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CENTRO DE FÍSICA APLICADA Y TECNOLOGÍA AVANZADA

CLEAN TRANSFER OF MoS_2 BY EUTECTOGELS PREPARED VIA *IN-SITU* PHOTOPOLYMERIZATION

Iván García Nieto*, Mario Flores Salazar, Andrés de Luna Bugallo, Josué D. Mota Morales

Centro de Física Aplicada y Tecnología Avanzada Campus UNAM-Juriquilla Boulevard Juriquilla No. 3001 Santiago de Querétaro, Qro. C.P. 76230, México.

*igarcian@pceim.unam.mx

ABSTRACT

Two-dimensional materials and their van der Waals heterostructures have demonstrated enormous potential for advancing technological innovations in electronics, optoelectronics, catalysis, and energy storage. The methods used to synthesize these heterostructures play a crucial role in determining their final applications [4]. In this context, atmospheric pressure chemical vapor deposition (APCVD) has been widely used to synthesize MoS_2 monolayers with tunable optoelectronic properties. However, the growth temperatures of these materials can exceed 700°C, which is incompatible with standard complementary metal oxide semiconductor (CMOS) microfabrication processes, for instance. One of the alternatives to this problem is to "transfer" these 2D materials after growth by placing them on substrates that are compatible with these processes without compromising the crystalline quality and uniformity of the 2D material.

Currently, transfer methods are limited and have drawbacks such as introducing defects into the material structure or surface contamination. In addition, the methods are complex and in some cases require the use of sophisticated equipment. To overcome these drawbacks and to minimize residues and structural damage generated during the process, the use of polymers, such as cellulose acetate or PDMS, as support elements for the crystals during their transfer has been reported.

On the other hand, deep eutectic solvents (DES) immobilized into non-aqueous gels, called eutectogels, have emerged as a sustainable alternative to flexible materials with tunable mechanical, thermal and adhesion properties [5]. To achieve the clean transfer of MoS_2 crystals, this study proposes the use of eutectogels obtained from monomer-containing DES (DESm) to assist in the 2D crystal transfer. By photopolymerizing DESm on MoS_2 crystals *in situ*, the crystals are transferred to target substrates.

The results obtained by Raman and photoluminescence spectroscopy show that it is possible to transfer MoS_2 crystals without structural damage or impurities introduced during the transfer process.

METHODOLOGY

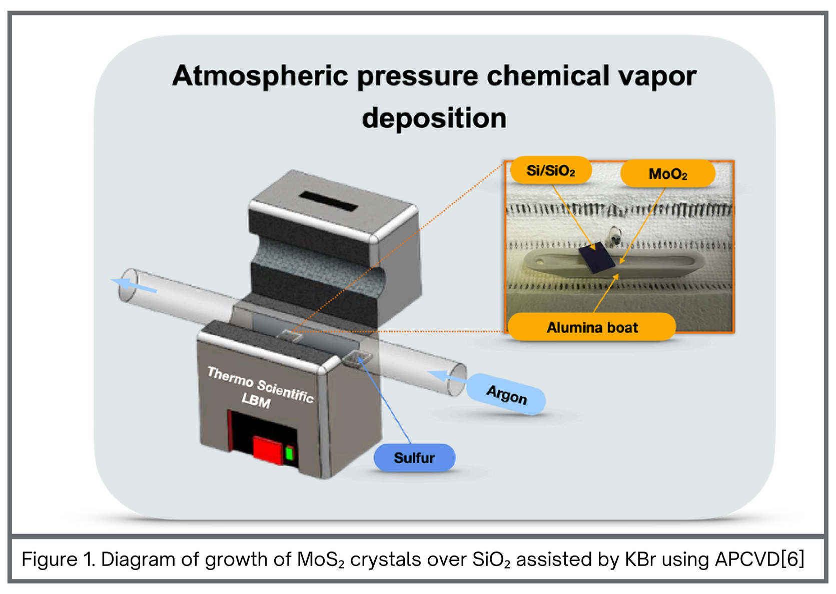

Figure 1. Diagram of growth of MoS_2 crystals over SiO_2 assisted by KBr using APCVD[6]

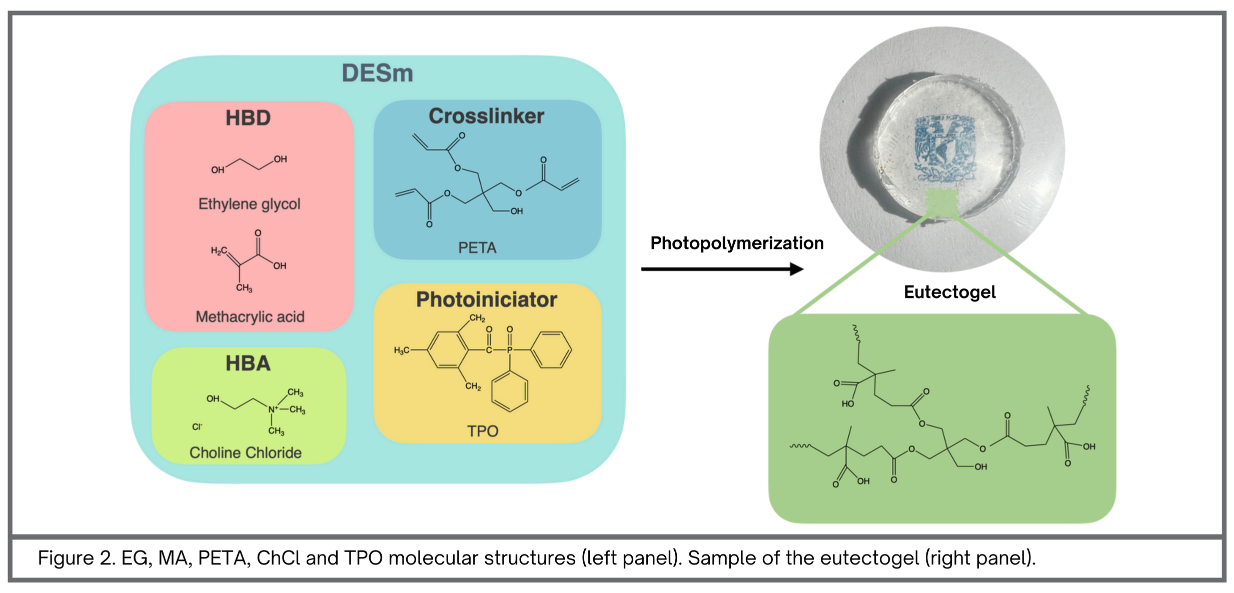

Figure 2. EG, MA, PETA, ChCl and TPO molecular structures (left panel). Sample of the eutectogel (right panel).

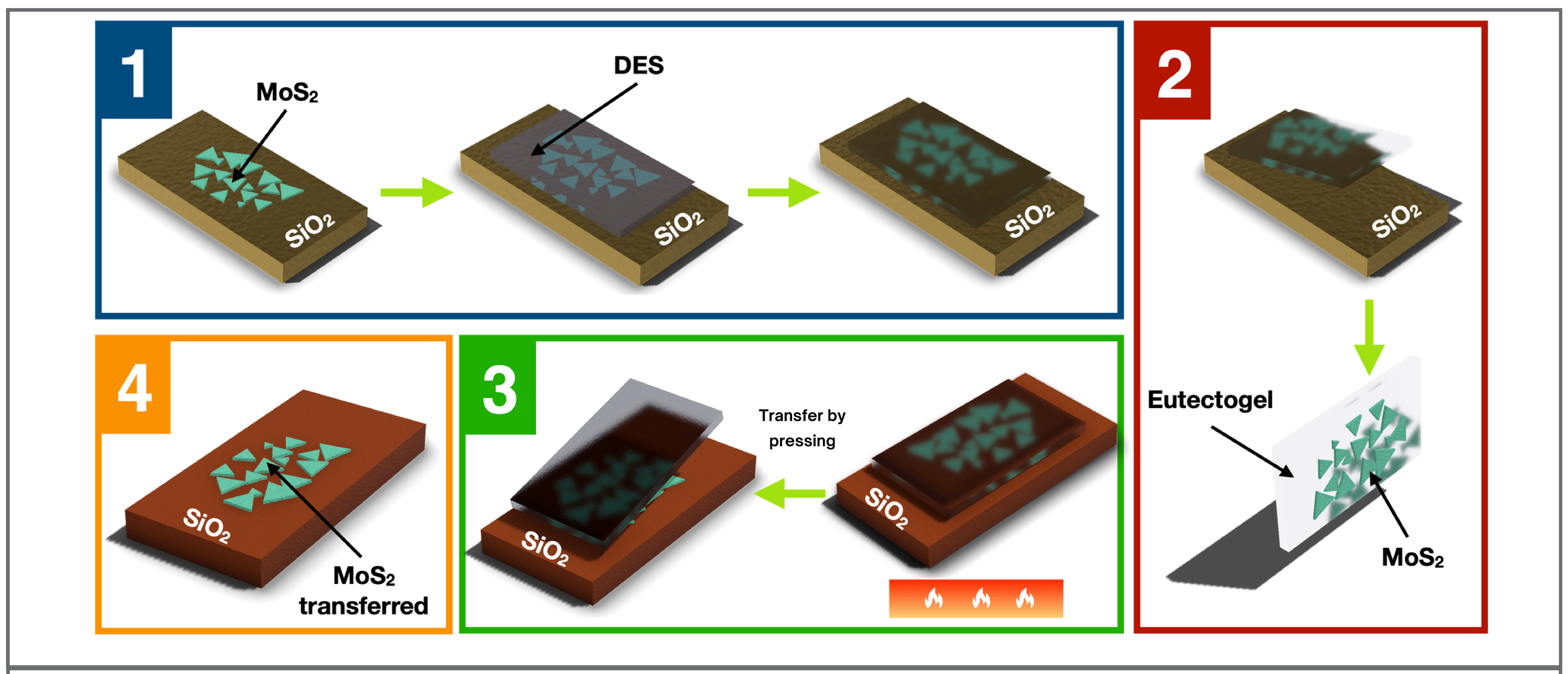

Figure 3. Experimental design of MoS_2 transfer to target substrates

RESULTS

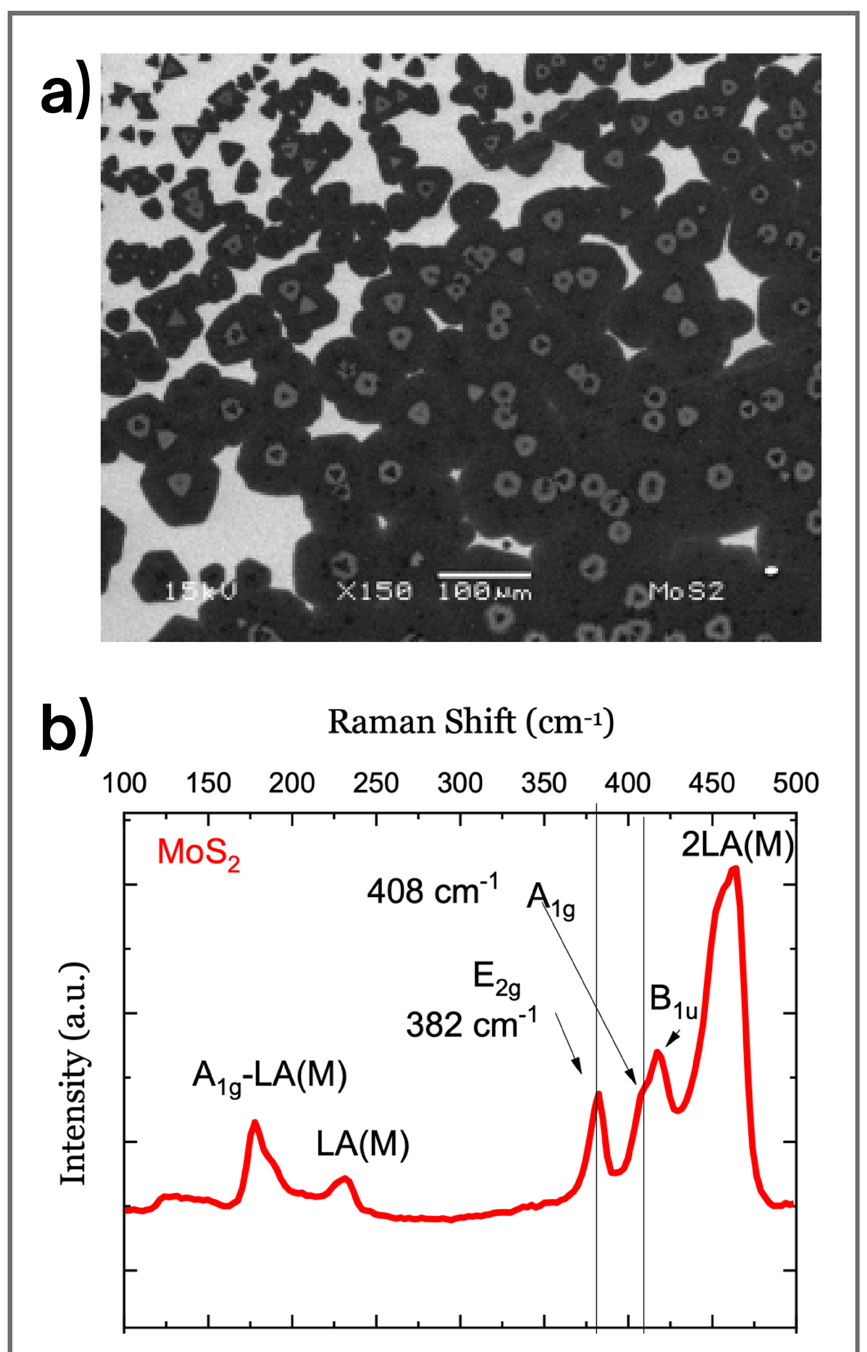

Figure 4. a) SEM micrograph b) Raman spectra of MoS_2 synthesized by APCVD (before the transfer process).

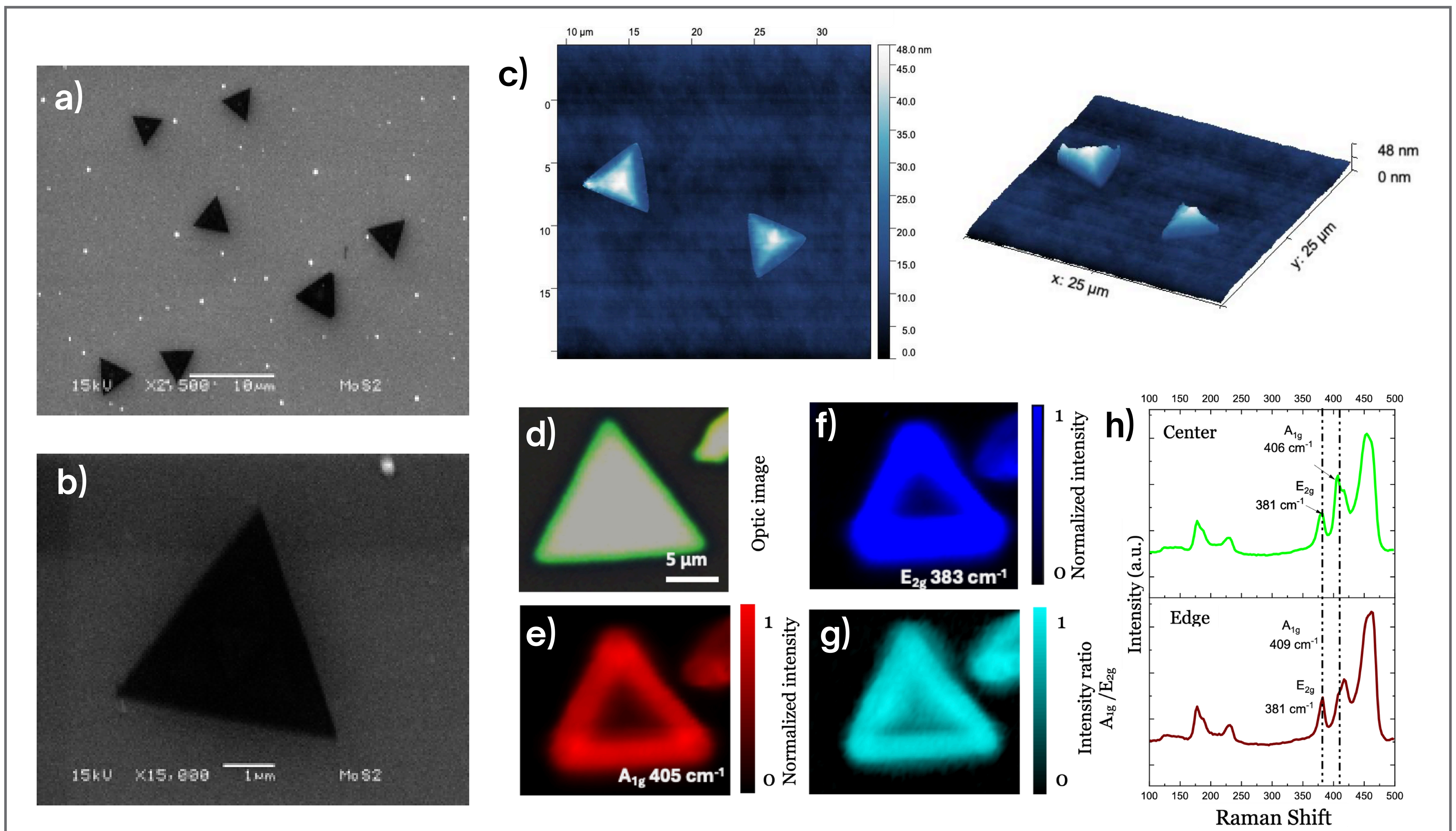

Figure 5. SEM micrographs obtained from transferred MoS2 a) 2500X and b) 15000X. c) Images obtained from AFM of MoS_2 transferred. d), e), f) and g) intensity mapping of the Raman signals of the transferred MoS_2 crystals, h) Upper (center of the crystal) and lower (Edge of the crystal) Raman spectra.

CONCLUSION

The process developed for the transfer of MoS_2 crystals using a DESm-based eutectogel marks a significant advance in the clean transfer of two-dimensional materials.

With respect to MoS_2 transfer using polymeric materials (PMMA or PDMSO) or even ice[3,2,1], the present work has the following advantages:

- It leaves no residues of polymer or other materials involved in the process.
- It preserves the structural and crystalline integrity of MoS_2 .
- Fast, simple and environmentally friendly process.

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