Multimodal spectroscopic assessment of mechanical and chemical properties of ABS objects in cultural heritage preservation

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Abstract. The 1960s saw the emergence of plastic as an indispensable component in various fields, including art and design. Acrylonitrile-butadiene-styrene (ABS) is widely used by artists and designers for a range of applications including sculptures and decorative pieces. Consequently, the necessity to conserve ABS from deterioration is a crucial issue in the field of cultural heritage preservation. Many studies have highlighted the criticality of the stability of the polybutadiene component when exposed to light. We propose a new multimodal spectroscopic approach to assess the conservation status of plastic design objects. This non-destructive approach combines correlative Brillouin and Raman micro-spectroscopy (BRaMS), external reflection IR spectroscopy and portable NMR relaxometry. BRaMS is a novel non-destructive technique in the field of heritage conservation, allowing simultaneous monitoring of chemical and mechanical changes occurring at the sample surface. The present study focused on photochemically aged LEGO® bricks made of ABS and aimed to i) correlate chemical and mechanical changes induced by light exposure and ii) introduce a surface degradation index (SDI), measurable in situ by external reflection IR spectroscopy, to assess the state of conservation of plastic artefacts. Finally, non-invasive investigations were carried out on real design objects using the MObile LABoratory (MOLAB) platform.

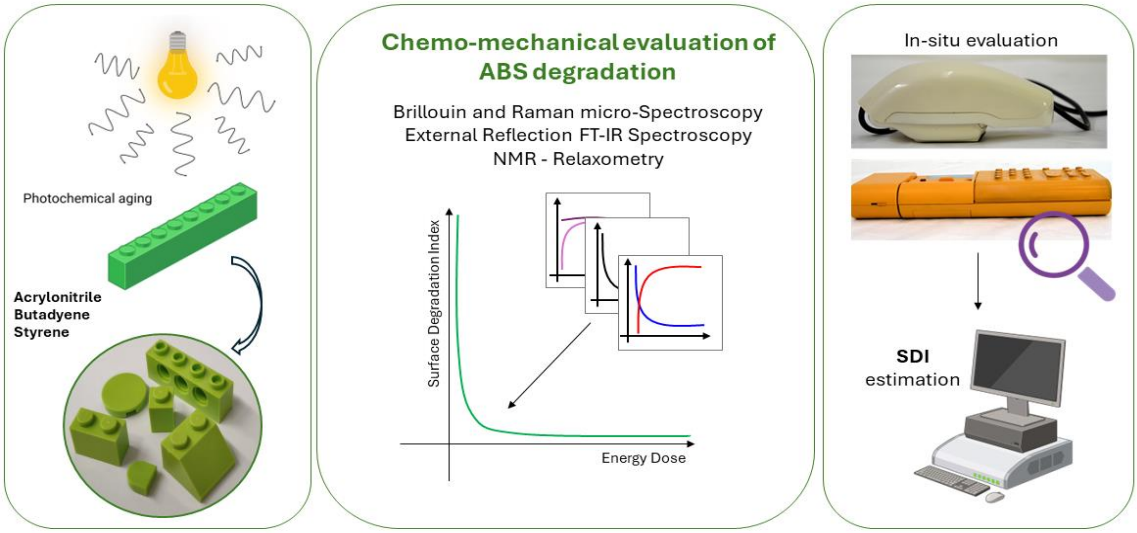

Fig. 1. Graphical representation of the experimental procedure and modelling (created with BioRender.com).

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Acrylonitrile-butadiene-styrene (ABS) is a popular material in art and design due to its high impact resistance, mechanical strength, and moldability. Its unique configuration, consisting of a continuous acrylonitrile-styrene phase and a dispersed rubbery phase, makes it a preferred choice for artists and designers to create sculptures and decorative pieces [1]. ABS degradation due to heat or light exposure causes radical oxidation of the PB component, resulting in decreased double-bond content and cross-linking. This can severely affect ABS strength, toughness, and flexibility [2]. Therefore, monitoring degradation is a crucial issue, fundamental to enabling preventive conservation measures, such as adjusting display conditions or implementing protective coatings. In this study, a non-invasive multimodal spectroscopic approach has been proposed to correlate ABS chemical and mechanical changes induced by photoaging. This approach combines in situ external reflection IR spectroscopy, portable NMR-relaxometry and Brillouin and Raman micro-spectroscopy (BRaMS), allowing for probing surface and subsurface polymer composition and mobility [3,4]. BRaMS is a novel technique that allows simultaneous measurements of Brillouin light scattering (BLS) and Raman spectroscopy in a combined setup, providing spatially resolved monitoring of chemical and mechanical changes at the sample surface. Specifically, BRaMS probes mechanical properties without external perturbations and operates in the gigahertz range. It integrates BLS with Raman information obtained simultaneously on the same point [5]. In our study, LEGO® bricks made of ABS were used as a model sample to investigate photochemical ageing [6]. The mechanochemical analysis reveals the correlation between the photo-oxidative reactions on the polybutadiene phase and the stiffening of the surface of aged ABS samples. Then, the comparison with external reflection IR spectroscopy allowed us to define a surface degradation index (SDI) to estimate the state of conservation of ABS, related to an equivalent light dose exposure. Finally, non-invasive external reflection IR spectroscopy and NMR relaxometry analysis were conducted on plastic design items, conserved at the Italian Design Museum and Kartell Museum within the access activity of the MOLAB platform of the European Research Infrastructure for Heritage Science.

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