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Review Article

Understanding the Concept of 4D Textiles

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Abstract: 4D printing includes the fourth dimension of time with the traditional 3D coordinates. Three dimensional (3D) Fabrics and textile items that can change shape and function over time are categorized as 4D Textiles. This transformation is caused by a complex interplay between hybrid materials and the exposure of external stimuli. For 4D textiles, elastic knitted fabrics and shape memory polymer are desirable materials. Medical products, soft robotics, architecture, automotive, sports, clothing and more fields may benefit from 4D textiles. In this study, the concept of 4D Textiles is reviewed in brief.

Keywords: 4D Printing, 4D Textiles, 3D Textiles.

CONCEPT OF 4D TEXTILES

4D printing is a more advanced version of 3D printing, in which the form, properties, and functions of the structure can be changed over time [1]. Skylar Tibbits was the first to introduce the term in 2013. The fourth dimension describes the time in which a change in properties might occur in addition to the three spatial dimensions [2] (shown in figure-1).

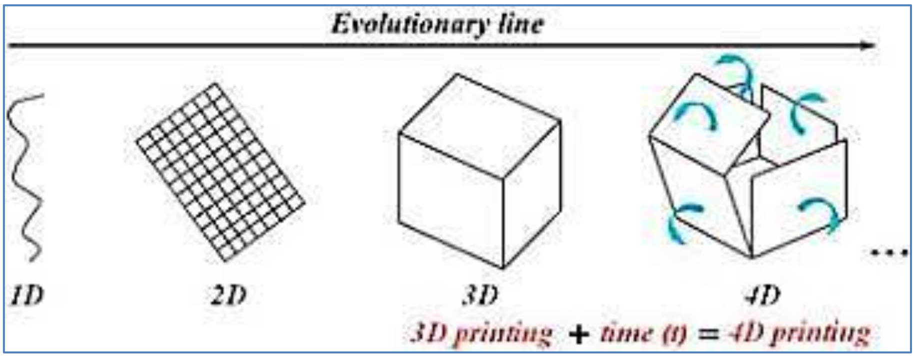

Fig-1: Schematic illustration of 1D, 2D, 3D, and 4D concepts [1].

Various types of stimuli used to shift the behaviors of active materials include moisture, light and heat, vibration, flow, UV radiation, microwaves, chemicals, electricity, force, and their combinations [3] (shown in figure-2). Additional effects are induced by the stimulus's duration and intensity [2]. A Schematic of the process to create 4D printing products that react to external stimuli are shown in figure-3. Presently, the shape changing ability of 4D-printed structures such as bending, elongating, twisting, and corrugating are being concentrated by the researchers [4]. Self-assembly, self-repair, and multi-functional purposes can be incorporated in the final structure, which allows time-dependent, predictable, reprogrammable properties [1]. Highly precise, robust and calibrated 4D objects are in great demand in number of fields such as military applications, robotic systems, space suits, healthcare, apparel, sports, etc. [5].

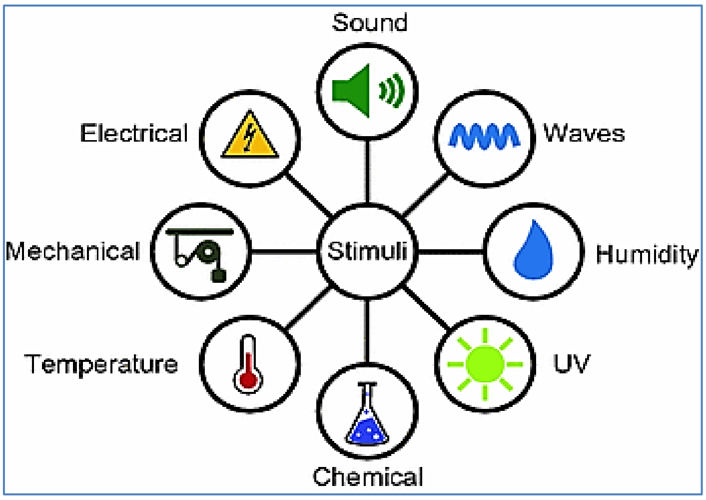

Fig-2: Stimuli that can activate the change over time [3].

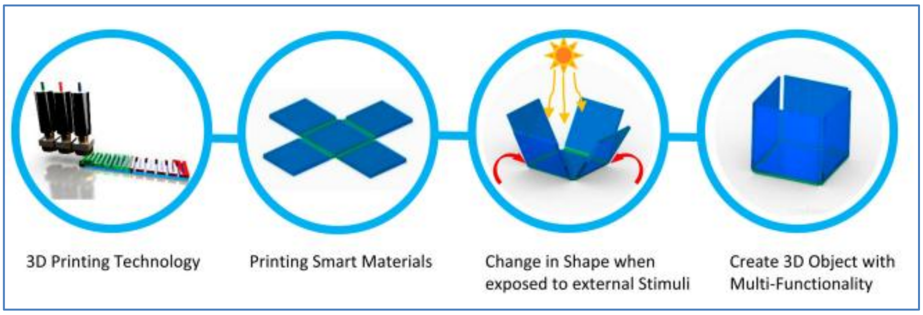

Fig-3: Schematic of the 4D printing process to create products that react to external stimuli [6].

Textiles have a number of attractive attributes, including the ability to be folded, twisted, and deformed easily. Textiles have a long history of practical uses ranging from clothing and decoration to more utilitarian structures, thanks to these and other properties such as aesthetic appearance, comfort, and flexibility [7]. Textiles are an excellent platform for ‘programmed' product that responds directly to environmental stimuli in a predictable and desirable manner as they are highly customizable and kinetic [8].

However, when additive manufacturing (also known as 3D printing) is combined with highly elastic, extensible textile materials, a new class of items called 4D textiles can be developed. The name emerges from the word "4D Printing" [3]. A 4D textile is comprised of at least one layer of textile that is usually made of smart materials or to which smart materials or smart structures are applied [2]. Different techniques could be used to construct 4D textiles. The use of shape memory materials in textiles is one approach that has achieved attention. Shape memory materials, for example, may be utilized by weaving, sewing, or braiding. 3d printing onto pre-strained textiles is another technique for producing textiles with variable function and appearance. Fabric and printed polymer are combined in the 4D textiles [3]. The membrane—the textile surface in 4D textiles is elastically pre-stressed, accumulating potential energy as an anisotropic spring store. The textile is then printed in specified areas. When the pre-tension is removed, the textile develops a restoring force which is countered by the elastic stiffness of the structure in the printed areas. The transition from a planar printed structure to a spatial shape is ensued by the formation of an energetic equilibrium state. The textile forms double-curved surfaces as a result of this mechanism, which realize the lowest possible energy level. Furthermore, tensions cause 4D textiles to build up several equilibrium states, allowing for shape alteration. Furthermore, tensions cause 4D textiles to build up several equilibrium states, allowing for shape alteration. The interface and mechanics are used to characterize the surface. The macroscopic deformation is dictated by the force–strain behavior of the textile surface. Synclastic and anticlastic primitives can be developed by printing on both sides of pre-stressed textiles. To customize dedicated functions with the material structure, the shape transforming behavior of the structures is utilized [2].

Textiles may be used as the substrate, including knitted fabrics, woven fabrics, braided fabrics, and nonwovens. Knitted items that are highly extensible and have a high restoring force are excellent substrates for 4D textiles. Elastic knitted fabrics are appealing due to their high strain to failure, which allows them to store a considerable amount of strain energy while also offering desirable pore geometry [3].

Fourth dimensions textiles are suitable for size-changing items, pressure-sensitive elements, acoustic textiles, and adjustable footwear. 4D structures may also be realized in the field of medical products, soft robotics, architecture, automotive, sports and clothing with huge potentiality. The benefits of 4D textiles in these fields include a high level of customization and functional adjustment [3]. Zhang et al. mentioned from their study that the remarkable shape memory behavior and mechanical properties, as well as versatility in microstructural nature, confirmed the ability of practical applications of 4D printing of textile composites [9].

CONCLUSION

Researchers are combining technology and textiles to innovate something new. However, 4D textiles is a relatively new field of research. It is possible to "program" a textile through the concept of 4D printing. From this perspective, the potential of 4D textiles are expected to have an effect on a variety of industries in the near future. More research would result in faster growth of 4D textiles in advanced manufacturing, smart textiles, healthcare, and other fields.

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