damaged by insects, fungus and water or humidity, was gifted by Rupam Kumar Sarma from Bam Beseria, Tezpur which were used for nondestructive and destructive experiments. Three mineral pigments, viz., Hengul (cinnabar, vermillion), Hāitāl (yellow orpiment), Khārimāti (clay), Tutia (blue vitriol, $CuSO_4.5H_2O$), Lā (lac, a hardened natural resinous sap collected from some trees) and an herbal pigment, viz., Nīl (Indigo) were obtained from Kamakhya Bhandar, Nagaon, Assam. Seed of Konibih (*Croton tiglium*) and Ghila (a hard fruit with red color, Nicker bean, *Entada scandens*), Chalkuwari (Aloe-vera, *Aloe barbadensis*) were collected from the local markets and university campus for the preparation of *Sāncipāt*. A thin coat of a fine paste of a skinned fatty pulse, called Matimah (*Phaseolus radiatus*) was collected from the local grocery shop and prepared in our laboratory. Sawdust was collected from the local timber industry for the purpose of restoration of woodcarvings. Bael (wood apple) is collected from the university campus for extraction of bael gum used in the conservation of *Sāncipāt* and preparation of different shades of pigments. A synthetic adhesive, Fevicol, polyvinyl alcohol-based glue, obtained from the local market was also used for restoring damaged woodcarving and for comparison purposes.

Analytical grade isopropyl alcohol, Ethanol (absolute 99.9%), cetrimide and thymol (2-isopropyl-5-methyl phenol) were *Sigma-Aldrich products*. The chemicals, i.e. sodium hydroxide (NaOH) extra pure AR 98% (SRL), hydrogen peroxide, (H_2O_2) 30% (Emplura), hydrochloric acid (HCl) 35% (Emplura), sulphuric acid (H_2SO_4) 98% (Merck), polyvinyl alcohol (PVA) hot (GS Chemical Testing Lab and Allied Industries),

Zirconium Oxychloride Octahydrate extra pure ($ZrOCl_2.8H_2O$) 99.5% (SRL), Polyvinyl Alcohol Hot, Degree of Polymerization 1700-1800 (GS Chemical Testing Lab & Allied Industries), Ethanol, absolute 99.9%, and distilled water were used as received without further purification. Sodium hydroxide (NaOH) was obtained from Merck, Mumbai. Potato dextrose broth (PDB), 10 g/ml of antibiotic and an antimycotic solution, 5g/mL of fluconazole are purchased from Mumbai's Himedia laboratories to use in microbial test. Other common solvents like molecular biology grade ethanol, supplied by Himedia Laboratories, Mumbai, isopropyl alcohol, AR grade, procured from *Sigma-Aldrich* were used without further purification. Sodium hydroxide (NaOH) extra pure AR 98% (SRL), hydrogen peroxide, (H_2O_2) 30% (Emplura), hydrochloric acid (HCl) 35% (Emplura), sulphuric acid (H_2SO_4) 98% (Merck), Laboratory grade tetrahydrofuran (THF) (RANKEN) were also used as a solvent.

Methods: This includes a thorough description of the procedures followed for preparation, instruments and instrumental techniques used in the study including the traditional methods of preparation of *Sāncipāt* manuscripts and traditional *Hengul-Hāitāl* painting.

The traditional process for making a *Sāncipāt* folio involves cutting a strip of bark several feet long and several inches wide from a mature Sānci tree, drying it in the sunlight, rolling it inside out, smoothing it out, and cutting it into folio-sized pieces. It also involves using tutia to partially degum the strip, drying and smoothening it again, applying a primer made of fatty paste, and applying Hāitāl and a border of Hengul. The traditional recipe of *Hengul-Hāitāl* painting involves grinding of the pigments, mixing with Bael gum and water, preparation of the surface with a primer coating of Kharimāti, application of the paint and finally a Lā-coating. About 30g of each Hengul and Hāitāl is ground in a hard granite mortar manually into fine powder. About 50mL of water is added to the natural pigment powder and ground again for about half an hour. Then the mixture is allowed to settle down for about 10 min. The powdered pigments are settled down with scum appearing at the surface. The scum is removed, and the pigment is ground again after replenishing the water. The process is repeated until the particle size is reduced to approximately 5-10 and 27-32 μm. The extraction method of cellulose was adapted from the method developed by Fitriana et al, 2020 in accordance with TAPPI method T-429

and ASTM D-588. Lignin was extracted as per the methodology described in TAPPI standard T222.

Different analytical tools and techniques viz., Hot air oven with Model No 101 (Sr No. 180217, Mfd. By Vindish Instruments Pvt. Ltd.), Digital weight balance, model ME204, Mettler Toledo, REMI R-8C centrifuge instrument with Resolution: $2.4A^0$ (FEI Company, USA) and at an accelerating voltage of 200 kV, UV visible spectroscopy (Shimadzu, UV-2450), FTIR (Perkin Elmer spectrophotometer model Frontier MIR FIR), p-XRD (Brucker AXS, D8 Focus X-ray diffractometer, Germany, Raman spectrophotometer (Model Renishaw basis series with 514 lasers), TGA (model Shimazu TGA-50), DSC (DSC 60, Simadzu), GPC (UV/V VISIBLE DETECTION-2489, REFRACTIVE INDEX DETECTOR-2414, HPLC PUMP-515, Waters Corporation, USA using EMPOWER-2 software), SEM and EDX (JSM-6390LV, JEOL software, Japan), DLS(Zeta potential and nano-particle size analyzer model Nanoplus-3), Digital gloss meter, make S.C. Dey & Co., Kolkata, Spectrophotometer, AGS, model x-rite Ci200UV, CHN analyzer (Model. Perkin Elmer, USA made 2400 series 2) were used to performed different scientific investigation in the work.

Chapter 3: Results and Discussion

Structure and properties of *Sāncipāt*: This section presents, for the first time, a scientific analysis of the physicochemical characteristics of the traditionally prepared model and old *Sāncipāt* folios at different stages of preparation. The present study reveals some interesting traditional pieces of knowledge associated with the preparation of *Sāncipāt* related to their attractive look, physical properties, composition, adhesion of the ink on it, and longevity of the manuscript in a harsh climate. Raw Sānci bark consists of native cellulose together with some hemicellulose and lignin devoid of nitrogenous compounds. The traditional degumming process partially removes the unwanted hemicellulose and lignin leaving mostly the fibrous cellulosic part. The smoothness of the surface, tensile strength, and gloss index of *Sāncipāt* are increased during the preparation of *Sāncipāt*. The antimicrobial test shows that raw Sānci bark has no antifungal properties but the Sānci bark after degumming in the presence of $CuSO_4$, and after application of a coating of Hāitāl and Hengul shows remarkable inhibition towards fungi. The antifungal property of the *Sāncipāt* manuscript has been attributed to a synergistic effect of $CuSO_4$ used during degumming and due to the application of Hāitāl and Hengul.

The study of the structural and morphological features of the cellulose and lignin extracted from both new and old Sānci bark indicated a natural degradation on both cellulose and lignin structure with time. Upon modification of cellulose and lignin with zirconyl oxychloride, the amorphous nature of $ZrO_2.nH_2O$ has caused a gradual reduction in XRD peak intensity observed for the modified cellulose (MC) and the modified lignin (ML). The Sānci bark cellulose has been found to be monoclinic dominant Iβ cellulose. The cellulose and the lignin showed complex structures, high carbon content, no or minimum nitrogen which impart strength and resistance to microbes in *Sāncipāt*.

Restoration and conservation of *Sāncipāt* manuscripts: The study of the structure and properties of *Sāncipāt* manuscripts has revealed some interesting traditional knowledge that contributed to the longevity of the manuscripts. Treatment of old partially damaged *Sāncipāt* with some commonly used solvent and chemicals, viz., isopropyl alcohol, thymol, and cetrimide have shown marked changes in physicochemical properties, structure, and mechanical strength of lignocellulosic *Sāncipāt*. Even prolonged exposure to water also causes such changes in *Sāncipāt*. Similar effects have also been observed with freshly prepared *Sāncipāt* after exposure to some common solvents and chemicals, namely, water, thymol, isopropyl alcohol, cetrimide, used in various conservation work.

On the other hand, some treatments of Sānci bark during the traditional preparation of *Sāncipāt*, viz., partial de-gumming in presence of Tutia and application of a thin coating of antifungal and insect repellant Hāitāl-Hengul pigments protect the folios from fungi and insects. Lā-charowā, a traditional way of varnishing, finally imparts physical strength and water resistance to the folios in addition to protecting the readers from exposure to Hāitāl and Hengul. Bael gum used in the mending of *Sāncipāt* does not leave any stain on the folio unlike many other traditional natural gums. Though Mahī, a unique traditional herbal ink used in writing *Sāncipāt*, is prepared in water and is as such water soluble, the ink has a strong adhesion on the folio and is hardly affected by water. Preservation of *Sāncipāt* manuscript between two flat wooden plates coated with Hāitāl avoids kinking or bending of the folios.

A novel method of restoration and conservation of *Sāncipāt* manuscripts has been proposed based on the traditional method of their preparation avoiding harmful chemicals and with minimum exposure to water. The method involves mild physical cleaning, mending with freshly prepared *Sāncipāt* using Beal gum, application of Hāitāl-Hengul with matched color, application of Lā, and keeping the manuscript between two

flat wooden plates coated with Hāitāl and rapping with a red cotton cloth. Results of piloting of the proposed method of conservation on eleven *Sāncipāt* manuscripts show that the method can be employed to save tens of thousands of precious *Sāncipāt* manuscripts existing in museums, Satras, and villages in Assam from natural damage.

Traditional Science in pigments and recipe of *Hengul-Hāitāl* painting: In this section, a scientific study of the ingredients, properties, and application of traditional *Hengul-Hāitāl* paints has been done and revealed some interesting traditional knowledge related to the pigments and their application. While mineral pigments of Hengul (mercuric sulfide, HgS), Hāitāl (arsenic sulfide, As_2S_3), and Kharimāti (calcium aluminum silicate clay) were used for red, yellow and white, respectively, an herbal pigment, viz., Nīl (Indigo dye, $C_{16}H_{10}N_2O_2$) was used for blue. The physicochemical analyses of the pigments have shown that while Hengul and Hāitāl samples contained some natural oxide and carbonate impurities, the sample of Nīl was found to be adulterated with crystalline iron cyanide. The sample of Hāitāl snowed 38% crystallinity, which was higher than 28% observed for Hengul. The particles of Hengul, Hāitāl and Nīl, after grinding, have been found to be distinctly distributed while that of the particles of Kharimāti have been found to be spread smoothly. The average particle sizes of the pigments were between 4 to 10μm. Measured low zeta potentials of the pigments indicated rapid agglomeration which was in fact observed in practice requiring complete use of the paints within 4-5 hours of preparation.

The use of three primary colors, viz., red, yellow, and blue in the tradition of preparing any desired shades is noteworthy. It was also interesting to note the selection of a non-staining robust natural gum, viz., Bael gum, to prepare the paints. However, there was hardly any change in the color properties of paint samples of different colors after replacing the Bael gum with a starch-based commercial gum. While all shades obtained from Hengul, Hāitāl, and Nīl have shown very good hiding power, all shades containing Hengul and Hāitāl have shown high brightness. It is also interesting to note the use of either Hengul or Hāitāl or both for the preparation of any of the shades except white probably to repel termites and fungi. It was also a practice to mix a little antifungal and insecticide tutia with Kharimāti for white color. The application of a primer coat of Kharimāti mixed with tutia is indicative of the traditional knowledge of the use of primer as well as the preservation of woodcarvings from fungi and insects. On the other hand,

the application of Lā coating finally is indicative of traditional knowledge of stopping the natural erosion of the paints and avoiding toxic Hāitāl by devotees of idols and utility items users upon touching.

Restoration of heritage woodcarving with *Hengul-Hāitāl* painting: A method of restoration of partially damaged woodcarvings has been proposed based on the findings of the ingredients, properties, and the traditional recipe of the *Hengul-Hāitāl* painting. For the rainy season, July to September should be avoided for the restoration for two reasons: firstly, for the unavailability of Bael gum, and secondly to avoid high humidity which makes drying difficult. The key steps of the restoration of woodcarvings are: (a) cleaning of woodcarvings, (b) removal of synthetic paints, (c) mending, (d) extraction of Bael gum, (e) application of primer coat of Kharimāti (f) application of *Hengul-Hāitāl* (g) application of Lā.

Restoration of some old partially damaged woodcarvings due to natural weathering or woodcarvings which had lost the antique look due to the application of enamel paints has shown good results receiving appreciation from local people. The revelation of ivory in nails and figures and the use of precious pigments indicate economically strong patronage of woodcarvings. The restoration has imparted a new but traditional look with enhanced glossiness to the woodcarving enabling preservation of the woodcarvings at least for another century in open public places like Namghars in an as is where is way. Thus, the present work brings to light a rich cultural heritage of making woodcarvings with an elegant painting tradition of medieval Assam involving interesting traditional science pertaining to glaze and durability.

Chapter 4: Conclusions and Future scopes

All the conclusions and the projected areas of study are enumerated in this final section.

Conclusions: The present study reveals some interesting traditional knowledge associated with the preparation of *Sāncipāt* manuscript related to their attractive look, physical properties, composition, adhesion of the ink on it, and longevity of the manuscript in the harsh climate. The antifungal property of the *Sāncipāt* manuscript has been attributed to a synergistic effect of $CuSO_4$ used during degumming and due to the application of Hāitāl and Hengul. The structure and composition of cellulose and lignin of *Sāncipāt* impart strength and resistance to microbes and weathering in *Sāncipāt*. These

properties of the cellulose and lignin of Sānci bark also make them potential candidate for application in catalysis.

The findings may help in developing a customized method of conservation of old *Sāncipāt* manuscripts. A novel method of restoration and conservation of *Sāncipāt* manuscripts, based on the traditional method of their preparation avoiding harmful chemicals and with minimum exposure to water is proposed. Results of piloting the proposed method of conservation on eleven *Sāncipāt* manuscripts show that the method can be employed to save tens of thousands of precious *Sāncipāt* manuscripts existing in museums, Satras, and villages in Assam from natural damage.

The present scientific study of the ingredients, the properties and application of traditional *Hengul-Hāitāl* paints has revealed some interesting traditional knowledge related to the pigments and their application. The use of three primary colors, viz., red, yellow, and blue in the tradition for preparing any desired shades is noteworthy. It is also interesting to note the use of either Hengul or Hāitāl or both for preparation of any of the shades except white probably to repel termites and fungi. Application of a primer coat of Kharimāti mixed with tutia is indicative of the traditional knowledge of use of primer as well as preservation of woodcarvings from fungi and insects. On the other hand, application of Lā coating finally is indicative of traditional knowledge of stopping natural erosion of the paints and avoiding toxic Hāitāl by devotees of idols and utility items by users upon touching. Low zeta potentials of the pigments indicated rapid agglomeration which was in fact observed in practice requiring complete use of the paints within 4-5 hours of preparation. While all shades obtained from Hengul, Hāitāl and Nīl have shown very good hiding power, all shades containing Hengul and Hāitāl have shown high brightness. Restoration of some old woodcarvings has shown good results receiving appreciation form local people. The restoration has imparted new but traditional look with enhanced glossiness to the woodcarving enabling preservation of the woodcarvings at least for another century in the open public places like Namghars in an as is where is way.

Future Scopes: The findings of the present study provide avenues for future research and development, particularly in applying the proposed technique to conserve and restore the historic *Sāncipāt* manuscripts and woodcarvings found in Assam using the conventional natural pigments known as Hengul and Hāitāl. There is a scope for further research and development for reviving these unique traditions for tourism commerce. Catalytic activity of modified cellulose and lignin of Sānci bark may also be explored.