Institution:
University of Cambridge

Unit of Assessment:
UoA9

Title of case study:
Spin out company Cavendish Kinetics Ltd

1. Summary of the impact (indicative maximum 100 words)
University of Cambridge research led to the creation of spin-out company, Cavendish Kinetics which developed a micro electro mechanical (MEMS) process technology that allows MEMS devices to be fabricated in a standard silicon foundry. The company is now producing RF MEMS technology for mobile phone applications allowing faster data transfer and lower power consumption. It initially developed a non-volatile memory product for harsh environments. The company has provided more than 350 person years of highly skilled employment (of which 140 person years are within the period) at offices in the US, UK, the Netherlands, and Korea. It has developed a large patent portfolio and raised tens of millions of US dollars in VC funding.

2. Underpinning research (indicative maximum 500 words)
Charles Smith joined the Semiconductor Physics group of the Department of Physics at the University of Cambridge as an Advanced EPSRC Fellow in 1991 before promotion to Lecturer in 1996. Starting prior to the period, in 1991, Smith (now Professor) began investigations into quantum phenomena in the electrical mechanical properties of nanometre scale devices. Smith began investigations into the thermal properties of nanometre scale devices [r1]. Part of the research involved fabricating free-standing metal structures less than 0,1 micron wide and thick and a few microns long. This was some of the first research into the nanomechanical properties at this length scale and directly led to the initial invention by Professor Smith of using micro-mechanical devices (MEMS) for non-volatile memory applications [r2]. This patent was submitted in 1993 and has been cited over 100 times in other patent applications.

Cavendish Kinetics Ltd [i1] was formed in October 1994 by Smith then an Advanced EPSRC Fellow working on quantum transport phenomena. VC funding was used by the company to continue research at the University Department of Physics into the area of the nano-mechanical properties of sub-micron MEMS devices. This research continued until 2002. The initial investigations were focussed on studying the lifetime issues related to fabricating MEMS devices on this length scale. Techniques for reliably fabricating devices on this length scale, using materials that would be allowed in a silicon foundry, were also performed during this period resulting in the following publications [r1, r3, r4]. That research showed that MEMS devices could be fabricated on this very small length scale, and that they could be switched millions of times reliably. It also showed that problems with adhesion at the contacts could be overcome and that the contact resistance was at a low enough level for real device applications. That research was basic underpinning research and not development work. The company paid for this research with grants to the Department of over £750,000.

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

R1. “Switching Characteristics of Electrostatically Actuated Miniaturized Micromechanical Metallic Cantilevers.”Teh WH, Luo JK, Graham MR, Pavlov A, Smith CG J. Vac. Sci. Technol. B (2003) 21 2360, DOI: 10.1116/1.1620515

R2*. Bi-stable memory element. Inventor: SMITH CHARLES GORDON [GB] Publication info: US5677823; (A), 1997-10-14; Priority Date: 1993-05-08.

R3. Teh WH, Liang CT, Graham M, Smith CG J. Microelectromech. Syst. (2003) 12 641 “Cross-Linked PMMA as a Low-Dimensional Dielectric Sacrificial Layer.” DOI: 10.1109/JMEMS.2003.817891

R4. Teh WH, Luo JK, Graham MR, Pavlov A, Smith CG
J. Micromech. Microeng. (2003) 13 591 “Near-Zero Curvature Fabrication of Miniaturized Micromechanical Ni Switches using Electron Beam Cross-Linked PMMA.” DOI: 10.1088/0960-1317/13/5/309

* References which best represent the quality of the underpinning research

Research grant GR/K93013/01): Quantized vibration of micro-mechanical structures combined with single electron charging, PI: Charles Smith, 25 March 1997 to 24 March 1999, Value: £100,258

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

The initial Cambridge research into building MEMS devices on the nano-scale showed that shrinking MEMS devices allows them to work faster, at lower voltages and more reliably. The speed of operation enabled these devices to be used for making small fast operating variable capacitors for mobile phone applications. The low resistance of the moving metal parts ensures operation with a high electrical quality factor. The advantage of using MEMS for memory products is that the low voltage operation removes the requirement for charge pumps in embedded memory applications.

As mentioned in section 2, the research underpinning the development of MEMS devices was considered enough to attract a considerable amount of VC funding. In 2000 the results were such that the company was able to raise $6,000,000 to hire a CEO and to set up a research lab external to the University, allowing the company to start developing its first silicon foundry compatible nano-scale MEMS device, a non-volatile memory product. This development work was performed outside the department. Pushing for the smallest possible MEMS devices allowed other products to be developed with enhanced performance properties such at the digital variable capacitor that is currently the main product of the company. Joint research grants between Cavendish Kinetics and the University of Cambridge Physics Department continued until 2005[i2]. Thereafter, in 2006 $15,500,000 more in VC funding allowed Cavendish Kinetics to set up a subsidiary in San Jose in California with the CMOS research team shifting from Germany to the US, allowing the company to grow to over 30 employees. Within the relevant period, a further $10 million in investments from Qualcomm and other VC’s came into the company (2011) [i4] which allowed the company to fully develop the digital variable capacitor products for mobile phone applications.

The latest 4G or LTE technology used in smart phones allows much faster data transmission because data can be split between more than one band, both during upload and download. In the UK there are three bands used for LTE, the value of the frequency used is different for different regions of the globe. There is no room in the phone to house more than one antenna, so to solve this problem phones use resonant filters connected to the antenna to tune them to work at different frequencies. At present this is achieved with a gallium arsenide switch connected to a fixed capacitor. This combination is expensive, because the switches need to operate up to several gigahertz without distorting the signal or damping the resonance. Ultimately it is predicted that smart phones will need to operate over 20 bands worldwide [i7]. The Cavendish Kinetics solution replaces all these components with a digital variable capacitor which is fabricated at a standard CMOS foundry. Cavendish Kinetics ported its unique MEMS process for nano-scale MEMS devices to a partner foundry TowerJazz Ltd that is manufacturing chips that will be sold to phone manufacturers. The first chip was launched in June 2013.

There is another advantage to the Cavendish Kinetics technology and this relates to the variation in the antenna performance depending on its position relative to your body. If a phone is sitting on the desk or in your pocket being used with headphones, the stray capacitance is different from when it is held in your hand next to your head. This causes a shift in the performance of the antenna which can be corrected for directly using Cavendish Kinetics technology in a way that is not possible with the current technology. Thus this product will allow new phone designs to take full advantage of new high speed mobile phone networks referred to as LTE or 4G which are now available in the US, Europe and Japan. It also results in a longer time between battery charges as less power is required. Being able to send and receive mobile signals more efficiently means that the mobile phone signal suppliers do not need to build extra phone mast to ensure fast data rates are available for everyone. As the chip replaces several other components, it can also lead to a reduction in the cost of the parts for the mobile phone.

Thus the research at Cavendish has led to a new product that became available in 2013 [i3] which reduces the energy consumption and improve the performance of mobile phones.
On a smaller scale, since 2008 the development has provided over 140 person years of

employment to engineers and scientists in the US, and Europe and has resulted in over 97 published patents [i10].

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

i1. Statement from CEO Cavendish Kinetics

i2. http://www.cavendish-kinetics.com/index.php/about/

i3. http://www.cavendish-kinetics.com/index.php/news-and-resources/mems-journal-article-120913/ 2013 launch of new product which reduces the energy consumption and improve the performance of mobile phones

i4. http://www.eetimes.com/document.asp?doc_id=1259675 $10 million in investment from Qualcom

i5. http://www.wellington-partners.com/wp/port_cavendish.html for confirmation of VC backing

i6. http://www.wellington-partners.com/wp/downloads/pfn/cavendish/2006/060501_cav.pdf for confirmation of investment figures

i7. http://niviuk.free.fr/lte_band.php for details of frequencies required for LTE

i8. http://www.3g.co.uk/PR/Feb2009/Extensive_Smartphone_and_Chip_Market_Study_3G.htm

i9. **"MEMS technology integrated in the CMOS back end"** R. Gaddi, R. Van Kampen, A. Unamuno, V. Joshi, D. Lacey, M. Renault, C. Smith, R. Knipe, D. Yost. *Microelectronics Reliability,* **50**, (2010), pp. 1593-1598, DOI: 10.1016/j.microrel.2010.07.113

i10. http://worldwide.espacenet.com/searchResults?compact=false&ST=advanced&locale=en_EP&DB=EPODOC&PA=cavendish+AND+kinetics