

Institution: Queen Mary University of London		
Unit of Assessment: 12		
Title of case study: Sugru®: a self-setting rubber for fixing, modifying and improving objects		
Period when the underpinning research was undertaken: 2008-31 Dec 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Julien Gautrot	Professor in Biomaterials and Biointerfaces	Sep 2011-Present
Emiliano Bilotti	Reader in Materials	Sep 2011-Present
James Busfield	Professor in Materials	Aug 1994-present
Ton Peijs	Professor of Materials	Feb 1999-Dec 2018
Period when the claimed impact occurred: 2014-31 Jul 2020		
Is this case study continued from a case study submitted in 2014? N		
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Sugru® is a mouldable adhesive glue for mending objects. It is one of FormFormForm Ltd's (FFF) commercial successes and was first developed in 2009 based on formulation work (composite mechanics, curing and stability) by Queen Mary researchers, and using novel silicone-based chemistries. Since 2013, Sugru has been sold in over 300 B&Q stores in the UK & Ireland and in over 2,000 Target stores in the US. In 2018, FFF was acquired by Tesa CE, for GBP7,600,000. In collaboration with Queen Mary, FFF has also developed a new range of family friendly formulations of Sugru, which were launched in 2018. By 2019, Sugru had been used to fix 20,000,000 objects, which means that significantly fewer objects were sent to landfill. Today, Sugru is used by customers from 175 countries world-wide and more than 80 percent of its sales are online.</p>		
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>In 2009, Queen Mary contributed to the development of Sugru®, owing to its expertise in polymers and rubbers (Peijs, Busfield, Bilotti). Sugru is a mouldable adhesive glue for mending objects. It is the main product of FormFormForm Ltd (FFF) and contains a combination of silicones and inert inorganic fillers which, when exposed to moisture in ambient air, turns into a room temperature vulcanizing (RTV) silicone rubber. Its mouldability is gained through control of the amounts of filler added into an active poly dimethyl siloxane (PDMS) base whilst retaining excellent cure properties and ultimate mechanical performance. The cross-linking of the silicone base is initiated by the presence of atmospheric water shortly after opening the packaged product. Therefore, a rigorous and careful selection of any fillers was needed to minimise the effect of chemisorbed water that could cause premature cross-linking. The surface chemistry of the fillers is also of importance, as they can affect the overall reactivity, processability and stability of the packaged product and its performance in bonding to a range of surfaces.</p> <p>Christopher Reynolds, Queen Mary's Nanoforce Research Manager, in collaboration with Busfield, Bilotti and Tom Dowden, tested the addition of resin microspheres, to reduce the weight of Sugru, in Queen Mary's Nanoforce labs in 2009 as part of a TSB feasibility grant [EQR.1]. The microspheres incorporated well with the PDMS base providing good mouldability and no chemical instability. The microspheres also reduced weight with acceptable reductions in strength and modulus. During processing, it was observed that adding the cross-linking catalyst at the beginning of compounding yielded a sample that required less filler to achieve the same mouldability. This is because early addition of the catalyst causes a pre-reaction and elongation of molecular chains. Since a small change in molecular length yields a large change in viscosity, to achieve the final viscosity less filler is needed. Thus, Queen Mary researchers demonstrated that a new lightweight version of Sugru can be manufactured with lower filler addition.</p> <p>Due to the commercially sensitive nature of the work, no papers about the initial collaborative research carried out by Queen Mary and FFF were published. However, a patent, assigned to FFF, was granted in 2012. The patent names Tom Dowden, now Principal Researcher at FFF, who was a researcher at Queen Mary in 2009 and contributed to the abovementioned research under the supervision of Peijs.</p>		

Since the initial collaboration, research and development has focused on the optimisation of formulations to improve adhesion, curing and colour of the products. From September 2014, research at Queen Mary, led by Prof. Julien Gautrot [EQR.2, EQR.3], has focused on the development of a new family-friendly version of Sugru. This has involved developing patented [3.1-3.3] novel cure chemistries, avoiding the use of toxic reagents and allergenic ingredients and improving the shelf-life and stability of the product [3.4]. This has enabled expansion of Sugru's targeted market to the family and toy markets, resulting in the launch of the new family safe formulation of Sugru in 2018.

Prof. Gautrot has also contributed to the development of methodologies enabling the characterisation of parameters affecting the cure time and depth of the putties developed [EQR. 4], resulting in a knowledge transfer partnership that holds the 'Winner of Best of the Best Future Innovator Award 2020.' This included the characterisation of some of the physical (temperature resistance) and mechanical properties of the silicone putties developed [3.4].

3. References to the research (indicative maximum of six references)

[3.1] Patent application 1: Ariscrisna, P.; Jerlhagen, A.; Shamsah, R.; Christogianni, P.; Mac, W.; Westall, S.; Nguyen, K.; Gautrot, J. E.; Pullen, J.; Dowden, T. & Buckingham, M. "Silicone Elastomer Composition." European patent application 16386022.4, filed 16 December 2016. UK patent application 1621650.9, filed 19 December 2016. PCT application PCT/GB2017/052086, filed 14 July 2017.

[3.2] Patent application 2: Ariscrisna, P.; Jerlhagen, A.; Shamsah, R.; Christogianni, P.; Westall, S.; Nguyen, K.; Gautrot, J. E.; Pullen, J.; Dowden, T. & Buckingham, M. "Silicone Elastomer Composition." European patent application 17386025.5, filed 14 July 2017. UK patent application 1711690.6, filed 20 July 2017. PCT application PCT/GB2017/053765, filed 15 December 2017.

[3.3] Patent application 3: Christogianni, P.; Dowden, T.; Ariscrisna, P.; Allen E.; Winkler, T.; Hoelger, C.; Dowden, A.; Nguyen, K.; Gautrot, J.; Buckingham, M.; Shamsah, R. & Blades, A. "Fast Curing Silicone Elastomer Composition." European patent application 20209076.7, filed 20 November 2020.

[3.4] Nguyen, K.D.Q.; Megone, W.V.; Kong, D.; Gautrot, J.E (2016). Ultrafast diffusion-controlled thiol-ene based crosslinking of silicone elastomers with tailored mechanical properties for biomedical applications. *Polym. Chem*, 7(33), 5281-5293. <https://doi.org/10.1039/C6PY01134A>

Evidence of quality of the research:

[EQR.1]: Reynolds, C. [PI]. (2008-2009). SugruPRO: A design tool to enable mass-customisation of sports equipment [120078]. *Innovate UK*. TSB Feasibility award. GBP15,000.

[EQR. 2]: Bilotti, E. [PI]. Gautrot, J. [Co-I]. (2015-2016). Photo-responsive graphene for anti-corrosive and conductive strong, compliant silicone nanocomposites [131805]. *Innovate UK*. Research Grant. GBP88,000.

[EQR. 3]: Bilotti, E. [PI]. Gautrot, J. [Co-I]. (2016-2018). Multifunctional graphene/silicone nacre-like composite films [H2020-MSCA-IF-2015-703020]. *Marie Curie*. Research Grant. GBP146,764.

[EQR. 4]: Gautrot, J. [PI]. (2017-2020). Novel Crosslinking Chemistries for Next Generation Composites [510868]. *Innovate UK*. Knowledge Transfer Partnership. Winner of Best of the Best Future Innovator Award 2020. GBP150,000.

4. Details of the impact (indicative maximum 750 words)

FormFormForm Ltd (FFF) focuses on the development of novel silicone-based chemistries for the design of tough adhesive composites. These are intended as mouldable adhesive glues for

mending objects. Its main product, Sugru® (figure 1), was first developed in 2009 based on formulation work that was carried out by Queen Mary researchers.

Sugru resembles modelling clay but sticks to most surfaces and dries to a tough, rubbery finish. It is flexible, waterproof, shock-resistant, electrically insulating and temperature-resistant up to 180°C and down to -50°C. It allows single users to personalise, fix and modify objects, devices or goods. The product is sold as a single component and does not need to be activated by the addition of a catalyst.

Sugru's commercial success

Since 2013, Sugru has been sold in over 300 B&Q stores in the UK & Ireland and since 2015 in over 2,000 Target Stores in the USA [5.1]. Furthermore, Sugru sells its products in retail outlets in Europe, US, and Canada.

Today Sugru is being used by customers from 175 countries worldwide and is widely available, including on Amazon (other retailers include Massmart in South Africa and Leroy Merlin in France). More than 80 percent of its sales are online.

In collaboration with Queen Mary, FFF has developed a new range of family friendly formulations of Sugru, which were launched in 2018. By 2019, Sugru had been used to fix 20,000,000 objects, which means significantly fewer objects were sent to a landfill [5.2].

Acquisition of FFF by Tesa CE

In 2018, FFF was acquired by Tesa CE, for GBP7,600,000, which has facilitated increased presence in 'bricks and mortar' stores across mainland Europe. Production, research and development related to Sugru has remained in London [5.3]. The benefits of the acquisition to both companies are summarised below:

Benefits to FormFormForm	Benefits to Tesa
<ul style="list-style-type: none"> Opening up new markets with German and French language websites (in 2019 sales from these websites were GBP7,000) Product stocked in European retail stores (eg OBI Next (Austria) and Bauhaus (Sweden)) 	<ul style="list-style-type: none"> FormFormForm providing expertise in online sales (80% Sugru sales are online; Tesa only had 2% sales online before acquisition of FFF) A route for Tesa into the US market

Sugru's position in the market place

Sugru's competitors and how they compare against Sugru are listed in the table below:

Product	Comparison with Sugru
Kintsuglue	Closest competitor in form and application but degrades in the sun
Fimo	Needs to be cured in the oven and is not flexible once set
Epoxy putties (e.g. Araldite, Milliput)	Typically two component and so are messy and less user-friendly
Blu tack (and similar products)	Remains sticky as it does not set
Tapes	Restricted applications

Sugru has a number of applications in fixing, modifying and improving objects

Sugru comes in a variety of colours and can be used for fixing or personalising a variety of everyday objects due to its ability to stick to most surfaces. Sugru user David Constantine said: "Knowing I can buy something without worrying about adapting it to my needs is a boon. I'm always



Figure 1: Sugru Mouldable Glue. Copyright [2020] by Sugru.com.

trying to adapt things and can now design and do it at home, rather than take it somewhere to be modified" [5.2].

Sugru has also been used for some more bespoke and creative applications as detailed in the case studies below:

Bespoke game controllers

American computer engineer Ben Heck, in partnership with FFF, has created a bespoke game controller, imaged in figure 2,



Figure 2: Game controller designed by Ben Heck, in partnership with FFF for Vivek Gohil. Copyright [2019] by Ovgadgets.

designed for people with muscular dystrophy. Ben specifically designed this controller for the British gaming vlogger Vivek Gohil. Sugru holds all the components of the controller together and gives it its unique shape. The weakened joystick springs allow for effortless movement and there are conductive touchpoints below the joysticks that replicate buttons. There is also an adjustable stand that makes the controller weightless for longer sessions [5.4].

Landscape gardening [5.2]

Award winning landscape gardener Peter Donegan has used Sugru in displays at the Hampton Court Palace Flower Show, RHS Cardiff, and at the Irish WW1 centenary peace garden at Chateau de Peronne, France. He used it to ensure that objects (eg light objects that can be easily blown away, picture frames that cannot be easily screwed to walls if the walls are thin board that will not take a screw) within displays are fixed in a way that "doesn't detract from their appearance," but provides him with confidence that "they will survive wind and judges and so will look good when it matters." He said that Sugru gives him "peace of mind" as he tries "to eliminate all the variables I don't have control of. Even a 1% chance something will fall or move is too much." Peter had previously used products like blu-tac that was not strong enough. Sugru also benefits from being readily removed when required.



From bespoke game controllers to tracking tortoises (figure 3), Sugru is a versatile and durable product that is valued for its reliability by its creative customers and proponents.

Figure 3: Sugru being used make a harness for pet tortoises' trackers to locate lost pets. Reprinted from *DIY Sugru Tortoise Tracker*, Petdiys. Copyright by Sugru.com [5.5].

Repair spaces [5.2]

FFF supports a number of volunteer-led initiatives in the repair space. They provide 'positive waste,' which is Sugru close to its sell by date, but is still usable. This is donated free of charge to events such as:

- Weekend Repair Shops: A 2017 event that was run in conjunction with Raeburn Design, a company that uses surplus fabrics and garments to create new clothing, luggage and accessories.
- The Restart Project: A social enterprise encouraging the repair of consumer products, in particular electronics. The organisation helps to repair objects, runs workshops on DIY skills and campaigns against 'planned obsolescence'
- The Repair Café: With over 2000 meetings globally, the Repair Café provides free spaces where tools and materials are made available to help users make any repairs they need to.

As a result of FFF's work in the repair space, Sugru has now developed a significant online community of enthusiasts, with a web community of over 2,000,000 makers and DIY enthusiasts, and 21,000 Twitter followers, along with the popular #mysugrufix hashtag.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] T Dowden. Principal Researcher. *FormFormForm* (testimonial letter, 9 May 2019). [Corroborator 1]

[5.2] Fresh Perspectiv (2020). *Impact Case Study: Mouldable Glue - Sugru™*

[5.3] Tesa acquires Sugru brand for £7.6m (2018, 23 May). Insightdiy. <https://www.insightdiy.co.uk/news/tesa-acquires-sugru-brand-for-76m/6227.htm#:~:text=Sugru%2C%20the%20mouldable%20glue%20company,shareholders%20have%20now%20accepted%20it>. 29 October 2020.

[5.4] F Fatima (219, 12 October). *Ben Heck innovates: a 'miracle' controller for the famous UK gaming vlogger with Muscular Dystrophy* [blog]. Ovgardgets. <https://uncannyvivek.com/2019/10/04/glued-together-with-sugru/> 30 March 2020

[5.5] *DIY Sugru Tortoise Tracker*. Petdiys. <http://petdiys.com/diy-sugru-tortoise-tracker/>. 29 October 2020.