Chapter 1
Smart Materials and Nanomaterials in Façade Applications

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ABSTRACT

Smart materials have revolutionized the realm of architectural design, particularly in the construction and optimization of building façades. These materials—capable of altering their properties in response to external stimuli such as temperature, light, moisture, or electric fields—offer dynamic solutions to long-standing challenges in energy efficiency, sustainability, aesthetics, and occupant comfort. In the context of

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façade design, smart materials are redefining the way buildings interact with their environment, marking a paradigm shift from static, passive exteriors to adaptive, responsive skins that enhance performance while embodying cutting-edge design principles. At the core of the importance of smart materials in façade design is their potential to significantly improve energy efficiency and thermal performance. Traditional façades are often limited by fixed thermal resistance and light transmission values, which can lead to excessive reliance on mechanical heating, ventilation, and air conditioning (HVAC) systems.

1. INTRODUCTION

Contemporary façade engineering increasingly treats the building envelope as an environmental interface rather than a fixed external shell. Responsive materials, adaptive façades, and sensor-aware envelope systems are therefore receiving growing attention because they allow buildings to negotiate solar gain, daylight, temperature variation, and user comfort more dynamically than conventional passive skins. (Jamilu et al., 2024; Gonçalves et al., 2024; Lee et al., 2021).

This chapter reviews key smart and nano-enabled material strategies for façades, including adaptive glazing, latent-heat storage, motion-capable components, multifunctional coatings, and durability-enhancing nano-additives. The introduction frames the topic briefly, while the later sections retain the original material-specific discussion so that the chapter remains full-length without repeating the same argument twice. (Grillo et al., 2022; Kuda & Yadav, 2022; Brzezicki, 2021; Faragalla & Asadi, 2022).

2. THE ROLE OF SMART MATERIALS IN FAÇADE DESIGN: IMPORTANCE AND IMPACT

Smart materials have revolutionized the realm of architectural design, particularly in the construction and optimization of building façades. These materials-capable of altering their properties in response to external stimuli such as temperature, light, moisture, or electric fields-offer dynamic solutions to long-standing challenges in energy efficiency, sustainability, aesthetics, and occupant comfort. In the context of façade design, smart materials are redefining the way buildings interact with their environment, marking a paradigm shift from static, passive exteriors to adaptive, responsive skins that enhance performance while embodying cutting-edge design principles. At the core of the importance of smart materials in façade design is their potential to significantly improve energy efficiency and thermal