# A DISPOSABLE DISCRETE-AGENT-RELEASE CARTRIDGE FOR FLEXIBLE ENDOSCOPES

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## ABSTRACT

We present a **disposable four-channel-cartridge** as a new tool **for flexible endoscopes** to release **adjustable and precisely defined agent volumes. The agent volumes are generated** by **externally triggered (0 – 11 kHz)** release of **discrete droplets ($V_{droplet}$ = 8 pl)** with flow rates up to **88 nl/s** in each channel. The miniaturized cartridge ($l \times w \times h$ = 9 mm × 1.2 mm × 1.4 mm) can be inserted into working channels of standard flexible endoscopes ($\varnothing_{working\ channel}$ = 2 – 3 mm). Up to **four different agents** are stored in separate **integrated reservoirs ($V_{reservoir}$ = 1 µl)**. Each channel is equipped with a bubble jet actuator which allows for **addressing the single reagents individually**. To prevent any diffusion based agent leakage a diffusion barrier is realized by forming a **stable phase separation** *via* capturing an air bubble in front of the dispenser's nozzle orifices.

**KEYWORDS:** multi channel discrete agent release, bubble jet actuator, minimal invasive surgery, phase gap

## INTRODUCTION

Endoscopic agent release devices presented so far [1] are mainly actuated at the proximal (rear) end to release the agent liquids at the distal (front) end. In such systems, fluidic capacities of the long supply-channels (~1 m) make it difficult to dispense precisely defined agent volumes. Moreover, the movement of the endoscopic tool and thus deformation of the supply-channel leads to agent leakage. Therefore, current systems are equipped with additional suction accessories to prevent unintentional medication [1]. In contrast, we present a disposable dispensing cartridge for the discrete release of defined agent volumes positioned and actuated at the distal (front) end of an endoscope.

## DISCRETE-AGENT-RELEASE CARTRIDGE

The realized small cartridge ($l \times w \times h$ = 9 mm × 1.2 mm × 1.4 mm) with its surrounding Teflon tube ($\varnothing_{tube}$ = 2.2 mm) is designed to fit into working channels of standard flexible endoscopes, e.g. bronchoscope with a working channel diameter of $\varnothing_{working\ channel}$ = 2.4 mm [3] (figure 1). Therefore, it can be positioned at user-defined locations within the working channel e.g. on a secure position within the working channel during insertion or movement of the endoscope and positioned next to the target tissue if agent release is desired.

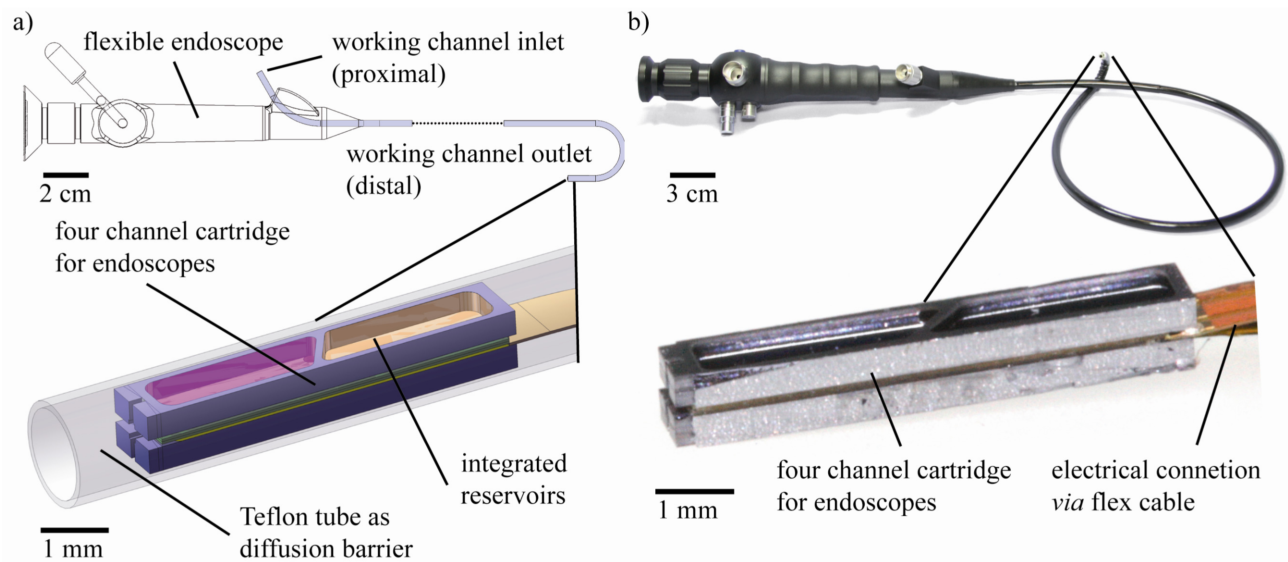


*Figure 1: a) A new bubble-jet-actuated four-channel dispensing cartridge was designed and fabricated for the insertion into flexible endoscopes. It features four integrated reservoirs as well as a hydrophobic diffusion barrier, preventing any diffusion based leakage, realized by inserting the dispenser into a hydrophobic Teflon tube. b) shows a photograph picture of the device designed for a bronchoscope with a 2.4 mm working channel.*

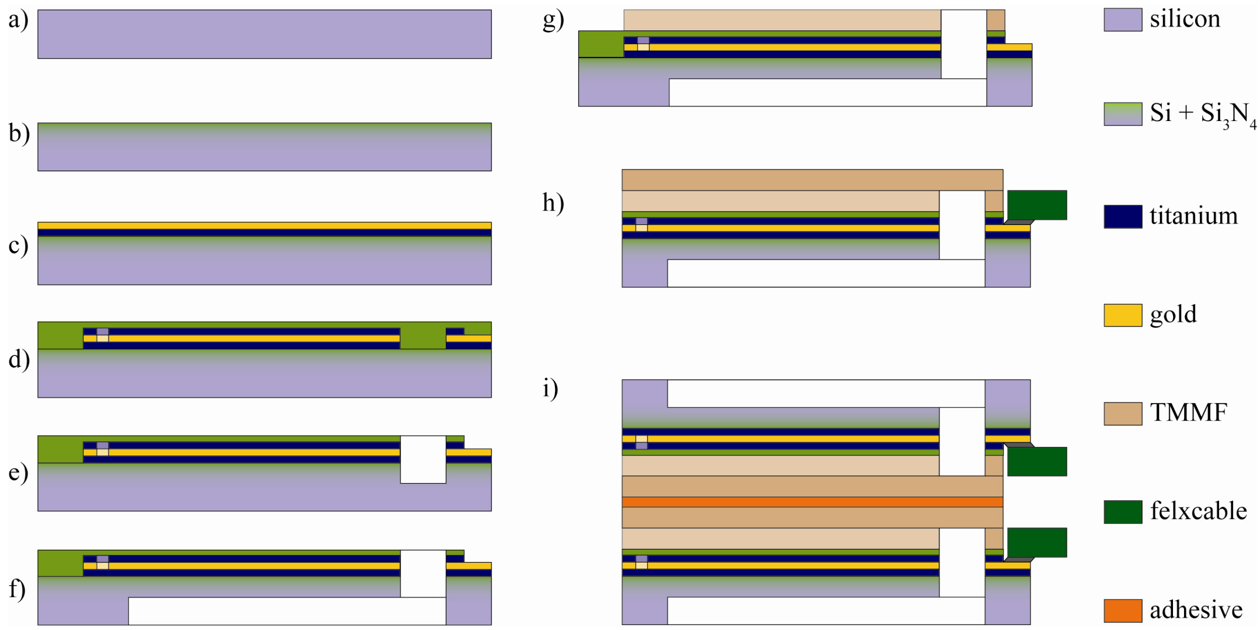


*Figure 2: Fabrication of the bubble-jet-actuated dispensing cartridge with integrated reservoirs: A standard 525 µm silicon wafer(a) is electrically passivated with $Si_3N_4$ (b). After deposition (c) and patterning of the heater metallization the metal layer is passivated with an second $Si_3N_4$ layer (d). Reservoirs and fluidic vias are etched into the bulk using Deep Reactive Ion Etching (e, f). The fluidic channels are fabricated and sealed by laminating and patterning TMMF dry film resist (g). After dicing and electrical connection (h) two individual cartridge halves are bonded by adhesive bonding (i).*

The miniaturized cartridge is fabricated by deposition and patterning of micro heaters on silicon and a layer of fluidic channels in TMMF dry film resist [2]. Reservoirs are integrated into the bulk using Deep Reactive Ion Etching of the silicon (figure 2).

In case of application within liquid environments, the surrounding Teflon tube acts as a hydrophobic diffusion barrier for preventing any diffusion based leakage. A stable air bubble ($t_{\text{stable bubble}} > 72$ h) is trapped in front of the nozzle orifices due to the effect of capillary depression. This air bubble forms a stable phase separation (figure 3, figure 4b) between the agent within the dispenser's nozzle and the environmental fluid and acts as a Phase-gap.

**DISCRETE-AGENT-RELEASE CHARACTERISTICS**

The disposable cartridge features four individually addressable bubble-jet actuated channels with four separate agent reservoirs ($V_{\text{reservoir}} = 1$ µl). The agents are released and focused onto the same release area ($r_{\text{release area}} < 100$ µm). The combination of releasing discrete agent volumes ($V_{\text{droplet}} = 8$ pl) externally triggered with repetition rates ranging from $f = 0 - 11$ kHz allows for the release of adjustable and precisely defined agent volumes with flow rates up to 88 nl/s per channel (figure 4). The verification of the droplet volume was performed by gravimetrical measurement of 55 droplet fusillades of 1000 shots each ($V_{\text{fusillade}} = 8$ nl, Cv = 8 %). User defined mixtures or online adapted medication protocols are conceivable as well as diagnostics, medication and staining – all without changing the tool.

During the usage within aqueous environment, the stable trapping of an air bubble (figure 4) within the hydrophobic diffusion barrier ensures a leakage-free application.

**CONCLUSION**

This work shows a feasibility study for highly defined releases of up to four different agents, combined with a very compact packaging that is designed for new approaches within minimal invasive surgery, e.g. tissue labeling or localized chemotherapy where no surgery is possible.

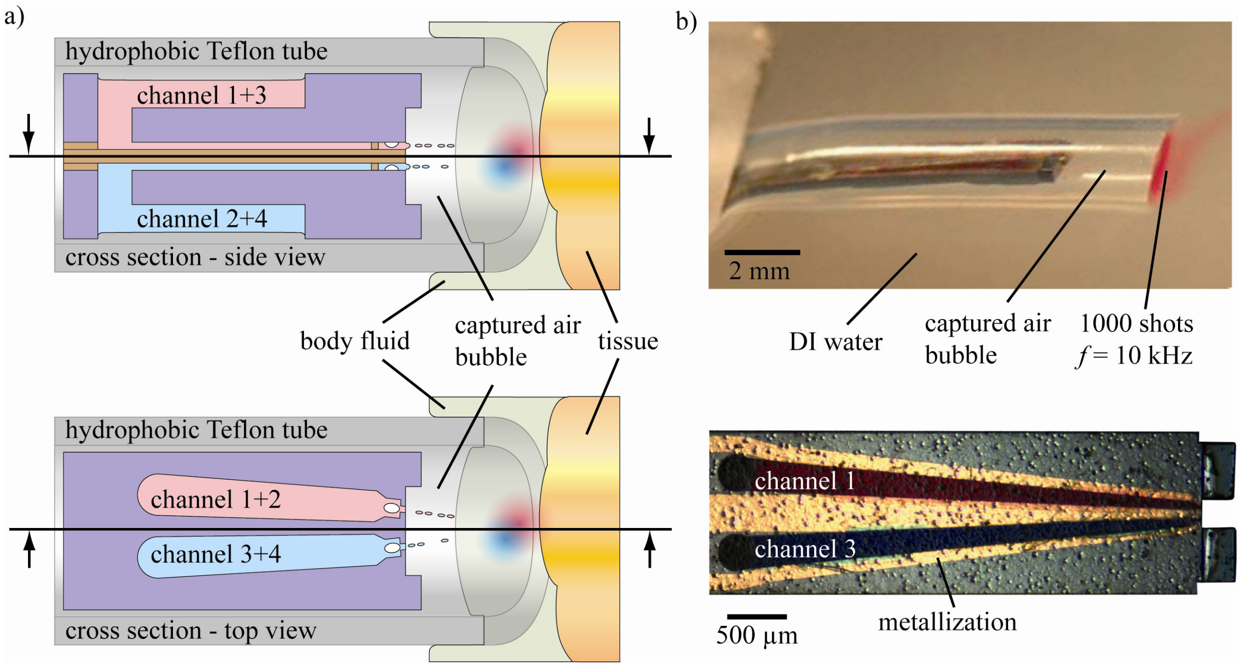


*Figure 3: Working principle. a) shows cross-section sketches of the dispensing cartridge. A stable phase separation between agent and liquid target medium is realized by capturing an air bubble in front of the nozzle orifice via the hydrophobic Teflon tube. Dispensed agent droplets fly through this air bubble and impinge next to the aimed tissue. Four individual channels allow for various therapeutic and diagnostic approaches with different highly potent agents. b) shows a photograph picture of the dispensing cartridge under water capturing a stable air bubble while dispensing 1000 droplets (8 nl) of red ink as well as the top view of one half of the dispenser filled with red and blue ink.*

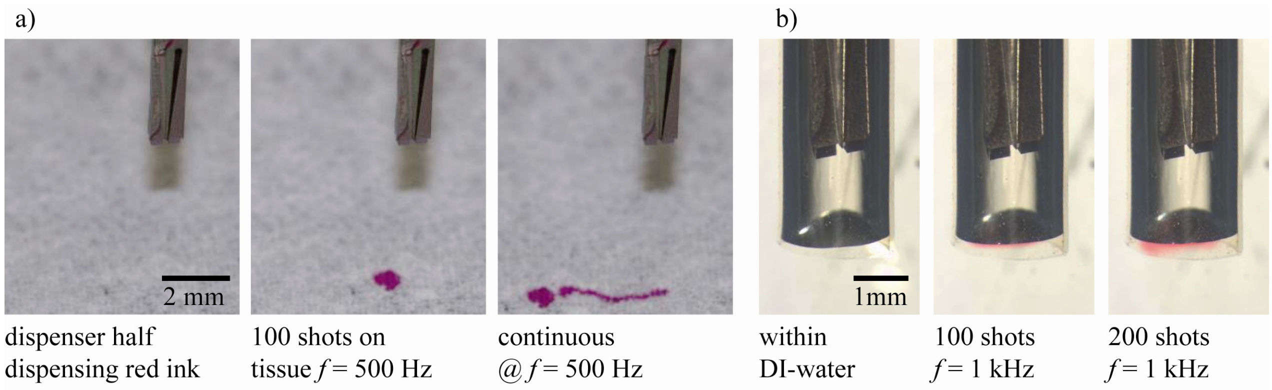


*Figure 4: a) shows the dispensing of red ink within air environment (one half of the dispensing cartridge without the surrounding Teflon tube) . b) The captured air bubble within the surrounding Teflon tube leads to a stable phase separation (Phase-gap) and thus diffusion based leakage can be prevented when the cartridge is actuated under water.*


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