

# National Textile Center

## FY 2003 (Year 12) Continuing Project Proposal

**Project No. C02-PH03.**

Competency: Chemical

### Integration of fabric formation and coloration processes

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#### **Project Team:**

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#### **Objective:**

The goal of this project is to study the integration of the fabric formation and coloration processes, with a view to establish a viable approach to combining the two processes. Such a development would dramatically reduce overall fabric handling, and in turn, improve the integration of fabric formation and textile wet processing. This anticipated reduction in handling should enhance agile manufacturing capabilities and provide the domestic textile market with an advantage in the industry.

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#### **Progress Statement:**

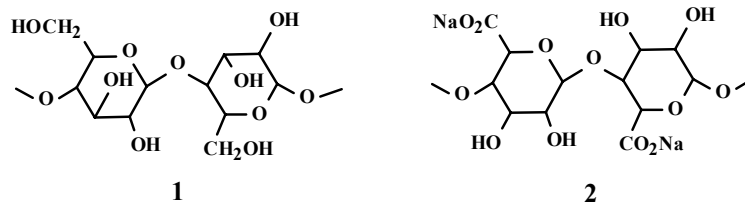
In its current state of technology, it is known that the digital inkjet printing process is not suitable for all types of fabrics and fiber types. Additionally, in attempting to integrate the fabric production and digital printing processes, considerations such as the presence of sizing agents and certain lubricants must be taken into account. Therefore, one of the initial aspects of this project included a comprehensive study of the range of fibers and fabrics that are suitable for the integration of fabric formation and digital printing.

Completed research thus far has focused primarily on determining which fibers are suitable for demonstrating this idea, using a five-step system for evaluation, see Figure 1. Unsized cotton fabric has been produced and pretreated with a variety of solutions in preparation for digital inkjet printing. After printing, samples were tested for a variety of performance characteristics, including colorfastness properties to light, laundering, and crocking.



**Figure 1.** Five-step system used for evaluating potential fiber types.

From our Year-1 studies, it is clear that preparing the woven cotton fabric with a sodium alginate solution prior to printing led to good colorfastness properties and increased print edge sharpness. As indicated in Figure 2, cellulose (1) and sodium alginate (2) molecules are structurally similar polysaccharides, making affinity between these two polar compounds possible. In carrying out experiments designed to demonstrate the feasibility of using an alginate solution as a warp size and to bind dyes, we compared the performance of treated and untreated yarns during the weaving step and measured the differences in abrasion resistance and hairiness. Results obtained thus far have provided support for our idea of using a single chemical auxiliary to function as a sizing agent and dye host.



**Figure 2.** Comparison of the structures of the cellulose (1) and sodium alginate (2) repeat units.

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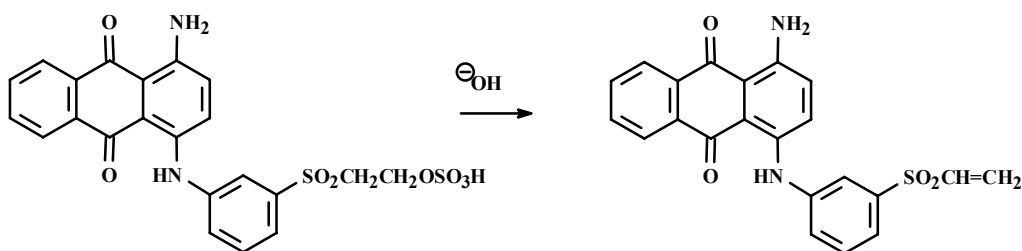
#### Next Year's Goals:

Having demonstrated the potential for linking the two processes, our approach to combining the weaving and fabric printing steps will now focus on expanding the knowledge base. Thus far we have focused on combining the weaving and printing processes for cotton fabrics and have been successful. We will now expand our studies to polyester and cotton/polyester blends. In the case of polyester, our Year-2 research will include the design, synthesis and use of special dye-containing cyclodextrins (CDs) that function simultaneously as warp sizes and latent colorants. To achieve this, it will be necessary to determine 1) the number of cyclodextrin units that must be linked together to give the viscosity needed in an effective warp size and 2) the size of cyclodextrins required for the types of dyes to be employed.

Following the proposed bench-scale experiments, a miniature production run will be conducted. Using a sample loom and desktop digital inkjet printer, the system will be developed and adapted to enable continuous fabric formation and printing. While this system may only simulate the integration process on a production level, it will demonstrate that the two processes can be combined in a manner that gives commercially viable textile testing results for strength, colorfastness, etc.

For cotton/polyester blends, different approaches to combining the fabric formation and printing processes can be utilized. In addition to using cyclodextrins as a warp size for both fiber types, the yarns may also be sized separately prior to weaving. After weaving, two printers could be placed in a series arrangement so that the cotton can be printed with one printer and the polyester with the other. This would open the door to using separate sizes for the two fiber types and would involve coordinating the printers similarly to what is done for roller or screen printing. Another option would involve surface modification of the polyester yarns with bifunctional aliphatic amines. This would allow the use of reactive dyes to print the polyester fibers. In turn, the dyes for cotton and polyester could be applied from one printer. However, the weaving properties of the surface-modified polyester are currently unknown and would have to be investigated.

With regard to dye choices for dyeing the cotton/polyester blends, an interesting starting point would involve reactive disperse dyes. In this regard, it has been shown that vinyl sulfone reactive dyes (cf. Figure 3) can undergo beta-elimination *in situ*, under pressure, making union dyeing with these dyes a logical option<sup>1</sup>. The water-soluble, ionic form of the dye would react with cotton, while the non-ionic form would behave as a disperse dye and interact with polyester. This approach will be examined, with conditions for exploiting this behavior an important point in our case.



**Figure 3.** Vinyl sulfone reactive dye suitable for *in situ* reactive-disperse dye formation.

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<sup>1</sup> J.P. Kim et al, *Fibers and Polymers*, 3(3), 85 (2002).

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**Approach:**

It is envisioned that the structures represented in Figure 4 could be used as warp sizes for natural and synthetic fibers and then dissolved away with hot water, leaving dye on the fiber surface. By using end-functionalized polyethylene oxide (PEO) oligomers to form soluble PEO-CD-Ics (inclusion compounds), blocking the PEO ends so CDs cannot slip off, linking the threaded CDs with epichlorohydrin, and finally removing the bulky PEO end-groups, it is possible to obtain a chain of CDs of the type shown schematically in Figure 4. It is anticipated that this group of units would serve as a warp size and simultaneously bind various dyes to the fiber surface.

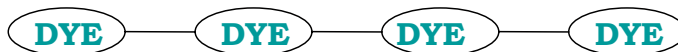


Figure 4. Representation for linked cyclodextrin units containing dye molecules.

As an initial demonstration of this concept, disperse dyes in the cyclodextrin matrix will be used and following size removal, surface dyes will be applied to PET via thermosoling. Following these experiments, a similar procedure will be used with reactive-disperse dyes on polyester/cotton substrates, and in future research, on nylon substrates. It will also be of interest to demonstrate that solid shades produced in this manner have the potential to be subjected to discharge printing to produce a variety of print patterns.

In the case of 100% polyester, dyes such as **3-4** will be used as initial model compounds for defining the appropriate interior dimensions of CD molecules for dyes to be printed on polyester. As an initial model compound for printing on nylon, we will use a reactive-disperse dye such as **5**. All three dyes should possess the chemical properties and molecular sizes needed for our purposes. The dyes will be synthesized and purified in our laboratories.

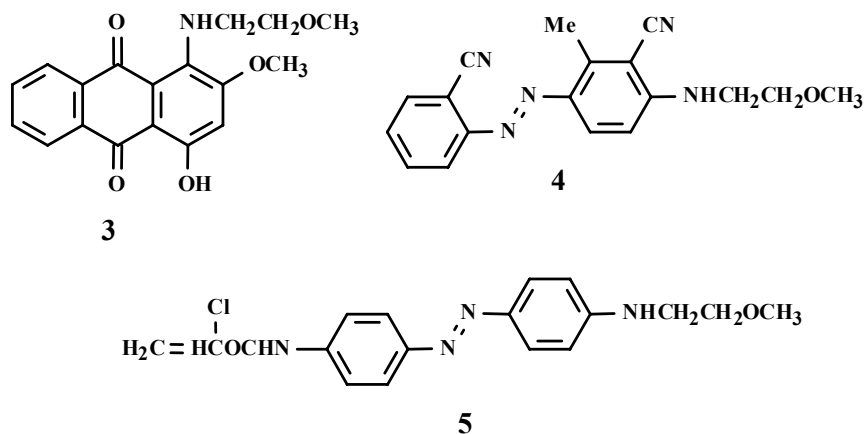


Figure 5. Model dyes for use in designing CD molecules for fabric formation/printing integration.

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**Outreach to Industry:**

Contact has been made with several companies with regard to the project. Two variations of cyclodextrins have been received from Wacker Biochemical, a German-based company, which has agreed to contribute to our research. Additionally, interactions with the following companies have occurred: Ciba Specialty Chemicals Corporation USA, Mutoh America, Inc., Wasatch Computer Technology, MacDermid Colorspan, DuPont Digital Printing Group and Rohm and Haas. In addition, Falcon, ENCAD, and Colorspan have provided four digital printers, which are being used in the research and these companies continue to interact with the project.

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**New Resources Required:**

No new resources required.