Despite the increasingly important role of stretchable electronics for use as the human–machine interface, their manufacturing in a commercially realistic manner remains an unresolved challenge. The bottleneck lies in the efficiency and scalability of transfer printing that is typically employed in the fabrication process to enable device stretchability via strain isolation. Here, the use of a polymer substrate with programmable rigidity for direct manufacturing of stretchable electronics is reported, forgoing the need for transfer printing while significantly enhancing strain isolation. The process starts with a stretchable elastomeric substrate synthesized via the thiol-acrylate click chemistry. Designable rigid islands can be introduced via spatially confined oxidation of the elastomer. Strain-sensitive microdevices can then be directly fabricated onto the rigid islands without transfer printing. Following this manufacturing scheme, a fast-responding stretchable temperature sensor is demonstrated, with unusual accuracy and real-time temperature monitoring capability suitable for use in a highly dynamic environment. Importantly, the critical fabrication step that introduces the programmable substrate rigidity is fully integrated into a well-established lithographic process. Therefore, the methodology not only reduces greatly the complexity in fabricating prototype devices but also points to a highly effective way for potential manufacturing in a commercial setting.